CLEANUP CRITERIA AND SCREENING LEVELS DEVELOPMENT AND APPLICATION

REMEDIATION AND REDEVELOPMENT DIVISION RESOURCE MATERIALS

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Protecting Michigan's Environment. Ensuring Michigan's Future.

In order to promote a consistent and informed approach for Michigan Department of Environmental Quality (MDEQ) staff, this document was developed to provide information to MDEQ staff and contractors on Cleanup Criteria and Screening Levels Development and Application.

This document is available as a technical reference to assist any party applying the generic cleanup criteria.

This document is explanatory and does not contain any regulatory requirements. It does not establish or affect the legal rights or obligations for application of the generic cleanup criteria. It does not have the force or effect of law and is not legally binding on the public or the regulated community. Any regulatory decisions made by the MDEQ regarding application of the generic cleanup criteria will be made by applying the governing statutes and Administrative Rules to relevant facts.

Approved:

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1.0 INTRODUCTION

This document provides information about the generic cleanup criteria developed by the Michigan Department of Environmental Quality (MDEQ) under Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (of NREPA) and the Part 201 Administrative Rules (Part 201). The generic cleanup criteria are the risk-based screening levels for corrective actions required under Part 213, Leaking Underground Storage Tanks, of NREPA (Part 213)[1]. The revised Cleanup Criteria Requirements for Response Activity Rules took effect on_____.

A fundamental objective of the MDEQ remediation and redevelopment programs is to manage risks from environmental contamination in a manner that is protective of public health, safety, and welfare, and the environment. The revisions to the generic cleanup criteria for groundwater, soil, surface water protection, and volatilization to indoor air are designed to protect for unacceptable risks to the environment and the public due to exposure to environmental contamination.

The revisions to the generic cleanup criteria are a comprehensive update of the 2002 generic cleanup criteria, new criteria for 15 additional hazardous substances, and a revision to the volatilization to indoor air exposure pathway. Stakeholder input has been an on-going part of the comprehensive updates since 2006, as follows:

- Recommendations from the Michigan's Part 201 Environmental Remediation Program Review were received April 2007.
- The criteria related recommendations were incorporated into a proposal for program revisions that were publically presented in 2009.
- The 2010 statutory amendments to Part 201 of NREPA directed the MDEQ to update criteria.
- The MDEQ initiated a stakeholder process in 2012 through the Michigan's Collaborative Stakeholder Initiative that included updates to the cleanup criteria rules. Many issues related to the cleanup criteria remained unresolved even after continuing stakeholder discussions regarding criteria in 2013.
- In 2013, as no consensus on changes could be reached the MDEQ re-promulgated the cleanup criteria rules with only minor revisions.
- In 2014, a focused Criteria Stakeholder Advisory Group (CSA) comprised of industry, academia, government and nonprofit representatives was established.

CSA recommendations regarding criteria updates were provided to the MDEQ in November 2014. Most of the CSA recommendations were accepted by the MDEQ, but a few recommendations were discussed further and resolved at an April 2015 meeting between the MDEQ and CSA[2]. The revisions to the generic cleanup criteria reflect the following guiding principles of the CSA process:

- Chemical, physical data and toxicity values used for developing criteria should

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[1] MCL 324.21304a(2)
[2] Refer to CSA Report and MDEQ response Attachment C and D

be based upon the best available sound scientific information that is widely recognized.

- Process of selecting national or international information sources needs to be clearly identified. Selection decisions need to rely on sound science and be transparent enough for an independent reviewer to readily determine how they were developed.
- Exposure assumptions used to calculate criteria need to be reasonable and practical and where reliable data exists, use regional or Michigan-specific data.
- Generic cleanup criteria must be protective of public health and natural resources such that there are no unacceptable exposures to hazardous substances.

The CSA process did not address all aspects of the criteria rules, or issues that surfaced during the drafting process. Where there was not specific guidance the guiding principles were included in developing the revisions.

Highlights of the rule revisions, consistent with CSA recommendations include:

- Reorganization to consolidate similar information.
- Information specific to Michigan's conditions, when available.
- Easy reference to information sources.
- Residential exposures include children and adults.
- Consideration of mutagenic cancer causing chemicals that affect children.
- Consideration of noncarcinogenic chemicals that cause developmental and reproductive effects.
- New rules using a tiered process for evaluating contaminant vapors in buildings.

Abbreviations and acronyms for terms used throughout this document are contained in Appendix 2.

2.0 GENERIC CLEANUP CRITERIA

The generic cleanup criteria represent concentrations of a hazardous substance[3] in different environmental media (groundwater, soil, and vapor) that allow appropriate risk management decisions regarding contaminated sites. Hereafter for simplicity, the generic cleanup criteria will be referenced as criteria. The remediation programs that rely upon the criteria use a risk-based approach. The criteria represent an acceptable risk[4] from environmental exposures. Therefore,

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[3] MCL 324.20101(1)(x) "Hazardous substance" means 1 or more of the following, but does not include fruit, vegetable, or field crop residuals or processing by-products, or aquatic plants, that are applied to the land for an agricultural use or for use as an animal feed, if the use is consistent with generally accepted agricultural management practices at the time of the application or stamp sands:
(i) Any substance that the department demonstrates, on a case by case basis, poses an unacceptable risk to the public health, safety, or welfare, or the environment, considering the fate of the material, dose-response, toxicity, or adverse impact on natural resources.
(ii) Hazardous substance as defined in the comprehensive environmental response, compensation, and liability act, 42 USC 9601 to 9675.
(iii) Hazardous waste as defined in part 111.
(iv) Petroleum as described as a regulated substance in section 21303.

[4] MCL 324.20120a(4)-Cleanup criteria carcinogenic risks and noncarcinogenic effects

the criteria are risk-based and do not necessarily represent safe or free from harm concentrations. Satisfying the criteria allows for response activity or corrective action to be considered protective of public health, safety, and welfare, and the environment[5].

Generic criteria are used by property owners and responsible parties to evaluate the potential for unacceptable human or natural resource exposure to hazardous substances. Generic criteria are a valuable tool for the property transaction process to assess liability risk related to the potential presence of hazardous substances. Generic criteria, when used alone or in combination with engineering controls, provide an important level of certainty and simplification to the regulatory process for those seeking to return brownfield property to productive use. Generic criteria obviate the need for conducting more costly site-specific analysis to generate site-specific criteria.

The MDEQ develops criteria for two categories: residential and nonresidential[6]. The criteria developed for the residential category are the unrestricted residential use criteria[7], and represent the concentrations that establish a facility[8] pursuant to Part 201and may establish a site[9] pursuant to Part 213.

The criteria and screening level values are promulgated in the Generic Cleanup Criteria Tables[10] as:

- Table 1. Groundwater: Residential and Nonresidential
- Table 2. Soil: Residential
- Table 3. Soil: Nonresidential
- Table 4. VI Tier 1 Groundwater, Soil and Vapor Screening Levels

Hereafter for simplicity, these tables will be referenced as Criteria Tables.

2.1 Generic Cleanup Criteria Application to Land Use Categories

Residential[11] and nonresidential[12] land use categories are defined by statute. Residential and nonresidential criteria are distinguished by the established generic set of exposure assumptions

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[5] MCL 324.20118
[6] MCL 324.20120a(1)-Cleanup criteria and land use categories
[7] MCL 324.20101(1)(i)-Cleanup criteria for unrestricted residential use definition
[8] MCL 324.20101(1)(s)-Facility definition
[9] MCL 324.21303(l)-Site definition
[10] R 299.46 Generic Cleanup Criteria Tables 1 to 4
[11] MCL 324.201(1)(ss) Residential" means that category of land use for parcels of property or portions of parcels of property where people live and sleep for significant periods of time such that the frequency of exposure is reasonably expected or foreseeable to meet the exposure assumptions used by the department to develop generic residential cleanup criteria as set forth in rules promulgated under this part. This category of land use may include, but is not limited to, homes and surrounding yards, condominiums, and apartments.
[12] MCL 324.201(1)(ii) Nonresidential" means that category of land use for parcels of property or portions of parcels of property that is not residential. This category of land use may include, but is not limited to, any of the following:
(i) Industrial, commercial, retail, office, and service uses.
(ii) Recreational properties that are not contiguous to residential property.
(iii) Hotels, hospitals, and campgrounds.
(iv) Natural areas such as woodlands, brushlands, grasslands, and wetlands.

for each criteria category. Generic criteria may be applied to residential, nonresidential or both land uses at a site, if all relevant requirements are satisfied for application of a pertinent criterion[13]. An understanding of the generic exposure assumptions is necessary to determine the applicability of the criteria derived for the category to a specific site[14]. While generic residential criteria may be suitable for any land use, nonresidential criteria need further evaluation to determine the applicability to site conditions[15]. As an example, the nonresidential criteria address adult workers as the generic receptor; therefore, if a land use defined as nonresidential allows a regular presence of children (e.g., campground, day-care) the nonresidential criteria are not appropriate to address the potential exposure risks.

If remedial or corrective action result in a final remedy that relies upon criteria for unrestricted residential use, no land or resource use restriction or monitoring is required. If the final remedy relies on other than unrestricted residential use criteria some form of land or resource use restriction[16] for the affected property is necessary. Land or resource use restrictions are intended to assure that activities or characteristics of the property continue unchanged into the future such that unacceptable exposures will not occur.

2.2 Application of Generic Cleanup Categories and Land Use Zoning

An unrestricted residential land-use remedy is acceptable for all zoning categories. A remedy other than unrestricted residential must be consistent with the current zoning of the property[17]. Preparation of documentation for the remedy and development of any land or resource use restriction must include a review of the uses allowed by local zoning ordinances. If the local zoning ordinance allow for uses with greater exposure potential than the generic exposure assumptions used to develop the nonresidential criteria (e.g., nonresidential land uses that would provide care for children, or allow housing for an on-site attendant), if those uses do not currently exist they must be specifically prohibited within the restriction. If the property is not zoned, a land use restriction must limit property uses to those consistent with exposure assumptions for the current use and/or proposed future uses.

2.3 Assessing Compliance with Generic Cleanup Criteria

Statistical analysis of environmental data may be appropriate to assess compliance with generic criteria. The MDEQ may approve the use of statistical methods or other scientific methods of evaluating environmental data when determining compliance with pertinent criteria if the methods are determined by the MDEQ to be reliable, scientifically valid, and best represent actual site conditions and exposure potential[18]. The MDEQ's Sampling Strategies and Statistics Training Materials (S^3TM) (MDEQ, 2002) document was developed to provide information for determining when it is appropriate to use statistics and which statistical methods are appropriate

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[13] MCL.324.20120a(7)
[14] For the purpose of this document site means an area, place, property, parcel or parcels of property, and not as defined at MCL 324.21303(l).
[15] R 299.4(7); R 299.34(4)
[16] MCL 324.20114c; MCL 324.20121; MCL 324.21310a
[17] MCL 324.20120a(6)-Consistent with zoning requirements
[18] MCL 324.20120a(14)

to use when evaluating compliance. The guidesheets of S^3TM, while dated, provide useful information for the current exposure pathways regarding sampling strategies and the appropriate application of statistics.

Fundamentally, to evaluate compliance with criteria all environmental data must reliably represent conditions of the environmental media[19], and must represent the exposure assumptions used to develop criteria[20]. An understanding of the generic exposure assumptions used to develop a criterion is necessary to determine whether the sampling adequately represents those exposure assumptions. For example, the cyanide residential direct contact criterion is based upon acute toxicity resulting in fatality; therefore, evaluating compliance with statistics is not appropriate since point-by-point exceedances can result in an unacceptable exposure.

The goal of samples used to estimate a representative concentration in an environmental medium is to represent both exposures and hazardous substance concentrations in an exposure unit. An exposure unit is the area over which an exposed receptor may reasonably be assumed to move at random and where contact with an environmental medium is equally likely at each location. The generic size of an exposure unit for a residential property is 1/4 acre and 2 acres for a nonresidential property, except for the soil inhalation criteria where the source size is based upon a ½ acre for both categories. In general, the MDEQ does not require adjustment to the generic criteria for larger sites. The exception is the requirement to modify the source size to establish the soil inhalation criteria. Refer to Section 12 for further explanation. Adjustment is not normally required because typical soil sampling tends to follow a directed sampling technique where the focus is on areas where contamination is known or suspected. Directed sampling is based on some prior knowledge or some logical basis (*e.g.*, follow-up sampling) such that any bias does not under-represent existing contaminant levels. Generally, only data from an appropriate exposure unit may be used in a statistical calculation for evaluating compliance.

2.4 Additional Generic Cleanup Criteria Application Information

To determine the necessity of any remedial or corrective action, or to determine what duties an owner or operator of a facility may have[21], relevant pathways[22] need to be identified. Information regarding facility conditions that make a pathway relevant is included within the rules that establish the health-based values for each pathway. Additional application and relevant pathway information is included in the following Sections' discussion regarding criteria development for each of the various pathways.

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[19] R 299.4(8)
[20] R 299.34(4)
[21] MCL 324.20107a; MCL 324.21304c-Duties of owner or operator of Part 201 "facility" or Part 213 "property"
[22] R 299.2(h) "Relevant pathway" means an exposure pathway that has a reasonable potential to occur at a facility including potential future uses. The components of an exposure pathway are a source or release of a hazardous substance, an exposure point, and, if the exposure point is not the source or point of release, a transport medium. These components are expected to be present such that human or nonhuman receptors have a reasonable potential to be exposed to a hazardous substance from a source or release. The existence of a municipal water supply, exposure barrier, or other similar feature does not automatically make an exposure pathway irrelevant.

3.0 GENERIC CRITERIA DEVELOPMENT FRAMEWORK

The CSA considered it critically important that revisions to the generic criteria be appropriately calibrated to ensure that sites of real concern are identified and addressed—and that sites with minimal potential for public health or environmental harm are not inadvertently brought into the remediation process. Following is a discussion of the general principles of risk assessment and selection methodologies the MDEQ used to determine appropriate calibration for the revisions to the criteria. A Glossary of terms Is provided as Appendix 1.

3.1 General Principles:

General principles used in criteria development include, risk assessment, acceptable risk, best available information, generic receptors, reasonable maximum exposures, exposure pathways, and individual and mixtures of hazardous substances. Each of the principles are discussed further in the following Sections.

3.1.1 Risk Assessment:

The statue directs the MDEQ to develop criteria based on generic human health risk assessment assumptions[23]. "Risk assessment" means the analytical process used to estimate the risk to the public health, safety, or welfare or to the environment associated with a release or threat of release of a hazardous substance at a site[24]. The MDEQ conducted risk assessment according to United States Environmental Protection Agency Human Health Evaluation Manual (USEPA, 2014) and other states current practices. Briefly, risk assessment consists of:

- Hazard identification and dose-response assessment – determining the adverse effect(s) and acceptable dose level(s).
- Exposure assessment – exposure pathways and receptor (including susceptible populations) identification.
- Risk characterization – risk estimates or cleanup levels estimation based on predetermined acceptable risks using exposures and effects assessment outcomes.

The collaborative Criteria Stakeholder Advisory Group (CSA) and CSA Technical Advisory Groups (TAGs) process were used in creating the decision frameworks for conducting three significant steps in the criteria update process, namely: chemical-physical parameter values update, toxicity values update, and generic exposure assumptions update. Refer to Figures 1 to 3, Attachment C and D, and Attachment H for further detail.

The MDEQ develops criteria for hazardous substances for different exposure pathways considering sound science (e.g., chemical-specific data, exposure factors, and Michigan soil and meteorological data), USEPA and other states' risk assessment practices, and CSA recommendations.

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[23] MCL 324.20120a(3)
[24] R 299.2(i)

The risk assessment activities conducted by the MDEQ to develop the criteria presented in the Criteria Tables have been documented. These documentations include:

- Chemical Update Worksheets for each hazardous substance. (Attachment E)
- Criteria Stakeholder Advisory Group (CSA) Final Report including Decision Frameworks for establishing physical-chemical values, toxicity values and exposure factors. (Attachment C)
- MDEQ Response to CSA Final Report. (Attachment D)
- Technical Support Documents and Background Documents for exposure values, fate and transport parameters, and statewide background concentrations. (Attachments G to M)
- MDEQ Toxics Steering Group (TSG) report on "Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria." (Attachment F)
- Chemical-specific background documents.
  - Carcinogenic PAHs (cPAHs) (Attachment N)
  - Cyanide (Attachment O)
  - Lead (Attachment P)
  - Methane (Attachment Q)

3.1.2 Acceptable Risk – Generally

The criteria are generally intended to address chronic[25] human health effects resulting from long-term exposure to carcinogenic and noncarcinogenic hazardous substances to protect public health considering acceptable risk levels defined by statute[26]. However, other health effects or safety concerns may occur for some hazardous substances or under certain exposure scenarios (e.g., acute). In addition to the generic criteria, when a hazardous substance poses risk due to: 1) acute toxicity or short-term toxicity, and/or 2) flammability and explosivity characteristic, the MDEQ may develop immediate response or screening levels.

Acceptable risks for carcinogenic and noncarcinogenic hazardous substances as defined are:

- For cancer risk due to carcinogenic effects or effects of carcinogens with mutagenic mode of action, the target risk is 1 in 100,000. An increased cancer risk of 1 in 100,000 is defined as the 95% upper bound on the calculated risk of 1 additional cancer above

[25] R 299.1(i)-Chronic toxicity definition

[26] MCL 324.20120a(4) If a hazardous substance poses a carcinogenic risk to humans, the cleanup criteria derived for cancer risk shall be the 95% upper bound on the calculated risk of 1 additional cancer above the background cancer rate per 100,000 individuals using the generic set of exposure assumptions established for the appropriate category or subcategory. If the hazardous substance poses a risk of an adverse health effect other than cancer, cleanup criteria shall be derived using appropriate human health risk assessment methods for that adverse health effect and the generic set of exposure assumptions established for the appropriate category or subcategory. A hazard quotient of 1.0 shall be used to derive noncancer cleanup criteria. If a hazardous substance poses a risk of both cancer and 1 or more adverse health effects other than cancer, cleanup criteria shall be derived under this section for the most sensitive effect.

the background cancer rate per 100,000 individuals continuously exposed to a carcinogen at a given average dose for a lifetime[27].

- For noncancer risk due to noncarcinogenic effects, including developmental or reproductive effects, the hazard quotient (the ratio of the exposure level at a site to no adverse effect level) is 1.
- If a hazardous substance poses a risk of both cancer and 1 or more adverse noncancer health effects, criteria are derived for the most sensitive effect.

In addition to the criteria developed pursuant to the Part 201 Administrative Rules, the incorporation of the Surface Water Quality Standards as generic GSI criteria[28] address the most sensitive effect from chronic human health effects for carcinogenic and noncarcinogenic effects, aquatic life effects, and wildlife effects from the bioaccumulative compounds of concern.

3.1.3 Best Available Information

Best available information is defined[29] when used in relation to a risk assessment or the development of criteria, to be the most scientifically credible and relevant data available for a particular hazardous substance, exposure assumptions, or the methodology for characterizing dose-response or risk.

The use of "best available information" in revising the criteria[30] is represented by requirements for 1) knowledge gained through research and studies; 2) best practices from other states; 3) sound science; and 4) available new information.

Similarly, the statute[31] requires "best available information" when developing site-specific criteria by instructing the MDEQ to approve numeric or nonnumeric site-specific criteria in a response activity if such criteria, in comparison to generic criteria, better reflect best available information concerning the toxicity or exposure risk posed by the hazardous substance or other factors.

In updating the criteria, the MDEQ used Decision Frameworks that are products of the CSA and MDEQ consensus (MDEQ, 2015). The Decision Frameworks described the process of identifying the physical and/or chemical-specific values, toxicity endpoints for different health

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[27] R 299.1(o)-Increased cancer risk of 1 in 100,000 definition
[28] MCL 324.20120e(1)(a)
[29] R 299.1(f) "Best available information" means, when used in relation to a risk assessment or the development of cleanup criteria, the most scientifically credible and relevant data available for a particular hazardous substance, exposure assumptions, or the methodology for characterizing dose-response or risk. Such information may include, but is not limited to, any of the following:
(i) The peer reviewed scientific literature.
(ii) Risk assessment guidance and databases maintained by the United States Environmental Protection Agency.
(iii) Other peer reviewed risk assessment guidance, databases, and other information sources recognized by the risk assessment community as scientifically reliable.
(iv) Other scientific studies that are acceptable to the department.
[30] MCL 324.20120a(17)-: The department shall evaluate and revise the cleanup criteria. The evaluation and any revisions shall incorporate knowledge gained through research and studies in the areas of fate and transport and risk assessment and shall take into account best practices from other states, reasonable and realistic conditions, and sound science. Following this revision, the department shall periodically evaluate whether new information is available regarding the cleanup criteria and shall make revisions as appropriate.
[31] MCL 324.20120b(1)

effects, and exposure factor values. The Decision Frameworks include Data Quality Objectives (DQOs) that are applied to data sources and used to meet the "best available information" requirement. For example, in identifying generic exposure assumptions (e.g. exposure duration, soil ingestion rate, and body weight), the DQOs that need to be met for data sources and generic value selection include:

- Clear and Comprehensive: The degree of clarity and completeness with which the data, assumptions, methods, quality assurance, sponsoring organizations, and analyses employed to generate the information are documented.
- Sound and Credible: The extent to which the scientific and technical procedures, measures, methods, or models employed to generate the information are reasonable for, and consistent with, the intended application, and are regularly maintained, subject to peer review, and the best available science.
- Transparent and Objective: The data are published or publicly available and free from conflicts of interest.

3.1.4 Generic Cleanup Criteria Receptors

For the residential category, the MDEQ characterizes the carcinogenic and noncarcinogenic health effects to children ages <1 to 6 years and the adult population by combining the exposures of these two subpopulations (e.g. age-adjusted intake rates) when developing health-based values. Risk to hazardous substances with developmental and reproductive effects are addressed by characterizing risk to children ages <1 to 6 years and pregnant females. The nonresidential health-based values address adult workers as generic receptor and pregnant workers for developmental hazardous substances. Refer to Section 3.2.5 and Attachment F for details.

3.1.5 The Reasonable Maximum Exposure (RME) Concept

This concept is used by USEPA to estimate the "reasonable maximum exposure" (RME) expected to occur under both current and future land-use conditions (USEPA, 1989). The RME concept results in a conservative (though not worse case) estimate of long-term exposure that is protective of the majority of the population (USEPA, 2002c). This concept combines average and upper percentile exposure assumptions to achieve a RME. The MDEQ includes RME estimates when assessing individual exposure pathways.

The exposure assumptions used in the calculation of generic health-based values were developed for the MDEQ by its contractor SRC, Inc. (SRC) using the CSA Framework for Determination of Exposure Values and the Data Quality Objectives. The exposure values represent a combination of "high-end" and central tendency values to produce an RME. For example, the life span, body weight, and skin surface area values represent central tendency values while exposure duration, exposure frequency, drinking water intake rate, soil ingestion rate, and soil adherence factors represent high-end values. The MDEQ followed USEPA's RME approach to protect the majority of the potentially exposed, susceptible population consistent with USEPA and other state agencies risk assessment practices.

The CSA recommended the use of a probabilistic approach to ensure that the combination of exposure factors used in developing the health-based values represents a reasonable maximum exposure (RME). This approach has not been used in this update due to MDEQ resource limitations, but will be discussed further as part of future criteria update efforts as agreed during the CSA-MDEQ April 2015 meeting.

3.1.6 Exposure Pathways

The MDEQ develops criteria for different exposure pathways to evaluate patterns of human exposure to hazardous substances in environmental media, such as, groundwater, soil, and vapor[32]: The criteria are based on generic human exposure assumptions determined by the MDEQ to appropriately characterize activities and patterns of human exposure associated with certain land uses. The MDEQ must utilize only reasonable and relevant exposure pathways in determining these assumptions.

An exposure pathway is the route a hazardous substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) the hazardous substance[33]. An exposure pathway has the following components:

- A source of contamination (such as an abandoned business);
- An environmental medium and transport mechanism (such as movement through groundwater);
- A point of exposure (such as a current or potential future private well or structure);
- A route of exposure (eating, drinking, breathing, or touching), and
- A receptor population (people potentially or actually exposed).

When these components are present or have the potential to be present in the future, the pathway is relevant[34].

The exposure pathways and environmental media considered in developing criteria and screening levels include:

Groundwater:

- Ingestion of groundwater as drinking water (MCL 324.20120a(5); R 299.10)
- Groundwater-surface water interface (GSI) [MCL 324.20120e(1)(a); R 299.6(10)]

Soil:

- Ingestion of and dermal contact with soil[35] (R 299.20)
- Soil leaching hazardous substances into groundwater (MCL 324.20120a(18); R 299.22)
- Inhalation of volatiles from soil via ambient air inhalation (R 299.26)
- Inhalation of soil particulates via ambient air inhalation (R 299.26)

Volatilization to indoor air: (R 299.27)

- Volatilization into indoor air from groundwater
- Volatilization into indoor air from soil

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[32] MCL 324.20120a(3)
[33] American Society for Toxic Substances and Disease Registry (ASTSDR) Glossary
[34] R 299.2(h) – Relevant pathway definition
[35] R 299.1(k)-Direct contact definition

- Volatilization to indoor air from vapors

Others:

- Flammability and explosivity of hazardous substances in groundwater (R 299.16)
- C_{sat} (R 299.18)

3.1.7 Criteria for Individual Hazardous Substances and Mixtures Assessment

The criteria generally represent an acceptable level of risk posed by individual hazardous substances from a single exposure pathway. However, certain group of chemicals (e.g., dioxins and furans, carcinogenic polycyclic aromatic hydrocarbons (cPAH), or trihalomethanes (THMs)) exhibit similar chemical or toxicity characteristics and these are evaluated using alternative approaches. Footnotes attached to the name of the hazardous substance in the Criteria Tables[36] represent the use of an alternative evaluation approach.

3.2 Selection Methodology – Input Values

The MDEQ-CSA Decision Frameworks present how the chemical -physical, toxicity and generic exposure value data and data sources should be evaluated and selected. Refer to Figures 1 to 3 and Attachment C and D. MDEQ adopted the CSA recommended Frameworks with some modifications agreed upon by both CSA and MDEQ.

The CSA recommendations included preparation of chemical update worksheets to document the results of the update reviews (pursuant to the decision frameworks). Chemical Update Worksheets have been developed for all hazardous substances reviewed. Refer to Attachment E. The worksheet information provides the basis for the Toxicological, Chemical–specific and Chemical-physical Tables included with the rules[37] The Criteria Tables include designations for the basis of the criterion, as recommended by CSA.

3.2.1 Chemical-physical Data

The identification and selection of chemical-physical values were conducted using the Chemical-physical Value Decision Framework. Refer to Figure 1 and Attachment C and D. This work is documented for each hazardous substance in Section A of the Chemical Update Worksheets.

3.2.2 Toxicity Endpoints or Reference Values

The toxicity endpoints are generally chronic values. These values are used in calculating the heath-based values that address acceptable risk to long term exposures via different exposure pathways. Generally, toxicity values are based on health effects. For some chemicals, acute exposure and safety concerns are addressed by criteria derived with alternative values.[38]

Reference values (RfVs) include:

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[36] R 299.49(1) Footnotes (J), (N), (O), (Q), and (W)
[37] R 299.50 Tables 1 to 3
[38] R 299.4(2) "…If a hazardous substance has a more sensitive effect than those associated with the chronic toxicity data used to calculate a generic criterion, than a criterion shall be developed to address the most sensitive effect."

- Ingestion:
  - Oral reference dose (RfDo) [R 299.2(f); R 299.36(1)]
  - Oral cancer slope factor (CSFo) [R 299.1(h); R 299.38]
- Dermal contact:
  - Dermal reference dose (RfDd) [R 299.2(f); R 299.36(1)]
  - Dermal cancer slope factor (CSFd) [R 299.1(h); R 299.38]
- Inhalation
  - Noncancer reference concentration (RfC) [R 299.2(e)]
  - Inhalation cancer unit risk factor (IURF) [R 299.1(q)]

The toxicity values are updated using the process presented in the Toxicity Value Framework. Refer to Figure 2 and Attachment C and D. This process is documented in Section B of the Chemical Update Worksheet. Section B also presents toxicity information on the drinking water standard, aesthetics value, mutagenicity, developmental effect, and absorption efficiencies.

3.2.3 Exposure and Fate and Transport Assumptions

The health-based values are calculated using exposure parameters such as averaging time, exposure duration, exposure frequency, ingestion rate, and body weight. Fate and transport models used in developing a certain values require assumptions for groundwater, soil, or vapor. MDEQ's contractor, SRC, based on the Decision Framework for Selection of the Generic Exposure Assumptions (Refer to CSA 2015, recommendation 2.7, TAG 2 Report - Appendix D) developed generic exposure and fate and transport values. The decision framework using the data quality objectives was intended to ensure the best available information, consistency and transparency. Recommendations were provided for the following:

- Body weight
- Drinking water intake rate
- Exposure duration and averaging time
- Particulate emission factor (PEF) from wind erosion and vehicular traffic
- Skin surface area
- Soil and dust ingestion rate
- Soil dermal adherence factor
- Soil direct contact exposure frequency
- Soil to ambient air volatilization factor (VF)

The MDEQ review of SRC recommendations led to further development of exposure assumptions where Michigan specific data was available and refined the exposure assumptions for developmental or reproductive exposures. The process used for selecting the generic exposure values is documented within the MDEQ Technical Support Documents (MDEQ TSDs) (MDEQ, 2015a to h) Refer to Attachment H.

During the update process, generic soil and soil temperature values were developed in response to the CSA recommendations to evaluate Michigan-specific data when available and to support the implementation of a tiered process for the volatilization to indoor air pathway. Further details regarding the development of the Michigan-specific data is available at Section 4.4.

3.2.4 Mutagenic Carcinogens

As recommended by CSA the MDEQ has addressed carcinogens identified as mutagenic by the USEPA[39]. Children ages < 1 to 16 years (early-life susceptibility) are shown to be more susceptible to the effects of a carcinogen with a mutagenic mode of action (e.g. tumor development) due to their rapid growth (USEPA, 2005a, 2005b). These mutagenic carcinogens are DNA reactive or have the ability to bind to DNA and can produce mutations subsequent to other key events (e.g. cytotoxicity, regenerative proliferation). The MDEQ protects children from this type of carcinogen by calculating health-based values from adjusted cancer potency factors.

USEPA (2005a,b) recommends the adjustment of cancer potency factors by applying chemical-specific safety factor or generic age-dependent adjustment factor (ADAF) to calculations of cleanup levels when evaluating cancer risk associated with exposure of children ages < 1 to 16 years to mutagenic carcinogens. The CSA recommended that this adjustment be made (CSA, 2015). Consistent with USEPA and CSA recommendations, the MDEQ modified the cancer potency values used in calculating HBVs for mutagenic carcinogens by using a generic ADAF of 10 for children ages < 1 to 2 years and a generic ADAF of 3 for children ages 2 to 16 years. The generic ADAFs are used if chemical-specific data to evaluate differences between adults and children are not available. For example, the potential for added risk from early-life exposure to vinyl chloride is accounted for by applying a chemical-specific ADAF of two for ages < 1 to 16 years (USEPA, 2007).

The Chemical Update Worksheets for each hazardous substance identified by USEPA as mutagenic includes information regarding the mutagenic mode of action. The list of mutagenic carcinogens is presented in Table 3. In the Criteria Tables, mutagenic hazardous substances are designated with Footnote (MM), and when a criterion is based on mutagenic effects, Footnote (MM) follows the numeric value.

3.2.5 Developmental or Reproductive Toxicity

Some hazardous substances may cause developmental or reproductive toxicity in humans. The CSA recommended that the MDEQ use USEPA information to develop a process to account for documented developmental or reproductive effects. The process for establishing health-based values for developmental or reproductive toxicity (DR Process) was developed by the MDEQ Toxics Steering Group (TSG) and includes identification of sensitive receptors and relevant exposure assumptions[40]. Refer to the MDEQ TSG Developmental or Reproductive Criteria Development Process Report (MDEQ TSG DR Process Report) - Attachment F.

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[39] R 299.38(2)

[40] R 299.34(2) The department may calculated generic cleanup criteria for certain hazardous substances using exposure assumptions other than those shown in the equations in these rules if either of the following conditions is satisfied: (a) A hazardous substance causes an adverse effect in a sensitive lifestage or subpopulation that is not adequately protected by a generic criterion or represented by any of the generic exposure assumptions. Adverse effects to be addressed by this subrule include, but are not limited to, developmental or reproductive effects. (b) The toxicokinetics of a hazardous substance are not best represented by the average daily does, when accounting for the most sensitive effect.

Developmental toxicity and reproductive toxicity are defined (MDEQ, 2015) as follows:

- "Developmental toxicity means adverse outcomes induced during exposure at any early-life stage from preconception through adolescence (USEPA, 2006b; WHO, 2011). This toxicity can occur at any point in the life span and may include: (1) death; (2) structural abnormality; (3) altered growth; and/or (4) functional deficiency (USEPA, 1991; USEPA, 2006b; WHO, 2011)."
- "Reproductive toxicity manifests as harmful effects on sexual function and fertility. This can include changes to the female or male reproductive organs, the related endocrine system, and/or pregnancy outcomes. For reproductive effects, the process… is intended to address those that occur as a result of early life exposures (i.e., from preconception through adolescence)."

A hazardous substance is identified as having developmental or reproductive toxicity if the oral or inhalation (noncarcinogenic) reference toxicity value determined for that substance is based on developmental or reproductive effects. Therefore, a substance may be identified as developmental or reproductive for oral exposure only (e.g., aluminum), inhalation only (e.g., formaldehyde), or both (e.g., methyl ethyl ketone).

The MDEQ protects sensitive subpopulations (i.e., children, pregnant residents, and pregnant workers) from developmental or reproductive toxicity by using available developmental or reproductive toxicity values (e.g., reference dose, reference concentration, minimal risk level)). The health-based value for a hazardous substance is based on the minimum value calculated for carcinogenic, noncarcinogenic, mutagenic, or developmental or reproductive effects.

The TSG DR Process is summarized in Figure 2 of the MDEQ TSG DR Process Report. Refer to Attachment F. Briefly, the DR Process consists of the following steps when developing developmental or reproductive-based values.

Step 1. Toxicity Value Decision Framework Literature Search
A literature search is conducted following the Toxicity Value Framework in order to identify the best available toxicity reference value for a hazardous substance.

Step 2. Determine Best Available Reference Value and Document.
Once the available information regarding developmental or reproductive toxicity is evaluated, the developmental or reproductive and/or non-developmental or reproductive reference values that are critical to protect for the most sensitive noncancer endpoint for a given exposure pathway are determined.

Step 3. Determine Developmental or Reproductive Receptor Based on Developmental or Reproductive Reference Value.
Based on currently available information for both toxicity and exposure, the young child and the pregnant woman (to protect her fetus) are the receptors for hazardous substances with

developmental or reproductive toxicity, unless there is chemical-specific information that a different developmental window of exposure is more appropriate.

Step 4. Calculate Developmental or Reproductive-based Cleanup Values.
This step uses toxicity value(s) from Step 2, the receptor exposure assumptions from Step 3, and the appropriate exposure pathway equations to calculate the developmental or reproductive health-based values. Exposure pathway equations including relevant exposure assumptions for developmental receptors are presented in the rules for drinking water[41], soil direct contact[42], soil inhalation criteria[43], and volatilization to indoor air[44].

Categories of Pregnant Receptors:
There is sufficient data for many hazardous substances that demonstrates that adverse endpoints can result from a single day or shorter exposure during prenatal development. Mortality, structural, or functional abnormalities are adverse effects that are most likely to occur from an acute or single event exposure. Developmental or reproductive toxicity that manifests as only altered growth (e.g., reduced birth weight, delayed ossification) without structural or functional changes is most likely to occur from repeated exposures during development. Based on chemical-specific developmental or reproductive adverse effects information, the exposure of pregnant receptors (residents and workers) to hazardous substances with developmental or reproductive toxicity is classified into either a single event exposure (SE) for mortality, structural or functional abnormalities; or a full-term exposure (FT) for altered growth. For those categorized as SE, the criteria will be developed assuming a single exposure to a pregnant receptor. For those hazardous substances categorized with FT developmental or reproductive toxicity, the exposure is assumed to occur over the full duration of the pregnancy. The environmental data used to determine compliance with these criteria must represent the exposure assumptions[45].

The Chemical Update Worksheet for each hazardous substance includes documentation of Step 1 to 3 of the DR process. Refer to Attachment E. A list of hazardous substances with developmental or reproductive toxicity is contained in Table 4. These hazardous substances are designated with Footnote (DD) in the Criteria Tables, and when a criterion is based on developmental or reproductive effects Footnote (DD) follows the numeric value.

4.0 CALCULATION OF HEALTH-BASED VALUES (HBVs) AND SCREENING LEVELS

The criteria presented in the Criteria Tables are based on calculated health-based values (HBVs) and other considerations[46] which include drinking water standards, aesthetic values, solubility, target detection limits, maximum soil ceiling concentration, and source contamination size (for soil to ambient air exposure). The HBVs are developed using different equations for

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[41] R 299.10
[42] R 299.20
[43] R 299.26
[44] R 299.27
[45] R 299.34(3) Refer to Section 2.1 for further discussion
[46] R 299.6

each exposure pathway and for each category of health effect. The pathway-specific final HBV for a hazardous substance is based on the minimum value calculated for carcinogenic, noncarcinogenic, mutagenic, or developmental effects[47].

4.1 Toxicity and Exposure Assessment

The HBVs are calculated risk-based values that protect for chronic toxicity and most sensitive effect using relevant and reasonable exposure assumptions[48]. The toxicity data and exposure factors (assumptions and fate and transport inputs) used in calculating the HBVs are summarized in Tables 5, 6, and 7 and the tables of Rule 50[49]. Additions to or modification of the SRC recommendations[50] for exposure and fate and transport inputs were made to accommodate new information or best science (e.g., soil characteristics, dispersion factors, or developmental effects). Refer to the MDEQ TSDs in Attachment H for additional information

4.2 Hazardous Substance Information

When sufficient information is available for a hazardous substance, HBVs have been developed for commonly encountered hazardous substances and for hazardous substances that have been identified as a contaminant of concern for specific sites.

4.2.1 Chemical-Physical and Chemical Specific Values

The selected values used in calculating the HBVs and their sources are presented in Table 2 Chemical-Physical Data and Table 3 Chemical-Physical Data of Rule 50[51]. This information is also available in the Chemical Update Worksheets for each hazardous substance. Refer to Attachment E.

4.2.2 Toxicity Endpoints or Reference Values

The selected values used in calculating the HBVs and their sources are presented in Table 1 Toxicological Date of Rule 50. Detailed information on Tier 1, 2 and 3 values including basis (e.g. critical studies and data sources) are documented in the Chemical Update Worksheets for each hazardous substance. Refer to Attachment E.

4.3 Exposure Assumptions

The exposure assumptions are presented in the Rules[52]. Tables 5, 6 and 7 present the exposure assumptions and inputs for each pathway including basis and source. More detailed information on how the exposure values are derived is presented in the MDEQ TSDs and MDEQ background documents. Refer to Attachment H to M.

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[47] MCL 324.20120a(4), which states in part: … If a hazardous substance poses a risk of both cancer and 1 or more adverse health effects other than cancer, cleanup criteria shall be derived under this section for the most sensitive effect.
[48] MCL 324.20120a(3), which states in part: The department shall develop cleanup criteria based on generic human health risk assessment assumptions determined by the department to appropriately characterize patterns of human exposure associated with certain land uses. …
[49] R 299.50 – Tables 1-3
[50] Refer to Attachment H
[51] R 299.50
[52] R 299.10 to R 299.27

For developmental or reproductive toxicants, the exposure assumptions used in calculating the values are shown in Table 5 and 6. The justification for these values is presented in the MDEQ TSG DR Process Report. Refer to Attachment F.

4.4 Soil-specific Information - Soil Type and Characteristics

The MDEQ has reviewed equation input values previously used for soil type characteristics and determined that a generic soil type was not used consistently with the development of generic soil criteria and C_{sat}[53]. The MDEQ has also determined that sufficient information is available to utilize Michigan specific data to establish a generic soil type and the associated generic input values. Refer to Attachment G for additional information.

4.4.1 Generic Soil Type

A review statewide of the United States Department of Agriculture, Natural Resources Conservation Service (USDA) soil-type maps was conducted of the 12 USDA soil-types and concluded the most prevalent soil-type throughout the state is sand. Refer to Attachment G Figure 2. More than 30 percent of the state's mapped soils represent the USDA classification of sand. Using sand specific soil characteristics as appropriate input values for the applicable soil criteria equations allows the resulting generic soil criteria to represent reasonable exposures for site conditions throughout the state.

The USDA classifications are based upon the relative percentages of sand, silt and clay. Refer to Figure 8. The Unified Soil Classification System (USCS) commonly used classifications cannot be directly substituted for USDA classifications. A table to assist the appropriate selection of the USDA classification has been developed[54] (Refer to Table 1 and Figure 8). A list of reasonably conservative specific soil characteristics has been developed by USEPA for the 12 USDA soils[55] (Refer to Table 2). These values were developed considering soil-physics science, available studies, and expert opinion. The sand-specific soil characteristics (e.g. soil bulk density, soil porosity) of this table are used in calculating the generic soil criteria.

Using sand as the generic soil type does not preclude the use of other soil types specific to the site when developing generic criteria using facility-specific[56] soil information.

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[53] R 299.18; R 299.22; R299.26; and R 299.27
[54] R 299.7(7)-Table 1
[55] R 299.7(7)-Table 2
[56] R 299.2(m) "Facility-specific" means department-approved generic input values that when representative of conditions at the facility may be used as input for the calculated health-based values. The parameter values include the following: (i) Environmental conditions that allow the resulting criterion to represent unrestricted generic residential categorical criteria that do not depend upon any land use or resource use restriction to ensure protection pursuant to Section 20120a(1)(a) of the act."

4.4.2 Soil Types Specific to the Site

Other soil types specific to the site may be used in developing generic criteria. The list of specific soil characteristics for the 12 USDA (Refer to Table 2), represents the MDEQ-approved facility-specific generic input values. When soil has been visually observed and documented sufficient to characterize a soil-type as sand, sandy loam, loamy sand, or loam, the facility-specific soil input values for those soil types may be used. These four soil types represent more than 90 percent of the state's mapped soils. MDEQ-approved methods may confirm other USDA soil types and the generic soil-type input values for the identified soil type may be used to determine alternative generic criteria.

When heterogeneous soils are present, a sensitivity analysis of all identified soil types is necessary to determine the soil-type that will generate the most restrictive soil criterion. To generate generic soil criteria, the soil-type that generates the most restrictive soil criterion is used. For developing volatilization to indoor air criteria, there are models or methods available to evaluate heterogeneous or multilayer soil present at a property that would allow development of site-specific criteria.

When non-native material consistent with materials defined as beneficial use by-products in Part 115 of the NREPA[57] is present, the generic soil type sand and sand-related input values may be used to develop generic criteria. Other non-native materials will require development of the related input values.

When determining soil types for alternative generic inputs, the use of <u>all</u> of the appropriate soil type-related values is required based on soil type that is more appropriate for the site than sand.

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[57] MCL 324.11502(8) "Beneficial use by-product" means the following materials if the materials are stored for beneficial use or are used beneficially as specified and the requirements of section 11551(1) are met:

(a) Coal bottom ash or wood ash used for beneficial use 3 or wood ash or coal ash, except for segregated flue gas desulfurization material, used for beneficial use 1, 2, or 4.

(b) Pulp and paper mill ash used for beneficial use 1, 2, 3, or 4.

(c) Mixed wood ash used for beneficial use 1, 2, 3, or 4.

(d) Cement kiln dust used as a flue gas scrubbing reagent or for beneficial use 1, 2, 3, or 4.

(e) Lime kiln dust used as a flue gas scrubbing reagent or for beneficial use 1, 2, 3, or 4.

(f) Stamp sands used for beneficial use 1 or 2.

(g) Foundry sand from ferrous or aluminum foundries used for beneficial use 1, 2, 3, 4, or 5.

(h) Pulp and paper mill material, other than the following, used for beneficial use 3:

(*i*) Rejects, from screens, cleaners, and mills dispersion equipment, containing more than de minimis amounts of plastic.

(*ii*) Scrap paper.

(i) Spent media from sandblasting, with uncontaminated sand, newly manufactured, unpainted steel used for beneficial use 1 or 2.

(j) Dewatered concrete grinding slurry from public transportation agency road projects used for beneficial use 1, 2, 3, or 4.

(k) Lime softening residuals from the treatment and conditioning of water for domestic use or from a community water supply used for beneficial use 3 or 4.

(*l*) Soil washed or otherwise removed from sugar beets that is used for beneficial use 3.

(m) Segregated flue gas desulfurization material used for beneficial use 1 or 3.

(n) Materials and uses approved by the department under section 11553(3) or (4). Approval of materials and uses by the department under section 11553(3) or (4) does not require the use of those materials by any governmental entity or any other person.

When a facility-specific soil-type is used to develop alternative generic criteria it should also be applied to the development of all applicable soil criteria (soil-water partitioning groundwater protection criteria, volatile soil inhalation criteria, volatilization to indoor air criteria, and C_{sat}). Additional information on the necessary field or laboratory testing necessary for establishing a USDA classification is being developed.

4.4.3 Generic Soil Temperature

Chemical-specific Henry's law constants (HLC) are used to estimate the partitioning of chemicals between different environmental media or to predict the emission or flux rates of a hazardous substance from groundwater, soil, or a vapor into indoor air or ambient air based on the system temperature. The chemical-specific HLC is typically reported at a standard temperature of 25 degrees Celsius. However, average subsurface soil temperatures are typically less than this value. Based on Michigan-specific soil data, the statewide average annual soil temperature is 10 degrees Celsius (283.15 Kelvin). Justification for the use of 10 degrees is available in Attachment I.

When calculating the soil-water portioning value, C_{sat}, and volatile soil inhalation values, a temperature adjustment factor (TAF) is applied to the HLC to account for the difference between the temperature that HLCs are typically reported and the generic average annual soil temperature value. A TAF of 0.5 (or ½) is used to estimate the HLC value at the Michigan average annual soil temperature of 10 degrees Celsius. The TAF-based approach does not limit a party from deriving a site-specific adjusted HLC at system temperatures other than 10 degrees Celsius if the system temperature better represent site conditions.

The equations for calculating the volatilization to indoor air screening levels do not use a TAF. Within these equations, the dimensionless HLC is corrected for average soil temperature using the Clausius-Claperyron relationship. This HLC correction is consistent with USEPA methods for volatilization to indoor air.

MDEQ-approved facility-specific soil temperatures by county have been developed[58]. Refer to Attachment G Table 1. Statewide soil temperature contours were determined from soil data collected at Michigan State University Extension weather stations across the state. Refer to Attachment G Figure 6. Based on the temperature contours, county-specific average annual soil temperatures (rounded to the nearest one half degree Celsius) were developed by determining a centroid temperature for each county.

Facility-specific, generic or site-specific temperature adjustments may be made to the equations for C_{sat}[59],, the soil-water partition value[60], and the volatile soil inhalation value[61]. Further information on the system temperature adjustment of the HLC is available in Attachment I.

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[58] R 299.7(7) – Table 3
[59] R 299.18
[60] R 299.22 – Equations 1 & 2
[61] R 299.26 – Equation 9

4.5 Volatile Hazardous Substances

A "volatile" is defined[62] as a hazardous substance that exhibits a Henry's law constant (HLC) equal to or greater than 0.00001 (or 10^{-5}) atmosphere-cubic meter per mole (atm-m^3/mol) at standard temperature and pressure. Some hazardous substances with HLC less than 10^{-5} atm-m^3/mol may be volatile. In cases where available information indicates a hazardous substance is or may become volatile, the MDEQ may develop a volatile-based screening level or criterion for the hazardous substance[63]. The MDEQ has determined, consistent with the USEPA's definition of volatiles, that there are hazardous substances with an HLC less than 10^{-5} atm-m^3/mol at standard temperature and pressure are or may become volatile based on additional information available for those hazardous substances (e.g., vapor pressure greater than 1 mm Hg). These hazardous substances are listed in Table 9 and are designated with Footnote (OO) in the Criteria Tables.

4.6 Equations for Calculating Health-Based Values (HBVs) And Screening Levels

HBVs for residential and nonresidential categories are calculated for the following health effects using generic equations:

- Carcinogenic health effects
- Noncarcinogenic health effects
- Carcinogens with mutagenic effects (residential land use only)
- Noncarcinogens with developmental and reproductive health effects

These equations including generic exposure assumptions and other input values are presented within the Rules[64]:

- Equations for Drinking Water Values (DWVs) – R 299.10
- Equations for Direct Contact Values (DCVs) – R 299.20
- Equations for Soil to Ambient air Inhalation Values for Volatiles (VSIVs) – R 299.26
- Equations for Soil to Ambient air Inhalation Values for Particulates (PSIVs) – R 299.26
- Equations for Soil to Groundwater Protection Values (GWPVs) – R 299.22
- Equations for Flammability and Explosivity Screening Levels (FESLs) – R 299.16
- Equations for Volatilization to Indoor Air Screening Levels and Criteria – R 299.27

The criteria for certain hazardous substances (e.g.,, asbestos, boron, cyanide, lead, methane, sodium, trichloroethylene, and vinyl chloride) are derived using alternative methods or modification to the generic equations to address unique risk assessment requirements for these substances.

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[62] R 299.2(k) – Volatile definition; R 299.49(1)(OO)
[63] R 299.26(2)
[64] MCL 324.20120a(19): "The department shall make available the algorithms used to calculate all residential and nonresidential generic cleanup criteria, and tables listing, by hazardous substance, all toxicity, exposure, and other algorithm factors or variables used in the department's calculations."

The chemical-specific, toxicological, chemical-physical input values used by the MDEQ to derive the criteria are shown in Tables 1, 2, and 3 of Rule 50[65] except as provided in the Criteria Table Footnotes[66].

4.6.1 Determination of Final Calculated HBVs

Groundwater, soil, and vapor HBVs for the residential and nonresidential categories are derived for different health effects. The minimum value calculated for carcinogenic, noncarcinogenic, mutagenic, or developmental effects represents the final calculated HBV[67].

Hazardous substances for which statewide default soil background concentration are available are designated with Footnote (B) in the Criteria Tables[68].

4.7 Special Considerations for Calculating HBVs

Additional considerations not otherwise addressed in this section include relative source contributions for noncarcinogens, and other injuries which require further consideration. These are discussed in the following Sections.

4.7.1 Relative Source Contribution (RSC) for Noncarcinogens

Relative source contribution[69] (RSC) is considered in calculating HBVs for noncarcinogenic effects due to exposures via drinking water, direct contact, soil to air inhalation, and volatilization to indoor air. The generic RSC for drinking water is 20 percent (0.2), unless chemical specific values are available. The generic RSC for soils is 100 percent (1.0), unless chemical-specific information indicates otherwise[70].

The RSC factor of 0.2 used in calculating the drinking water noncancer HBV is consistent with federal and state drinking water standards. The generic RSC of 0.2 assumes that a receptor receives 20 percent of his/her exposure to a hazardous substance from drinking water while 80 percent of their exposure comes from other sources. The RSC accounts for the fact that there are many chemicals to which people are exposed through a variety of media and activities. The 0.2 RSC is substituted with a chemical-specific value when data are available.

4.7.2 Other Injuries Which Require Considerations

The MDEQ considers alternatives to the generic development of HBVs to ensure protection of public health, safety, and welfare, and the environment[71]. Generic criteria developed to address

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[65] R 299.50
[66] R 299.49
[67] R 299.6(2)
[68] R 299.49(1)(B)
[69] R 299.2(g) – Relative source contribution definition
[70] MCL 324.20120a(4), states in part: "For the noncarcinogenic effects of a hazardous substance present in soils, the intake shall be assumed to be 100% of the protective level, unless compound and site-specific data are available to demonstrate that a different source contribution is appropriate."
[71] MCL 324.20120a(16); R 299.28 To assure that hazardous substances in contaminated environmental media do not pose unacceptable risks not accounted for by other rules in this part, the concentration of a hazardous substance in a given environmental medium shall meet cleanup criteria based on sound scientific principles and determined by the

any of the listed concerns (e.g., phytotoxicity) are footnoted within the Criteria Tables. Refer to Section 14 for further discussion.

5.0 GENERAL CONSIDERATIONS FOR DETERMINING GENERIC CRITERIA

The HBV is compared to the hazardous substance's solubility in water and soil maximum ceiling concentration. Solubility represents the extent to which a hazardous substance will dissolve in water and a ceiling concentration for groundwater criteria. The assumptions for soil criteria may be invalid (for example, soil adherence and wind-borne dispersion assumptions) with contaminant concentrations at the maximum ceiling concentration (and higher), due to the presence of the hazardous substance itself.

If the target detection limit or the background concentration of a hazardous substance is greater than the criterion then the target detection limit or background concentration, whichever is larger, for the hazardous substance is the criterion[72].

5.1 Solubility

If the calculated HBV is greater than the solubility limit of the hazardous substance in water at 25 degrees Celsius, then the solubility limit becomes the generic groundwater criterion[73]. Criteria to which this applies are designated with Footnote (S) in the Criteria Tables.

5.2 Soil Maximum Ceiling Concentration

The maximum ceiling concentration for health-based soil criteria are 10 percent by dry weight, or 1.0E+8 parts per billion. The percent by dry weight has been revised to align with USEPA methodology (USEPA, 2016). The Criteria to which this applies are designated with a Footnote (D) in the Soil Criteria Tables. Ambient air soil criteria shown in the Soil Criteria Tables require source size adjustment prior to application of the maximum ceiling concentration[74].

5.3 Target Detection Limits (TDLs) for Groundwater, Soil and Vapors

When the TDL for a hazardous substance is greater than a criterion developed for a category, the criterion is the TDL for the hazardous substance in that category[75].

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department to be necessary to protect the public health, safety, and welfare and the environment from any of the following:
(a) Food chain contamination.
(b) Damage to soil or biota in the soil that impairs the use of such soil for agricultural purposes.
(c) Phytotoxicity.
(d) Physical hazards.
(e) Nonsystemic or acute toxicity.
(f) Injury that may result from the direct transport or runoff of hazardous substances in soil into surface water.
(g) Injury to the groundwater resource which may impair its use for other purposes that are determined by the department to be reasonable and relevant considerations at a facility.
(h) Other injury that requires consideration."

[72] MCL 324.20120a(10)
[73] R 299.6(6)
[74] R 299.49(1)(Y)
[75] MCL 324.20120a(10), R 299.6(8)

The TDL is defined[76] as the detection limit for a hazardous substance in a given environmental medium that is specified by the MDEQ on a list that is published not more than once a year. The MDEQ identifies 1 or more analytical methods, when a method is available, that are judged to be capable of achieving the target detection limit for a hazardous substance in a given environmental medium. The target detection limit for a given hazardous substance is greater than or equal to the method detection limit for that hazardous substance. In establishing a target detection limit, the MDEQ considers the following factors:

(i) The low level capabilities of methods published by government agencies.

(ii) Reported method detection limits published by state laboratories.

(iii) Reported method detection limits published by commercial laboratories.

(iv) The need to be able to measure a hazardous substance at concentrations at or below criteria.

If a calculated HBV is less than the target detection limit for that hazardous substance in a given medium, then the target detection limit is the criterion[77]. Criteria to which this applies are designated with a Footnote (M) in the Criteria Tables. The Criteria Table presents both the TDL and the HBV of the hazardous substance. For example, shown below, 5 is the TDL value; 0.32 is the HBV. The bottom line indicates the basis for the 5.

5 (M); 0.32 tdl

5.4 Background Concentration

A background concentration may be substituted for a generic criterion when the background concentration is higher than a criterion shown in the Criteria Tables[78]. A background concentration is defined[79] as the concentration or level of a hazardous substance that exists in the environment at or regionally proximate to a facility that is not attributable to any release at or regionally proximate to the facility. A person may demonstrate that a hazardous substance is not present at a level that exceeds background concentration[80].

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[76] MCL 324.20101(1)(bbb)
[77] R 299.6(8)(a); R 299.49(1)(M)
[78] MCL 324.20120a(10)
[79] MCL 324.20101(1)(e)
[80] A person may demonstrate that a hazardous substance is not present at a level that exceeds background concentration by any of the following methods:

(i) The hazardous substance complies with the statewide default background levels under R 299.46 of the Michigan administrative code.

(ii) The hazardous substance is listed in table 2, 3, or 4 of the department's 2005 Michigan background soil survey, is present in a soil type identified in 1 or more of those tables, and meets 1 of the following:

(A) If a glacial lobe area in table 2, 3, or 4 lists an arithmetic or geometric mean for the hazardous substance that is represented by 9 or more samples, the concentration of that hazardous substance is the lesser of the following:

(I) Two standard deviations of that mean for the soil type and glacial lobe area in which the hazardous substance is located.

(II) The uppermost value in the typical range of data for the hazardous substance in table 1 of the department's 2005 Michigan background soil survey.

(B) If a glacial lobe area in table 2, 3, or 4 lists a nonparametric median for the hazardous substance that is represented by 10 or more samples, the concentration of that hazardous substance is the lesser of the following:

If proposed to be substituted for a generic criterion, background concentrations for groundwater must be established. A person proposing a background concentration for ambient air or indoor air will have to demonstrate that the concentration exists in the environment unaffected by a release.

A person may demonstrate that a hazardous substance is not present in soils at a level that exceeds background concentrations that comply with the statewide default background levels[81]. Statewide default background levels[82] in soil are available for some hazardous substances, specifically metals. The Soil Criteria Tables present the statewide default background levels for metals.

The hazardous substances of the Soil Criteria Tables are designated with Footnote (B) when statewide default background levels are available. Background levels are considered when evaluating exposures related to soil including direct contact, ambient air particulates inhalation, groundwater protection and volatilization to indoor air.

The statewide default soil background levels for inorganics in soil are based on data from the 2015 Michigan Background Soil Survey. The statewide default soil background levels presented in Table 8 represent the mean and standard deviation of concentrations for 17 inorganics. Cyanide, mercury and silver from the 1993 statewide default soil background levels list are not included in the 2015 list for statistical reasons (e.g., high percentage of non-detects). Beryllium, strontium, and vanadium statewide default soil background levels are added to the list as the data was considered adequate. Refer to Attachment J.

6.0 DEVELOPMENT OF DRINKING WATER VALUE (DWV) AND GENERIC DWC

The health-based drinking water values (DWV) are calculated using equations and inputs presented in Rule 10[83]. The residential DWV is the minimum of the five health-based DWVs calculated for these health effects: carcinogenic, mutagenic, noncarcinogenic, developmental or reproductive effect on child, and developmental or reproductive effect on pregnant resident. For the nonresidential DWC, the DWV is the minimum of HBVs calculated for carcinogenic, noncarcinogenic, and developmental or reproductive effect on pregnant worker.

(I) The 97.5 quantile for the soil type and glacial lobe area in which the hazardous substance is located.
(II) The uppermost value in the typical range of data for the hazardous substance in table 1 of the department's 2005 Michigan background soil survey.
(C) The concentration of the hazardous substance meets a level established using the 2005 Michigan background soil survey in a manner that is approved by the department.
(iii) The hazardous substance is listed in any other study or survey conducted or approved by the department and is within the concentrations or falls within the typical ranges published in that study or survey.
(iv) A site-specific demonstration.

[81] MCL 324.20120a(10); R 299.49(1)(B)
[82] MCL 324.20101(1)(e)-Background concentration definition
[83] R 299.10

When establishing the generic DWC, the state drinking water standard (SDWS), the national secondary drinking water regulation, or aesthetic value when available are considered[84]. Figure 4 illustrates this process.

6.1 State Drinking Water Standard

When the calculated HBV[85] for a hazardous substance differs from the state drinking water standard, the drinking water standard is the criterion[86]. Criteria to which this applies are designated with a Footnote (A) in the Groundwater Criteria Table.

6.2 Aesthetics Value

If a hazardous substance imparts adverse aesthetic characteristics to groundwater[87]at a concentration less than the state drinking water standard or the calculated HBV[88], then the aesthetic-based criterion is the drinking water criterion in the Groundwater Criteria Table[89]. The DWC based on aesthetics value is designated with a Footnote (E) in the Groundwater Criteria Table.

6.3 TDL and Solubility

The generic DWC is based on the DWV, SDWS or aesthetics except when:

- The groundwater TDL is greater than the DWV, the TDL is used in place of the DWV as the generic drinking water criterion;
- The DWV is greater than the solubility limit of the respective hazardous substance. The solubility limit is used in place of the DWV as the generic drinking water criterion; or
- The TDL and solubility limit are both less than the DWV; the TDL becomes the generic criterion.

6.4 Application of Generic Drinking Water Criteria

The drinking water pathway is relevant to all groundwater in an aquifer. An aquifer is defined[90] as a geological formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs. The drinking water pathway is also relevant to groundwater not in an aquifer if the groundwater can reasonably be expected to transport a hazardous substance into an aquifer in a concentration that exceeds the generic

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[84] MCL 324.20120(5), which states: If a cleanup criterion derived for groundwater in an aquifer differs from either: (a) the state drinking water standards established pursuant to section 5 of the safe drinking water act, 1976 PA 399, MCL 325.1005, or (b) the national secondary drinking water regulations established pursuant to 42 USC 300g-1, or (c) if there is not national secondary drinking water regulation for a contaminant, the concentration determined by the department according to methods approved by the United States Environmental Protection Agency below which taste, odor, appearance, or other aesthetic characteristics are not adversely affected, the cleanup criterion shall be the more stringent of (a), (b), or (c) unless the department determines that compliance with this subsection is not necessary because the use of the aquifer is reliably restricted or controlled under provisions of a postclosure plan or a postclosure agreement or by site-specific criteria approved by the department under section 20120b."
[85] R 299.10
[86] R 299.6(4)
[87] R 299.9
[88] R 299.10
[89] R 299.6(5)
[90] R 229.1(e)-definition of "Aquifer"

residential criterion. If the drinking water pathway is not relevant, the drinking water generic criteria are not applicable.

The point of exposure for the drinking water criteria is presumed to be any point in an affected aquifer.

7.0 GROUNDWATER-SURFACE WATER INTERFACE CRITERIA (GSI)

The generic groundwater-surface water interface (GSI) criteria shown in the Groundwater Criteria Table represent the minimum of the water quality standards for surface water developed for toxic substances or otherwise applicable water quality standards for surface water, developed pursuant to Part 31 of NREPA[91].

The derivation of the GSI criteria for certain hazardous substances depends on the pH or water hardness, or both, of the receiving surface water; therefore, the final chronic value (FCV) for the protection of aquatic life is calculated based on the pH or hardness of the receiving surface water[92]. Footnote (G) of the Criteria Table provides direction for these substances. Where water hardness exceeds 400 mg of $CaCO_3$ per liter of water, 400 mg $CaCO_3$/L is used for the FCV calculation of these hazardous substances. The generic GSI criterion is the lesser of the calculated FCV, the wildlife value, and the surface water human non-drinking water value (HNDV), for these hazardous substances. A calculator to assist the development of these GSIC is available on the MDEQ Web site.

The GSI criteria presented in the Groundwater Criteria Table are not protective for surface water that is used as a drinking water source. A groundwater discharge directly to the Great Lakes and their connecting waters or a discharge in close proximity to a water supply intake in inland surface waters are considered discharges to surface waters that require alternative GSI criteria. When groundwater is expected to discharge to a drinking water source, the generic GSI criteria is the surface water human drinking water value (HDV). Footnote (X)[93] of the Criteria Tables provides a table that lists the hazardous substance, the HDV, and instructions on determining the applicable criterion.

Part 31 also provides GSI criteria for total phosphorous, total dissolved solids, and dissolved oxygen. These are included in the Groundwater Criteria Table, application of these criteria is provided in Footnote (EE)of the Criteria Tables[94].

Information regarding the application of generic GSI criteria is available in the MDEQ Groundwater-Surface Water Interface Pathway Compliance Options Resource Materials.

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[91] MCL 324.20120e(1)(b); R 299.6(10)
[92] R 299.49(1)(G)
[93] R 299.49(1)(X)
[94] R 299.49(1)(EE)

8.0 FLAMMABILITY AND EXPLOSIVITY SCREENING LEVEL (FESL)

The flammability and explosivity screening values (FESVs) are calculated for hazardous substances using the lower explosive limit (LEL), chemical-physical and chemical-specific values, specifically molecular weight and Henry's law constant (HLC). The generic groundwater criteria (DWC, GSI) are intended to address chronic human health effects resulting from long-term exposure. However, safety concerns may occur for some hazardous substances under certain exposure scenarios. The FESLs address those volatile hazardous substances in groundwater that may pose fire and explosion hazard risks during subsurface excavation activities; therefore, FESLs are developed for hazardous substances having a flash point less than 60 degrees Celsius. The exposure scenario intended to be addressed by the FESLs is characterized as a person working in a trench or excavation (e.g., subsurface excavation to conduct utility line repair, maintenance, and installation).

8.1 Methodology

The FESVs are developed based on methodology presented in the USEPA, *Guidance to Protect POTW Workers from Toxic and Reactive Gases and Vapors* (USEPA, 1992). Persons working in a POTW are subject to safety or health risks from exposure to hazardous substances present in the waste waters. In particular, gases or vapors from volatile hazardous substances can accumulate in the collection system or volatilize in the treatment plant posing a serious fire or explosion risk, as well as potential acute inhalation toxicity. To address this situation, the USEPA issued regulations requiring POTWs to identify hazardous substances and to control potential exposures to toxic vapors and reactive substances (i.e., materials that cause fire, explosion, or intense chemical reaction) in the waste waters. In 1990, the USEPA amended the General Pretreatment Regulations found in Title 40 of the Code of Federal Regulations, Part 403 (40 CFR 403) establishing measures to strengthen the control of hazardous substances discharged to POTWs. The amendments added two prohibitions pertaining to POTW worker health and safety. These are presented in 40 CFR 403.5(b)(1) and 403.5(b)(7), and respectively prohibit:

- Pollutants which create a fire or explosion hazard in the POTW, including, but not limited to, waste streams with a closed cup flashpoint of less than 140° Fahrenheit, or 60° Celsius (C) using the test methods specified in 40 CFR 261.21; and
- Pollutants which result in toxic gases and vapors within the POTW in a quantity that may cause acute worker health and safety problems.

To address these requirements, screening level calculations were developed to determine if a specific industrial discharge could cause a fire or explosion hazard and/or acute vapor toxicity (USEPA, 1992). In the absence of other acceptable methodologies, the MDEQ adapted the screening level calculation for a fire and explosion hazard to establish the FESV. The methodology used to develop the FESV does not incorporate exposure-specific assumptions such as trench dimension or soil characteristics. The methodology is based on mass transfer of a hazardous substance in the dissolved phase to the vapor phase as a function of the Henry's law constant or HLC. When the calculated FESV of a hazardous substance is greater than the solubility level for that substance, the solubility level becomes the generic FESL.

Formerly the MDEQ provided acute inhalation screening levels (AISLs) adapting the USEPA screening levels for acute vapor toxicity. The AISLs were removed from the Criteria Tables in 2013 as requested by stakeholders.

8.2 Application of FESL

The FESLs are not intended to be protective of incidental ingestion, inhalation including acute vapor inhalation or dermal contact. The FESLs should not be applied for long-term exposure scenarios, such as to standing water in a sump or drain, or for household water (e.g., showering, laundry). The LEL basis for the FESL is intended for occupational settings, with limitations on exposure duration, frequency, and/or activity. Long-term, chronic exposures to concentrations of a hazardous substance in groundwater at or near the FESL may not be protective against chronic or acute adverse health effects.

The FESL should not be interpreted as levels in groundwater that are explosive and/or flammable. Instead these screening levels are used to trigger evaluation of exposure environments where additional response or corrective actions may be necessary[95]. Refer to Methane Background Document - Attachment Q. These screening levels are not used in determining whether a location where hazardous substances are present is a Part 201 facility or Part 213 site.

The FESLs are chemical-specific and may not be protective when a mixture of ignitable and/or explosive substances are present. Mixtures of such substances may have a greater cumulative effect and increased hazard potential even at concentrations lower than individual FESLs. Known mixtures of ignitable and/or explosive substances need to be evaluated on a site-specific basis.

9.0 GENERAL CONSIDERATIONS FOR DETERMINING GENERIC SOIL CLEANUP CRITERIA

To determine the final soil criterion, the HBV of a hazardous substance is compared to the TDL and maximum ceiling concentration. The final value and basis will depend on these comparisons. If a statewide default soil background concentration is available and greater than the criterion, the background concentration may be used as the criterion. The decision-making process involved in determining the final soil criteria is described in Figure 5. The final value will also need to be compared to C_{sat}.

9.1 Theoretical Saturation Concentration (C_{sat}) for Soil

The C_{sat} of a hazardous substance is an important element in evaluating risk to hazardous substances in soil. C_{sat} is an estimate of the concentration at which the soil pore water, pore air, and surface sorption sites are saturated with a single hazardous substance, based upon the properties of the soil and hazardous substances. Concentrations greater than C_{sat} for a single contaminant indicate NAPL is likely present.

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[95] R 299.4(10)

C_{sat} concentrations are not themselves risk-based values. The purpose of a C_{sat} value is to identify an upper limit to the applicability of generic risk-based soil criteria since certain assumptions and models used in the generic algorithms are not applicable when NAPL contamination is present in soil. In addition, soil concentrations greater than C_{sat} raise concerns relative to physical hazards, such as corrosivity and flammability, contact-site toxicity, aesthetic impacts, and/or ecological impacts which are not incorporated into the development of generic soil criteria. These factors must be considered in determining appropriate response activity or corrective action at a site[96].

C_{sat} is calculated using the chemical-specific and chemical-physical generic input values presented in Chemical-specific and Chemical-physical Tables of Rule 50[97]and the C_{sat} equation in Rule 18[98]. MDEQ-approved facility-specific inputs may be substituted for generic inputs to develop an alternative generic criterion. Refer to Attachment G. An alternative site-specific criterion may be established based on the organic carbon content of soil (*foc*) established for a site and substituted for the generic input. Refer to Attachment M.

In the Criteria Tables a criterion for a hazardous substance that exceeds C_{sat} is designated with Footnote (C), except for the ambient air criteria. The ambient air criteria column header contains the Footnote (C) to identify the required comparison of the final source-size modified generic VSIC or PSIC to C_{sat}. Refer to Section 12 for further discussion regarding source-size modification.

When a soil criterion exceeds C_{sat}, a person proposing or implementing response activity must document whether additional response activity is required to control NAPL to protect against risks associated with NAPL by using methods appropriate for the NAPL present[99].

10.0 DIRECT CONTACT VALUE (DCV) AND CRITERIA (DCC)

The health-based direct contact values (DCV) are calculated using equations and inputs presented in Rule 20[100]. The residential DCV is the minimum of the five health-based DCVs calculated for these health effects: carcinogenic, mutagenic, noncarcinogenic, developmental or reproductive effect on child, and developmental or reproductive effect on pregnant resident. For

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[96] R 299.4(9): "If a generic soil cleanup criterion developed under R 299.20 to R 299.27 is greater than the C_{sat} concentration for that hazardous substance as shown in the generic soil cleanup criteria tables of R 299.46, then the generic soil criterion may not apply in all cases. If the release is a mixture of hazardous substances, then comparison to C_{sat} is not appropriate. All of the following apply:
(a) A person proposing or implementing response activity shall evaluate whether additional response activity is required to control NAPL or to protect against risks associated with NAPL that are not accounted for in development of the generic soil criteria.
(b) A site specific risk evaluation may be conducted for each relevant exposure pathway when NAPL is present.
(c) Corrective action for a petroleum release regulated under part 213 of this act shall evaluate NAPL pursuant to part 213 of this act."
[97] R 299.50
[98] R 299.18(2)
[99] R 299.49(1)(C)
[100] R 299.20

the nonresidential DCV, the DCV is the minimum of HBVs calculated for carcinogenic, noncarcinogenic, and developmental or reproductive effect on pregnant worker.

The DCV considers two exposure pathways: incidental soil ingestion and dermal contact. Similar to the drinking water pathway, the incidental ingestion of hazardous substances in soil is determined using soil ingestion rates (IRs) and the chemical-specific ingestion absorption efficiency (AEi). For dermal contact to soil, the dermal contact rate is calculated using skin surface area (SSA), soil adherence factor (AF), dermal absorption efficiency (AEd), and event frequency (EV). The chemical-specific values for these inputs are shown in the Chemical-specific Table of Rule 50. The Chemical-specific Table also presents the basis for each value. The development of the exposure assumptions, including process and data sources are explained in Attachment H.

10.1 TDL, Maximum Ceiling Concentration, Background and C_{sat}

The generic DCC is based on the DCV, except when:

- The calculated DCV is greater than the maximum ceiling concentration (1.0E+8 parts per billion), the maximum ceiling concentration becomes the criterion.
- The soil TDL is greater than the DCV the TDL becomes the criteria.

A statewide default or site-specific soil background level may also be used in place of the generic DCC when the criterion is less than background. For hazardous substances with generic DCC greater than their soil saturation concentrations (C_{sat}), a Footnote (C) is presented after the numeric DCC value to indicate the requirement for further site evaluation concerning saturated soil conditions.

10.2 Application of DCC

Direct contact is considered a relevant pathway for all sites. Compliance with soil DCC is required throughout the soil column for land use categories[101]. However, exposure controls and land use restrictions may be employed to prevent or limit exposures using the limited land use categories.

Statistics are appropriate for evaluating this exposure pathway, except as otherwise footnoted in the Criteria Tables. The 95 percent upper confidence level (UCL) on the arithmetic mean of soil concentrations may be used to determine compliance with the soil DCC. The 95 % UCLs must reasonably represent the areas over which exposures are expected to occur. The generic size of an exposure unit for a residential property is 1/4 acre and 2 acres for a nonresidential property. The distribution of the data (i.e., normal, lognormal, or other) must be identified before the 95 percent UCL can be properly calculated. Refer to S^3TM on how to appropriately calculate the 95 % UCL. Sample results from hot spots or significantly elevated areas should be addressed separately and not included in the calculation of the 95 % UCL. Refer to S^3TM for additional details on identifying hot spots.

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[101] R 299.18(4)

11.0 GROUNDWATER PROTECTION CRITERIA (GWPC): DRINKING WATER PROTECTION CRITERIA (DWPC) AND GSI PROTECTION CRITERIA (GSIPC)

To assure that soils do not pose a threat of aquifer contamination, the concentration of a hazardous substance must either be at or below the applicable Part 201 groundwater criterion for that hazardous substance in soil leachate, considering all relevant pathways or be at or below the concentrations developed as groundwater protection criteria[102]. Leach testing is not required to make this demonstration if the total concentration of a hazardous substance in soil does not exceed the generic soil GWPC.

11.1 Ground Water Protection Value (GWPV) Determination

The groundwater protection value (GWPV) is based on the higher of the values derived as follows[103]:

- Soil-water partition value (SWPV), if sufficient information is available to derive the value for the hazardous substance. The SWPVs are calculated using equations and inputs presented in Rule 22[104].
- The generic groundwater criterion (DWC or GSI) multiplied by 20.

11.2 The Soil-Water Partitioning Methodology

The soil-water partitioning methodology is based on assumptions related to the fate and transport of contaminants migrating from subsurface soil to groundwater. Generally, the migration of contaminants from soil to groundwater can be broken down into two stages:

- Contaminant release from soil into the soil pore water and pore air (i.e., contaminant release into soil leachate).
- Contaminant transport through the soil and groundwater to a receptor point (e.g., a drinking water well).

The USEPA Soil Screening Guidance provides a generic equation that accounts for both of these processes (USEPA, 1996c). The soil-water partitioning methodology is considered suitable for generic statewide application because it utilizes simple conservative assumptions about the release and transport of contaminants in the subsurface and also has the flexibility to allow for facility-specific adjustments if adequate data are available.

The soil-water partitioning methodology presented in the Soil Screening Guidance incorporates a linear equilibrium equation to estimate hazardous substance release from soil into soil leachate by relating the concentration of hazardous substance adsorbed to soil organic carbon to the concentration in the soil leachate. As hazardous substances in soil leachate move

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[102] MCL 324.20120a(18): The need for soil remediation to protect an aquifer from hazardous substances in soil shall consider the vulnerability of the aquifer or aquifers potentially affected if the soil remains at the facility. Migration of hazardous substances in soil to an aquifer is a pertinent pathway if appropriate based on consideration of site specific factors.; R 299.22(1)
[103] R 299.22(1)
[104] R 299.22(3)

through soil and groundwater, they are subjected to physical, chemical, and biological processes that can reduce the hazardous substance concentration at the receptor. The soil-water partitioning methodology addresses only one of these attenuation processes which is contaminant dilution in groundwater. By incorporating a simple water-balance equation, a dilution attenuation factor is calculated to account for soil leachate dilution in groundwater. The dilution attenuation factor is expressed as the ratio of the soil leachate concentration to the acceptable groundwater concentration. This dilution attenuation factor is used to calculate the target soil leachate concentration (*C*), which is the product of the applicable groundwater criterion and the dilution attenuation factor. This concentration is based on the most restrictive of the relevant groundwater exposure pathways that requires protection (i.e., drinking water or groundwater surface water interface). For example, if the DWC for a particular hazardous substance is 0.05 mg/L and the dilution attenuation factor is 16, *C* would be 0.80 mg/L. Once established, *C* is used in the soil-water partitioning equation to determine the hazardous substance concentration in soil protective of the relevant groundwater exposure pathway.

The dilution attenuation factor used for the SWPV has been changed from 20 to 16 to more accurately reflect conditions at Michigan sites. The chemical-specific dimensionless Henry's law constant (*H'*) are multiplied by a temperature adjustment factor (TAF) of one-half (0.5) to account for reduced volatility of a hazardous substance under lower annual average soil temperatures of 10 degrees Celsius in Michigan (Howe *et al*., 1987). Except for mercury, inorganic hazardous substances do not exhibit a significant vapor pressure. As a result, *H'* is assumed to be zero when calculating a SWPV for inorganics. The USEPA provides background information for the remaining parameters and the corresponding assumptions used in the soil-water partitioning equation (USEPA, 1996c).

11.3 Drinking Water Protection Criteria (DWPC) and GSI Protection Criteria (GSIPC)

The generic DWPC and GSIPC are based on the GWPV values except under the following conditions:

- When the GWPV is less than the groundwater TDL, the TDL becomes the generic criterion;
- When the GWPV is greater than the maximum ceiling concentration of the respective hazardous substance, the maximum ceiling concentration becomes the generic criterion;

A statewide default soil background level or site-specific background soil level may also be used in place of the generic DWPC or GSIPC if the generic criterion is less than a statewide default or site-specific background soil level.

The GSIPC for hazardous substances with GSI criteria that are calculated using receiving water's pH or hardness, listed with Footnote (G) of the Criteria Tables, are the greater of the 20 times the GSI criteria or the soil-water partition values using the GSI criteria developed with the procedure described in Footnote (G).

The GSIPC based on protection of a drinking water source are listed in Footnote (X) of the Criteria Tables. The Footnote (X) list includes hazardous substances with GSI criteria that are

calculated using receiving waters pH or hardness. For these substances the GSIPC is the greater of 20 times the GSI criteria developed with the procedure described in Footnote (G) value or the GSI soil-water partition value using the GSI criteria developed with the procedure described in Footnote (G).

For hazardous substances with generic GWPC greater than its respective C_{sat}, Footnote (C) is shown after the numeric GWPC value in the Criteria Tables to indicate the requirement for further site evaluation concerning saturated soil conditions.

11.4 Application of GWPC

MDEQ-approved facility-specific inputs, including temperature adjustment may be substituted for generic inputs to the soil water partition equation to develop alternative generic criteria. Refer to Attachment G. An alternative site-specific criterion may be established based on the organic carbon content of soil (f_{oc}) established for a site and substituted for the generic input. Refer to Attachment M.

If the GWPC is exceeded, generic criteria may be satisfied by conducting leachate testing with comparison to the applicable groundwater criteria. On a site-specific basis, it may be demonstrated that existing soil concentrations are not, and will not, leach in concentrations that would exceed groundwater criteria, if appropriate to the conditions of a site.

The generic GWPC are not applicable to hazardous substances present in non-soil matrices such as slag, tailings, wood, coal tar, stamp sands, and other solid or semi-solid material. In these instances, a site-specific evaluation such as leach testing is necessary.

The migration of contaminants from soil to groundwater is a relevant pathway for any site where groundwater is in an aquifer. This pathway is also relevant for groundwater that is not in an aquifer but may transport a hazardous substance into an aquifer at a concentration that exceeds the generic residential drinking water criteria. Restrictions on groundwater use for drinking at a site do not preclude the need to comply with appropriate soil criteria to assure that groundwater will comply with the residential criteria at the property boundary. This is necessary to assure protection of off-property resource uses (drinking water, and surface water impacts), unless those off-property uses can be reliably restricted.

The soil leaching pathway for GSI protection is relevant for all land uses if an investigation or the application of best professional judgment leads to the conclusion that groundwater is reasonably expected to vent to surface waters in concentrations that exceed the generic GSI criteria[105]. If mixing zone criteria have been established for a specific hazardous substance, then the SWPV for protection of the GSI can be determined by substituting the mixing zone-based GSI criterion as the applicable groundwater criterion when calculating in the SWP equation. The SWPV is then compared to 20X the mixing zone-based GSI criterion and the

[105] MCL 324.20120e(3)

greater of the two becomes the GSIPC. The GSIPC calculated directly from generic or mixing zone-based GSI criteria do not need to be met at all points at the site if a demonstration is made that an alternative soil concentration will not leach hazardous substances to the groundwater at levels that result in an exceedance of the generic or mixing zone-based criteria at the GSI. Predictions of any fate and transport modeling used as part of such a demonstration must be confirmed by field measurements.

12.0 SOIL TO AMBIENT AIR INHALATION VALUES AND GENERIC CRITERIA (VSIC and PSIC)

The criteria for soil based on inhalation of hazardous substance emission to ambient air from a contamination source area are called soil inhalation criteria. The calculated HBVs for hazardous substances that can volatilize are called volatile soil inhalation values (VSIV). For particulate hazardous substance emissions, the calculated HBVs are called particulate soil inhalation value (PSIV). The health-based VSIVs and PSIVs for the residential and nonresidential categories are calculated for different health effects using equations and inputs presented in Rule 26[106]. The minimum HBV calculated for carcinogenic, noncarcinogenic, mutagenic, or developmental effects represents the calculated residential VSIV or PSIV.
For the nonresidential HBV, the minimum of HBVs calculated for carcinogenic, noncarcinogenic, or developmental effect on pregnant worker represents the calculated residential VSIV or PSIV.

The adjustment of the ½ acre VSIC and PSIC to derive the final HBVs based on contamination source area sizes appropriate for the site is required[107]. The final HBVs are the basis for the generic VSIC and PSIC for the property together with considerations of TDL and maximum soil concentration. Refer to Sections 12.2 and Attachment L for guidance on source size modification and development of generic PSIC and VSIC.

12.1 Infinite and Finite Volatile Soil Inhalation Values Based on Vertical Contamination Depths

The VSIVs are calculated using chemical-specific soil to air volatilization factors. Volatilization factors are calculated for contamination sources with infinite and finite contamination depths. The volatilization factor for an infinite source is calculated using the infinite source equations presented in Equation 9 of Rule 26. For 2 or 5 meter finite sources, the volatilization factors are derived using Equation 10 of Rule 26. The flux (J^{ave}) used for infinite volatilization factors is a calculated value; the finite volatilization factors is a modeled flux (J^{ave}) using the USEPA Exposure Model for Soil-Organic Fate and Transport (EMSOFT) model (USEPA, 2006a).

The Soil Criteria Tables present both infinite and finite volatile soil inhalation criteria (VSIC) for a hazardous substance. The infinite VSIC is used if the vertical extent of the hazardous substance source has not been adequately characterized. The finite VSIC may be used when the vertical extent of the hazardous substance source has been adequately characterized throughout the site. Finite generic VSIC may be derived using flux for other finite sources using

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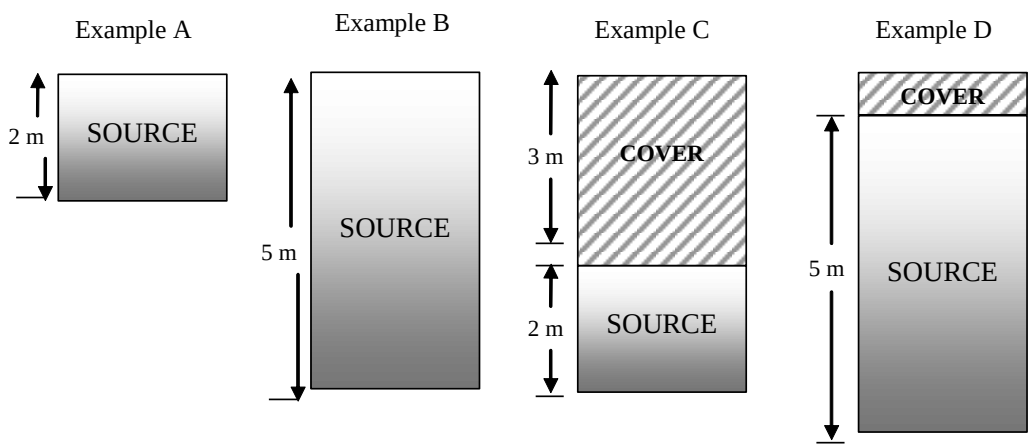
[106] R 299.26
[107] R 299.26(8) to (9), R 299.49(1)(Y)

the USEPA EMSOFT model. Site specific finite sources may be developed using an alternative modeling method approved by the MDEQ.

The finite VSIV based on the EMSOFT modeled flux rate (J_s^{ave}) assumes no cover layer and a contamination source thickness that starts from ground surface to a contamination depth of either 2 or 5 meters. Examples to illustrate the assumptions are provided below. Examples A and B exemplify no cover layer. Where an overlying layer of clean soil is present as shown in Example C, the subsurface contamination source thickness of 2 meters is considered the source thickness. The use of the 5 meter finite VSIC is also appropriate for Example D.

Finite Source VSIC and Source Thickness Examples



12.2 Modification of Soil Inhalation Value Based on Source Area Size

When using the VSIC or PSIC presented in the Criteria Tables, it is necessary to consider the source area size of the contamination specific to a site. The health-based VSIV and PSIV are calculated using emission factors (volatilization factor and particulate emissions factor, respectively), which contains a dispersion factor (Q/C) input based on a particular source area contamination size or "source size"[108]. "Source size" in this context means the extent of areal contamination. Refer to Attachment L.

The generic VSIC and PSIC presented in the soil Criteria Tables are based on VSIV and PSIV calculated using the volatilization factor or particulate emissions factor for a half-acre source size. The soil inhalation values must be adjusted when the contamination source area sizes appropriate for the property is not a half acre. The soil inhalation values using appropriate site source size can also be calculated using the equations, exposure assumptions, and other inputs presented in Rule 26[109] and the source-size-based volatilization factor or particulate emissions factor. To facilitate the development of the modified VSIV or PSIV based on source area size, the half-acre soil inhalation criteria values in the Criteria Tables may be multiplied by an

[108] R 299.26(9)
[109] R 299.26

appropriate modifier provided in the table below to derive the final VSIC or PSIC. Where the actual source area size falls between the sizes given in the table, the modification uses the modifier for the next larger source size. This table is also presented in Rule 26 and Footnote (Y) of the Criteria Tables.

12.3 Dispersion Factor (Q/C) Values for Various Source Sizes

The dispersion factor (Q/C) values, modeled using 2010-2014 Michigan meteorological data and the AERMIC Dispersion Model (AERMOD), are used as basis for generating the modifiers. Refer to Attachment K for Q/C development methodology.

Table of Q/C Values and Modifiers

Contamination Source Area Size (ft^2 or acres)	Dispersion Factor (Q/C) (g/m^2-s per kg/m^3)	Modifier for deriving final VSIC/PSIC
100 ft^2	295.82	6.97
400 ft^2	129.34	3.05
1000 ft^2	91.05	2.14
2000 ft^2	73.72	1.74
½ acre	42.45	1.00
1 acre	37.24	0.88
2 acres	32.81	0.77
5 acres	28.02	0.66
10 acres	25.02	0.59
20 acres	22.27	0.52
30 acres	20.89	0.49
50 acres	19.24	0.45
75 acres	18.06	0.43
100 acres	17.21	0.41
150 acres	16.17	0.38
200 acres	15.43	0.36
300 acres	14.50	0.34
400 acres	13.88	0.33
500 acres	13.38	0.32
1000 acres	12.02	0.28
1500 acres	11.25	0.26

12.4 Generic SIC Determination

After appropriate source-size modification to the half-acre based VSIC or PSIC of the Criteria Tables, the value must be compared to the target detection limit (TDL) and maximum soil ceiling concentration to determine the final generic criteria.

12.4.1 SIC Comparison to TDL and Maximum Soil Ceiling Concentration

The source size-modified VSIC or PSIC is the final generic criteria for the site except:

- When the modified VSIC or PSIC is less than the soil TDL; the soil TDL becomes the final generic criterion; or
- When the modified VSIC or PSIC is greater than the maximum soil ceiling value, the maximum ceiling value becomes the final generic criterion.

12.4.2 C_{sat} Comparison

The final generic VSIC or PSIC of a hazardous substance must be compared to its respective C_{sat} value to determine whether further evaluation for NAPL may be necessary[110]. The Footnote (C) presented in the ambient air pathway header of the Criteria Tables identifies the requirement for comparison of the final generic criteria to C_{sat}.

12.4.3 Statewide Default Soil Background Levels

A statewide default or site-specific soil background level of a hazardous substance may also be used in place of the soil inhalation criterion, if the generic criterion is less than background. Michigan-specific soil background levels for different metals are shown in Table 8.

12.5 Examples of Source Area Size and Generic Soil Inhalation Criteria Determination

Source area size may be determined by the property boundaries when property lines are well defined and off-site migration of contaminants does not occur. For unknown and/or large contamination areas, the source area size and modified VSIC and PSIC for contaminated areas may be determined using an iterative approach. Examples of this approach are presented in Attachment L.

12.6 Facility-specific Generic Soil Input Values

The generic soil-type values may be substituted with facility-specific values for the following soil characteristics using MDEQ-approved values by soil type[111]:

(a) Dry soil bulk density
(b) Soil water-filled porosity
(c) Soil air-filled porosity
(d) Soil temperature (Refer to TAF Background Document - Attachment I).

Refer to Attachment G.

12.7 Site-specific Input Values[112]:

Site-specific inputs where MDEQ-approved substitute inputs are not available may be developed. The resulting site-specific criteria require MDEQ approval. These inputs do not require any land or resource use restriction to reduce exposures or assure the effectiveness or integrity of a remedy the site-specific criteria may be approved for unrestricted residential use.

Site-specific soil values for the following inputs may be used in place of generic values:

(a) Fraction of organic carbon in soil (f_{oc}). Refer to Attachment M.
(b) Surface material silt content (s).

Site-specific meteorological data values for the following inputs may be used in place of generic assumptions:

(a) Dispersion factor (Q/C)

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[110] R 299.4(9)
[111] R 299.26(11); R 299.7
[112] R 299.26(12)

(b) Wind speed (Ew).
(c) Mean number of days with at least 0.01 inch of precipitation (p).

12.8 Application of the SIC

Inhalation of hazardous substance emissions in ambient air from soil is a relevant pathway for all facilities. To determine overall compliance with criteria for the soil to ambient air pathway, compliance must be demonstrated for both the final generic VSIC and PSIC for each hazardous substance of concern.

The generic soil inhalation criteria are intended to be protective of chronic human health effects that may result from exposure to ambient airborne contaminants. The soil inhalation criteria do not account for, and may not be protective of other endpoints such as acute human health effects, odors, ocular irritation, physical hazards (e.g., reactivity, corrosivity, or ignitability), nuisance dust conditions, and/or ecological impacts. The potential occurrence of these effects must be evaluated to determine if more restrictive applicable criteria are needed to ensure protection for these endpoints[113].

Statistics are appropriate for evaluating this exposure pathway. Use of statistics is practical where there are adequate data available on the emission source areas, as appropriate to the site. The 95th percent upper confidence level of soil concentrations, calculated using methods described in S^3TM may be used to determine compliance if such values are representative of the areas where emissions are likely to occur.

13.0 VOLATILIZATION TO INDOOR AIR PATHWAY (VIAP) AND CRITERIA (VIAC)

The volatilization to indoor air pathway (VIAP) is the exposure pathway describing the inhalation of hazardous substance vapors volatilizing from a vapor source to indoor air. The generic criteria addressing this pathway are called volatilization to indoor air criteria ("VIAC")[114] and are based upon the following:

- For groundwater, the VI Tier 1 Screening Values and VI Tier 2 Generic Unrestricted Criterion, consider a contaminant vapor source located within or wetting the foundation of an enclosed building with a basement constructed with block or poured concrete walls and floor.
- For soil, the VI Tier 1 Screening Values and VI Tier 2 Generic Unrestricted Criterion, consider a contaminant vapor source located in close proximity to the foundation of an enclosed building that is slab on grade with a poured concrete floor.
- For vapor, the VI Tier 1 Screening Values and VI Tier 2 Generic Unrestricted Criterion, consider a contaminant vapor source located in close proximity to the foundation of an enclosed building with a basement constructed with block or poured concrete walls and floor.

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[113] MCL 324.20120a(16); R 299.28
[114] R 299.27(2)

To identify sites that warrant further evaluation of the VIAP, the VI Tier 1 screening values were developed. The screening values serve as a reference point for assessing the significance of potential health risks associated with the VIAP. The screening values may be used as the criterion to evaluate the potential for vapor intrusion to occur when no further site data is available or for determining whether a property is a facility[115].

The development and application of the VIAC and the associated tiered process is presented in this section. The tiered approach is intended to accelerate the decision making process and facilitate the development of facility-specific generic criterion or site-specific criterion. The generic VIAC identify a concentration of a hazardous substance that is protective of an acceptable risk associated with health effects that result from chronic exposure via inhalation. The generic VIAC are not protective of aesthetic characteristics such as odors, and are not protective of exposures that may result from human intake or contact or through other exposure pathways, such as short-term and acute exposures. Additionally, the criteria may not be protective of physical hazards, such as flammability, explosivity, reactivity, corrosivity, or ecological impacts. An evaluation of the relevance of other exposure pathways, as well as short term and acute exposures, is necessary to ensure that no unexpected or unaccounted for exposures occur at intervals not consistent with the development of the generic criterion.

The development of the risk based screening value for a hazardous substance for each tier was based on methodology presented in the USEPA's 2004 User's Guide for the Evaluating Vapor Intrusion into Buildings. The exceptions are for situations where groundwater is in contact with a structure and where a source of vapors is within one meter of the structure for vapor samples. The tiered approach[116] is the following:

- VI Tier 1 Screening Level means the initial screening levels used to identify a release of a hazardous substance as a vapor source.
- VI Tier 2 generic criterion means the VI Tier 1 screening level that incorporate facility-specific geological and physical site conditions, and establish the generic criteria for unrestricted residential use.
- VI Tier 3 which consists of:
  - VI Tier 3A which means the VI Tier 2 generic criterion that also incorporates the use of facility-specific land use or building information, or both, and requires a land or resource use restriction.
  - VI Tier 3B which is site-specific criterion developed using an alternate method or model approved by the MDEQ. The application of VI Tier 3B site-specific criteria may or may not require land or resource use restrictions.

The general concept is similar to the outline and tiers proposed by the CSA (2014), though these tiers are not exact due to statutory limitations. Figure 6 presents the VI Tier Process[117].

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[115] R 299.27(5)(b)
[116] R 299.27(12) Figure 1
[117] R 299.27(2)(c); R 299.7(12) – Figure 1

13.1 General Information

Key terms and terminology used in the assessment of the VIAP are defined in Rule 27[118]. Further explanation and general information is provided below.

"Vapor intrusion"[119] is the general term given to the migration of hazardous vapors from any subsurface vapor source, such as contaminated soil, groundwater, or non-aqueous phase liquid (NAPL) through the soil and into an overlying building or structure. The vapors can enter a building by diffusing through concrete or migrating directly through cracks in basements and foundations, as well as through conduits and other openings in the building (e.g., sewers, drain lines, access vaults, storage sheds, pump houses, etc.). Consideration of vapor intrusion also applies to situations where buildings have not yet been constructed within a contaminated area at a property.

A "relevant pathway"[120] is defined to mean an exposure pathway that is reasonable and relevant because there is a reasonable potential for exposure to a hazardous substance to occur to a human or nonhuman receptor. An exposure pathway is not determined to be complete or incomplete but rather whether the pathway is relevant.

A "source of vapors"[121] is a key term in dealing with the VIAP and is more commonly referred to as a vapor source. The term "vapor source" means a release of a hazardous substance that may form vapors that have the potential to migrate. In general, a source of vapor may include, but is not limited to:

- Shallow groundwater (only),
- Vadose zone soil (only),
- Shallow groundwater and vadose zone soil, and
- NAPL comprised of volatile hazardous substances, within the shallow vadose soil and/or in the capillary zone above the water table.

"Lateral inclusion zone"[122] means the horizontal distance beyond a vapor source that may make a property or structure vulnerable to the migration of vapors. Identified as:

- 100 feet from the extent of a chlorinated vapor source or other vapor source.
- 30 feet from the extent of a petroleum vapor source.
- Distances could be greater than those identified in (i) and (ii) and must be evaluated when the concentration of a hazardous substance in any media exceeds the unrestricted generic residential criterion within those distances.

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[118] R 299.27(1)
[119] R 299.27(1)(g)
[120] R 299.2(h); Refer to Section 3.1.6
[121] R 299.27(1)(l)
[122] R 299.27(1)(e)

"Facility-specific"[123] means the MDEQ approved generic input values that when representative of conditions at the facility may be used as input for the calculated health-based values. The generic input values include the following:

- Environmental conditions that allow the resulting criterion to represent unrestricted generic residential categorical criteria that do not depend upon any land use or resource use restriction to ensure protection.
- Land use or building conditions that when used to develop VIAC allow the resulting volatilization to indoor air criteria to represent restricted categorical criteria.

A source of vapors is identified in the tiered approach by comparing the concentration of the hazardous substance (soil, groundwater, and vapor) to the VI Tier 1 screening levels or the VI Tier 2 VIAC, which allows for the use of facility-specific geologic characteristics. Vapor intrusion can be evaluated by comparing the detected contaminant concentrations at a site to the VI Tier 3A. It is important to understand moving to a higher tier does not necessarily mean that the VIAC values for any or all media will increase. The VIAC values generated in the VI Tier 2 or VI Tier 3A evaluation are dependent upon the facility-specific input values for the site which is the subject of the evaluation. In those instances where the input values are similar to the inputs used in the previous tiers, no increase in the VIAC will occur.

For the VIAP, a source of vapors or a release of a hazardous substance may result in a "vapor cloud" which is a hazardous substance in vapor phase in the subsurface with no colocated contamination in the soil or groundwater. A vapor cloud can be the source of vapor intrusion.

13.1.1 The VIAP

The VIAP is considered a relevant pathway for volatile hazardous substances[124], including properties within the lateral inclusion zone. The VIAP is evaluated using soil, groundwater, and vapor samples to satisfy the criteria for each media pursuant to the VI Tier process and is be based upon the following:

- The CSM accurately represents the VIAP;
- The sample collected is aligned with the location of the vapor source and is appropriate for evaluating the VIAP;
- A vapor source may be present and represent a risk to human health, when the VIAC for soil or groundwater are the target detection limit (TDL) and the concentration of a hazardous substance in soil or groundwater do not exceed the health-based criteria; and
- A sample of the vapor volatilizing from the source may be the best available information to represent in-situ conditions at the facility for evaluating a vapor source and the ability for vapors to migrate when comparing vapor samples that are co-located (or similarly located) with the subsurface source.

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[123] R 299.1(l) – Facility-specific definition; R 299.7
[124] R 299.27(2)

Volatile hazardous substances[125] may include volatile organic compounds (VOCs), select semi-volatile organic compounds, and inorganic analytes.

13.1.2 Conceptual Site Model (CSM)

The conceptual site model (CSM) is a written or illustrative representation, or both, of the surface and subsurface conditions[126]. The CSM represents the VIAP and includes the physical, chemical and biological processes that control the transport, migration and potential impacts of contamination to a human or ecological receptor, or both.

The use of a CSM is critical in demonstrating and evaluating multiple lines of evidence. The CSM is the first element, and an important step in evaluating the relevance of the VIAP[127].

13.1.3 Criteria Stakeholder Advisory Group (CSA) Recommendations

CSA recommendations form the basis for the development of the tiered approach (CSA, 2014). In the tiered approach, groundwater, soil, and soil gas samples are collected and compared to initial screening values, values that could be refined as more data specific to the site become available. The initial screening values are intended to be used for situations where minimal site details or information is known or available. The initial screening values identify the presence of a potentially significant vapor source, not whether there is, or could be, a risk of vapor intrusion.

The complete recommendations from CSA are included in Attachment C and D. A number of the recommendations are briefly discussed below:

13.1.3.1 Tiered and Investigative Approach to Vapor Intrusion

The CSA recommended that the MDEQ use a tiered approach as the most appropriate process to investigate whether or not contaminants represent a source of vapors and pose an unacceptable risk from vapor intrusion, and also encouraged the MDEQ to adopt an approach similar to that detailed by the Technical Advisory Group (TAG) (CSA, 2014). In describing the process, the TAG stated that the "*process be a relatively simple, step-by-step approach that uses a modified Johnson & Ettinger (J&E) model to develop generic screening levels and criteria.*" The TAG also stated that while conceptually the tiered approach is a step-by-step process, parties do not need to progress through each individual step. Steps may be bypassed depending on site conditions and/or the circumstances of an investigation.

13.1.3.2 Use of Alternative Methods or a Site-Specific Approach

The CSA recommended allowing the use of "*an alternative method or model for assessing vapor intrusion risk that utilizes only site-specific (geologic) variables or a combination of site- and building-specific variables*." The CSA identified that the alternative approach should be "*scientifically sound and supported by adequate site information.*"

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[125] R 299.2(k) – Volatile definition; Refer to Section 4.5
[126] R 299.27(1)(d)
[127] R 299.27(2)(d)

13.1.3.3 Finite vs Infinite Mass for Soil

The TAG spent time discussing, but did not reach consensus regarding options for incorporating the finite mass calculations into the process for the development of the generic VIAC. The two non-consensus items were: 1) the size of mass that should be considered for the generic application, and 2) the results of an investigation (preliminary or otherwise) do not typically yield sufficient information to define or know the full extent of contamination or the contaminant mass.

Therefore, the TAG recommended the use of an infinite contaminant mass for soil (i.e., undefined and potentially covering the entire site) in the development of the generic criteria. The MDEQ tier process does allow for finite mass calculations in the development of site-specific criteria and the use of alternative methods.

13.1.3.4 Indoor Air

The CSA recommended the use of indoor air sampling data be considered in the VIAP evaluative process as *"part of an alternative method and a line of evidence to determine whether the vapor intrusion pathway is relevant and is posing risks to human health*." The CSA specified the need for a scientifically sound indoor air collection method and appropriate data and stated, *"the sampling strategy must be scientifically sound and account for actual site conditions, including background sources of contaminants and any potential spatial or seasonal variability*."

13.1.3.5 Depth to Groundwater

As discussed at length and agreed to by the TAG, the development of the generic criteria must incorporate a conservative building construction. The vapor intrusion screening levels for residential land use should be developed using values that account for a typical residential structure with a basement. A typical residential basement is constructed a minimum of two meters below ground. The anticipated height of the capillary fringe ranges from 0.2 m to 1 m (depending on soil type); the first tier, initial screening value for groundwater assumes the depth to groundwater is at less than three meters (< 3 meters).

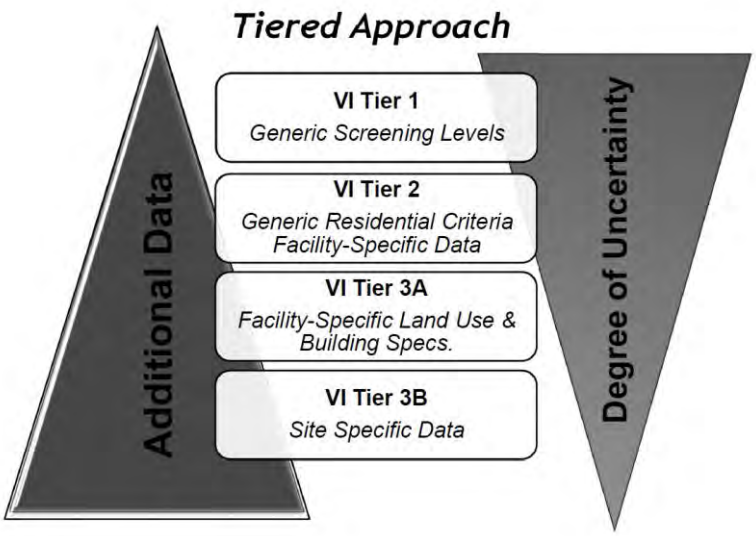
It is assumed when groundwater is at a depth of less than three meters (< 3 meters) there is potential for the direct volatilization of contaminants in groundwater to the indoor air. A basement is assumed to be present or a building with a basement could be constructed without appropriate restrictions.

13.1.4 General Concepts of the Tiered Approach

The MDEQ in collaboration with the CSA agreed in concept to a tiered approach for the evaluation of the VIAP. As generally conceptualized, such an approach would allow for the development of screening values and "generic" criteria that could identify a potential vapor source and vapor source contaminants and concentrations that have the potential to pose an unacceptable exposure and/or health risk to occupants of existing or future structures at a site. The conservatively developed screening levels and generic criteria can be used for comparison by practitioners to identify contaminant concentrations that may not be protective of human health in the beginning stages of an investigation or assessment at any site.

The conservatively developed screening levels and generic criteria should be unlike the groundwater volatilization to indoor air inhalation criteria (GVIIC) and the soil volatilization to indoor air inhalation criteria (SVIIC), which were not appropriate for comparison at a majority of sites. Though the GVIIC and SVIIC were intended, and developed to be "generic" criteria, the development and selected inputs into the equations resulted in limiting the number of sites where these criteria could actually be used.

A conceptual view of the tiered approach is depicted below:



13.2 VIAP Evaluation

To evaluate the VIAP, sufficient data must be collected. Limited data may only allow for comparison to the VI Tier 1 screening levels which identify a potential source of vapors, but do not necessarily equate to the existence of a source or a risk via vapor intrusion. The tiered approach can identify sites needing further assessment and allows for the generation of facility-specific criteria. However, the party conducting the evaluation must carefully understand and evaluate the assumptions used in their development of "generic" VIAC to determine whether any conditions exist at the site that would render the evaluation using the developed "generic" VIAC inappropriate.

The suggested minimum site characterization information needed to progress through the tiered evaluation includes the generation of, and the ability to describe the following information:

- site conceptual model,
- nature and extent of contaminant distribution,
- soil lithologic descriptions and locations,
- maximum soil and groundwater contaminant concentrations, and
- vapor concentrations from points aligned with the vapor source.

A person seeking or required to obtain MDEQ review should include this information in their submittal.

The number of samples of each contaminated media and information necessary to accurately describe the site conditions will vary by facility. To use the VIAC it is important to understand the assumptions used in their development. If the conditions at the site are not in line with the assumptions used in the development of the VIAC, this is evidence that the approach to evaluating the VIAP may need to be refined.

Key assumptions used in the development of the VIAC using the Johnson & Ettinger Model include:

- Contaminant vapors enter the structure primarily through cracks and openings in the walls and foundation.
- Convective transport occurs primarily within the structure's zone of influence and vapor velocities decrease rapidly with increasing distance from the structure.
- Diffusion dominates vapor transport between the source of contamination and the zone of influence of the building.
- The entrance into the structure of all vapors originating from below the structure.
- All soil properties in any horizontal plane are homogeneous, with isotropic properties that characterize the subsurface, and are based on the most conservative soil type present at the site.
- All sources of contaminants whether in the dissolved, sorbed, or vapor phase can be modeled; the contaminant concentrations are below the aqueous solubility limit, the soil saturation concentration, and/or the pure component vapor concentration.
- Neither sorption nor biodegradation is considered in the transport of vapor from the source to the base of the structure.

In the development of the VIAC, there are two exceptions to the use of the Johnson & Ettinger model:

- When groundwater in contact with the structure (Refer to Section 13.3).
- When a source of vapors is within 1 meter of the structure and contaminant vapors enter the structure not only through cracks and openings in the walls and foundation, but through diffusion directly across the concrete (Refer to Section 13.6).

When a party elects to rely on a sample of the vapor as the best available information for evaluating the VIAP, the sample must be collected appropriately and the data must undergo an appropriate quality assurance and quality control evaluation. In assessing the quality of the data to evaluate the VIAP, the evaluation must include all of the following, at a minimum:

- Consideration of the location of the vapor sample relative to the source.
- How the vapor point was installed and the sample collected.
- The methodology used.
- In the presence of shallow groundwater, confirmation that the vapor sample was not collected beneath or within an area saturated or likely saturated by groundwater, which includes the capillary fringe.

A vapor sample may not be able to be collected at every site. A vapor sample cannot be collected when groundwater is in contact with the structure; no separation exists between the

top of the water table and the bottom of the structure. In this situation a site-specific evaluation is necessary.

13.3 Groundwater In Contact With a Structure

Groundwater is in contact with a structure when the vertical separation distance is less than or equal to 0 cm[128]. In areas throughout the state, groundwater is shallower than the depth to the bottom of the structure. Groundwater may be continually in contact with the structure, or, seasonal groundwater fluctuations may result in a depth to groundwater shallower than the depth to the bottom of the structure.

The vertical separation distance considers seasonal variations of the first encountered groundwater and is the lesser of the following[129]:

- The distance between the top of the capillary zone of the first encountered groundwater and the bottom of the structure.
- The distance between the first encountered groundwater and the bottom of the foundation and subsurface utilities that may be present beneath the structure.

When either of the above conditions occurs, it is assumed that one or more of the following conditions is or is likely to occur when groundwater is a source of vapor:

- A structure is present and groundwater can be observed within the structure;
- A structure is planned or present and has a foundation that may include a footer or other subsurface structural component, that is or may become wetted by groundwater and groundwater is not likely observed within the structure; and
- A structure is planned or present and utilities or other subsurface features such as a sump, a drain tile, a footing drain or other feature are present and have the potential to be in contact at any time/duration with groundwater.

When any of the above conditions exist, the use of J&E Model is not appropriate to establish an attenuation factor. Groundwater that is a source of vapors and is in contact or may be present within a structure can volatilize directly into indoor air or directly across an intact concrete surface.

13.3.1 Presence of Shallow Groundwater in Michigan

The MDEQ evaluated the presence of water in Michigan at three discrete depths. Refer to Attachment G):

- 0-5 feet below ground surface;
- 0-10 feet below groundwater surface; and
- 0-15 feet below ground surface.

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[128] R 299.27(3)(b)

The evaluation indicated that over 55 percent of the state is likely to encounter water less than 5 feet below the ground surface and 65 percent of the state is likely to encounter groundwater at a depth of 10 feet below the ground surface. The evaluation further identified that only 29 percent of the state is likely to encounter groundwater at a depth greater than 15 feet below the ground surface. Attachment G Figures 9 thru 11, depict the depths to groundwater statewide and indicate shallow groundwater is present across the state and is not an isolated occurrence. In every county in Michigan, groundwater can be expected to be encountered not only at a depth of less than 10 feet below the ground surface, but at a less than five feet.

13.3.2 Groundwater in Contact

When groundwater is in contact with a structure, the MDEQ used an approach identified by Martí et al (2015) for the development of criteria. The equations[130] assume groundwater is in contact and wetting (even though it may not be visible) the entire footprint of the floor of the structure (A_{GWIC}) over the entire exposure duration.

In the development of the criteria, consideration was given to using a portion of the floor less than the entire footprint. However, reducing the portion of the floor covered by water requires one to factor in several other considerations, not appropriate in the development of the generic criteria. For those parties implementing a site-specific evaluation (VI Tier 3B) refer to Section 13.3.2.1 through Section 13.3.2.5 for a discussion of the other considerations.

13.3.2.1 Groundwater in Contact – VI Tier Approach

In the development of the criteria, groundwater at depths below surface of less than three meters (< 3 meters) is assumed to be in contact with a structure and periodically or persistently intrude into the structure (e.g. basement space). In the development of the tiered approach, failure to account for the depth to the first encountered groundwater would mean the generic criteria would not be applicable for 65 percent of the state; in every county of the state there are areas where groundwater is <3 meters below ground. Failure to not address the statewide presence of shallow groundwater in the development of the VIAC could cause confusion for the regulated community as the generic unrestricted criterion would not be applicable at sites located in these areas (See Figure 10 of Attachment G).

As identified in Section 13.1.3, it was recommended the tiered process be a relatively simple, step-by-step approach. The VI Tier 1 approach was modified to account for groundwater in contact with a structure, for the reasons indicated above. However consideration for the depth of groundwater >3 meters was retained in VI Tier 2 and VI Tier 3A, and a site-specific evaluation under a VI Tier 3B is allowed.

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[130] R 299.27(10)(b)

13.3.2.2 Groundwater in Contact – Duration and Time

The time groundwater is in contact or intruding into a structure can vary significantly over short distances; even for similarly constructed buildings that are adjacent to each other. It can be difficult to verify when groundwater is or is not in contact with a structure even when extensive site characterization data is available.

The actual amount of variation expected will depend on numerous factors, including but not limited to:

- depth to groundwater;
- type of construction and/or, method of construction;
- seasonal groundwater variation; and,
- type and presence of native soil and/or back-fill material.

A significant portion of the groundwater in Michigan is shallow. Refer to Section 13.3.1. It is anticipated the majority of the homes constructed with a basement will likely have some portion of the structure in contact with groundwater. If reducing the duration or groundwater contact time with a structure, consideration must be given to whether the groundwater in contact is the source of vapors. If groundwater is a source of vapors and not in contact with a structure, diffusion across the concrete and directly through the cracks will continue to occur with little to no dispersion.

A modification to the duration or groundwater contact time can be performed as part of a VI Tier 3B site-specific evaluation when consideration is given to the potential risk for when groundwater is not in contact, nor wetting the foundation. This will require information specific to the site and documentation that the input values used are the most representative of actual site conditions.

13.4 Building Specific Input Values

Recommendations for building specific input values are consistent with those used by USEPA. Further discussion of specific inputs follows.

13.4.1. Modifying Enclosed Floor Space Length and Width (L_B and W_B) – Residential and Nonresidential

A modification of the enclosed floor space length and width (L_B and W_B) is acceptable as part of a VI Tier 3B site-specific evaluation requiring information specific to the site and documentation that the input values used are the most representative of actual site conditions. The site-specific input values must have undergone a sensitivity and validation analysis.

Residential and nonresidential structures typically consist of a number of rooms that may or may not be connected horizontally or vertically; and there may be variation in vapor sources (e.g., location) and vapor concentrations in the subsurface. In the modification of the size of a structure it should not be assumed rooms are interconnected. An inspection or investigation of the above and below ground building construction (e.g., depth of footers, location of footers, additions to original structure) should be conducted. Additionally, the investigation should

determine the annual variation of vapors across the entire building area where a source of vapors is present in the subsurface.

The sensitivity and validation analysis includes, but is not limited to the following actual building parameters:

- Building air exchange rate;
- Enclosed-space floor thickness;
- Enclosed-space floor length and width; and
- Enclosed-space height.

The sensitivity and validation analysis would include:

- An evaluation of the smaller areas contained within the structure;
- An evaluation of how the footings, walls, air exchange patterns impact the data; and
- An evaluation of whether the inputs used are representative of the actual site conditions.

The parameters and conditions identified above, as well as, the distribution of contaminants beneath the structure all have the potential to influence the ability for vapors to enter the building and affect the quality of the indoor air. Therefore, it must be demonstrated that the contaminant concentrations generated in a VI Tier 3B site-specific evaluation are protective of human health, for the given site and structure conditions.

13.4.2 Building Mixing Height (Enclosed Space Height)

The volume of a building is determined by the interior building area and height. The Johnson & Ettinger Model assumes subsurface volatiles migrating into a building are completely mixed within the building volume in the portion of the building in contact with the source of vapors. The building mixing height is dependent on a number of factors including:

- the height of that area of the floor in contact with the source of vapors,
- the heating, ventilation and air conditioning (HVAC) system operation,
- environmental factors such as indoor-outdoor pressure differentials and wind loading,
- occupied areas or areas likely to be occupied, and
- seasonal factors.

For a single-story house, the variation in mixing height can is approximated by the room height of that area of the floor in contact with the source of vapors. However, there is some degree of correlation between the mixing height and building air exchange rate.

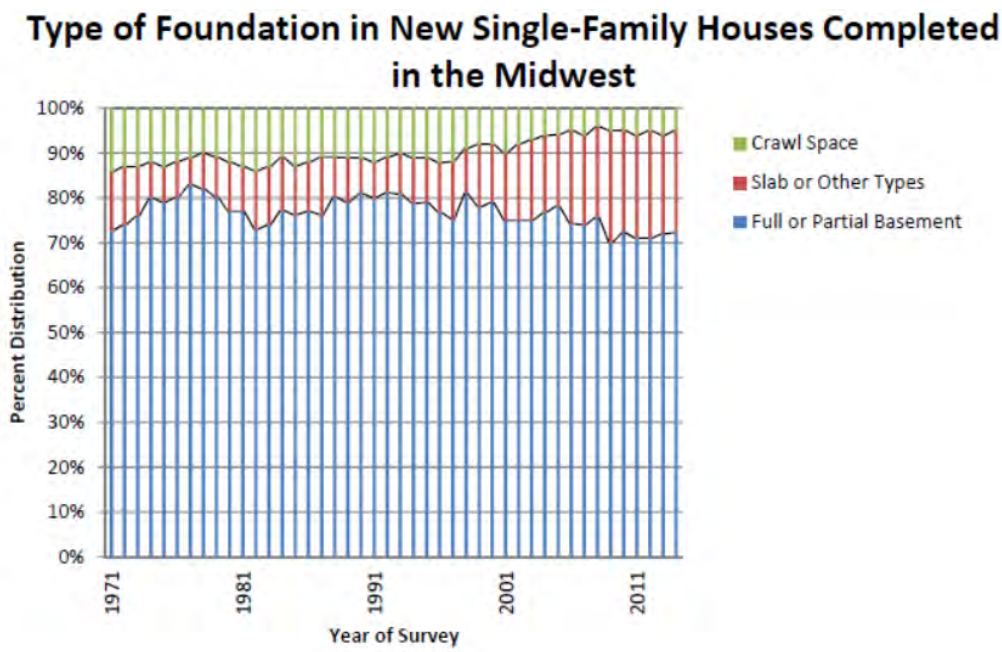
13.4.2.1 Building Mixing Height - Residential

The MDEQ in the development of the residential VIAC has used a mixing height (H_B) value of 2.44 meters; a value representative of a residential home with slab-on-grade construction or a residential structure with an occupied basement.

The USEPA uses a mixing height of 3.66 meters for residential structures with a basement. This value is based on the assumption the basement is not occupied (not fit for occupancy) and

all exposure occurs on the first floor. This height allows for an approximate two-fold reduction or attenuation in vapor concentrations between floors to where the occupancy occurs.

US Census data illustrates that since 1971, 77% of homes in the Midwest have been constructed to include a basement. Basements are commonly finished, partially finished, or could be finished to include bedrooms or living space and daily occupancy. A mixing height value of 3.66 meters that does not account for basement occupancy is not appropriate or accurate to describe a residential home in Michigan.



Data provided by the US Census Bureau for the number of homes completed with a crawlspace, slab –on-grade (or other) and full or partial basement in a single-family home since 1971 in the Midwest. All data is available at: http://www.census.gov/construction/chars/

With an occupied basement, all exposure would occur in the basement, not on the first floor. Therefore, the MDEQ has adopted the USEPA value of 2.44 m (USEPA, 2004) for a slab on grade where vapors are migrating directly into the living space. This value does not account for the vapors migrating through an unoccupied area prior to the exposure occurring.

13.4.2.2 Building Mixing Height - Nonresidential

The MDEQ in the development of the nonresidential VIAC, has used a mixing height (H_B) value of 3.66 meters; a value representative of both a building with a basement and slab-on-grade construction. In the nonresidential scenario, it is assumed the basement is unoccupied space.

13.4.2.3 Modifying the Mixing Height (H_B) – Residential and Nonresidential

A modification of the enclosed space or mixing height (H_B) is acceptable as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation the input value used is the most representative of actual site and structure conditions. Modification of this input value may also require the use of a land or resource use restriction.

The use of the 3.66 meter mixing height for a residential or nonresidential structure may be appropriate when it can be verified the basement is not habitable and likely to remain uninhabitable. A basement is considered uninhabitable when the following exist and can be documented:

- As measured from floor to ceiling, the height of the basement is less than 7 feet high in every part.
- There is not, nor the potential for, the installation of a bathroom, water fixture (including facet) or area were laundry may be done.
- The basement does not contain a method of egress either as a window or other form of opening that would allow egress.
- No evidence of human habitation.

The use of a mixing height of 3.66 meters in the development of residential criteria would also require the implementation of a land or resource use restriction to ensure the continuance of the conditions that make the basement uninhabitable.

13.4.3 Indoor Air Exchange Rate

In the development of the generic VIAC, the air exchange rate (AER) for a given structure is a sensitive variable. Ventilation and air exchange rates have three main components:

- Infiltration, or uncontrolled leakage of air into a building through openings in the building;
- Natural ventilation through open windows and doors; and
- Mechanical ventilation provided by fans (Nazaroff, 1992).

Ventilation rates as reported in the literature vary significantly, however the data suggests two broad trends:

- There is a general reduction in ventilation rates over the past two decades, and lower ventilation rates for houses located in cold climates (e.g., compare U.S. and Canadian data).
- In regions with relatively cold climates, the recent trend has been to construct “air-tight” houses with reduced ventilation rates to minimize energy consumption and costs (Gusdorf and Hamlin, 1995).

13.4.3.1 Indoor Air Exchange Rate – Residential House

In the development of the residential VIAC, MDEQ with concurrence from the CSA has used an air exchange rate (AER) of 0.25 air exchanges per hour (AEH) for a single family residential house.

The results from 22 studies reporting building air exchange rates in Hers et al. (2001) showed AEH’s varied from approximately 0.1 AEH for energy efficient “air-tight” houses (built in cold climates) (Fellin and Otson, 1996) to over 2 AEH (ASHRAE (1985); upper range). One of the most comprehensive US studies conducted by Murray and Burmaster (1995), looked at air exchange rates in 2,844 residential houses. The data set was sorted and analyzed on a seasonal basis and according to climatic region. The results of the data analysis were reported

for the 10th, 50th and 90th percentile, indicating AEH values of 0.21, 0.51 and 1.48, respectively. However, when looking at data for the winter season and houses in the coldest climatic areas (Region 1, e.g., Great Lakes area and extreme northeast U.S.), AEH values for the 10th, 50th, and 90th percentiles were 0.11, 0.27 and 0.71, respectively (Hers et al., 2001).

Based on Hers et al, a value of 0.25 AEH is not the most conservative value as it closely aligns with the 50th percentile. A value of 0.25 AEH is also aligned with the value used by the USEPA (2004). It is likely that the AEH will vary over the course of year and that greater air exchange rates will occur in the spring and fall when residences typically open windows for cooling and comfort. As such the MDEQ has determined the use of this value is appropriate for the residential single family home scenario.

13.4.3.2 Indoor Air Exchange Rate – Apartment

In the development of the generic VIAC under VI Tier 3A, MDEQ has identified an air exchange rate (AER) of 0.61 air exchanges per hour (AEH) for apartment buildings. An evaluation of the VIAP using criteria developed under a VI Tier 3A may require the use of a land or resource use restriction.

The value of 0.61 AEH is only appropriate for the evaluation of the VIAP for a site with a large multiple floor building comprised of units intended for residential-living. The AER of 0.61 AEH is not appropriate for structures that were formerly used as a single family home; a row house; a series of linked or densely packed houses, semi-detached houses, duplexes, or other similar structures.

13.4.3.3 Indoor Air Exchange Rate - Nonresidential

The USEPA (2011) (Refer to Table 19-26) identified AERs for all different types of commercial buildings ranged between 0.3 AEH and 4.1 AEH with a mean of 1.5 AEH and a 10th percentile of 0.60 AEH. Information provided in the USEPA's 2011 Exposure Factors Handbook, indicates the confidence in determining an AER for non-residential buildings is low, in part because:

- A limited amount of data is available;
- Long-term air exchange rates are not well characterized and individual commercial buildings were typically measured during only one season;
- Studies have been found to under-predict seasonal average air exchange by 20–30% (Sherman, 1989). Turk et al. (1987) estimates a 10–20% error of measurement in the technique used to measure ventilation in commercial buildings.

Dr. Steve Song, Ramboll Environ, Inc., (TAG 2014) provided information on air exchange rates based American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE, 62.1-2010). Refer to Attachment C. The information indicates there is a wide range of AERs even within the same structure. TAG members agreed there is no state or federal requirement to meet or maintain the AERs established in the ASHRAE, nor should it be expected the rates could be obtained.

In the development of the generic nonresidential VIAC, the MDEQ has established two different AERs for nonresidential scenarios.

The air exchange rate of 1.0 AEH is appropriate for all nonresidential land use scenarios (e.g., office) except those where:

- The structure was a former residential single family home;
- Air exchange rates are modified or reduced as a means to reduce energy costs;
- Air handling mechanisms and/or filters have reduced the over air exchange rate; or
- The building is occupied by a sensitive population for a majority of the time the business is in operation (e.g., daycare or school). Refer to Section 2.1.

The air exchange rate 1.5 AEH is intended for building uses classified as manufacturing; an establishment covered by the classifications provided by sector 31-33 – manufacturing, of the North American industry classification system, United States, 2012, published by the office of management and budget.

It should be understood, the air exchange rate of 1.5 AEH is not appropriate if there are areas within the building that are unique and separate from the manufacturing process area (e.g., office); in these types of areas the nonresidential air exchange rate (1.0 AEH) is more appropriate. As identified by the ASHRAE, 62.1-2010 an AER of 1.5 AEH is only appropriate for building uses classified as manufacturing. There may be several areas within a structure where the actual AEH may less than or greater than the 1.0 or 1.5 AEH. This includes, but is not limited to: areas of sorting, packing, light assembly areas (.55 AEH); warehousing space (.63 AEH); and shipping/receiving areas (1.46 AEH). In structures where the work force is segmented, it may be more appropriate to evaluate VIAP for the structure based on actual exposures utilizing multiple AEH values.

As stated previously stated, the AER for a structure is a sensitive variable in the development of the criteria. The use of an AER value not suitable for the building in question in the development of criteria to evaluate the VIAP, may underestimate the potential for unacceptable exposure. Care needs to be taken to ensure that the inherent variability, as well as the expected range of AER in a given structure is appropriately accounted for in the application of the generic criterion.

13.4.3.4 Modifying the Air Exchange Rate – Residential and Nonresidential

A modification of the AER is acceptable as part of a VI Tier 3B site-specific evaluation. This requires information specific to the site and documentation that the input value used is the most representative of actual site/structure conditions. Modification of this input value may also require the use of a land or resource use restriction.

In certain circumstances, a site-specific AER may be used to in place of the MDEQ generic AER value and an unrestricted site use may still be possible. The party conducting a VI Tier 3B using a site-specific AER value must be able to provide sufficient information to document the value is representative of the annual air exchange rate. The documentation must indicate

consideration was given to, and can successfully document that the expected maximum and minimum rates for the buildings with the existing heating and cooling system.

13.4.4 Foundation Type - Basement and Slab-On-Grade

In the development of the groundwater and vapor VI Tier 1 screening levels and the VI Tier 2 VIAC, the structure is a residential home with a basement foundation. In the development of the soil VI Tier 1 screening level and the VI Tier 2 VIAC, the structure is a residential home with slab-on-grade foundation.

The use of a structure with basement foundation aligns with the both the CSA recommendation and available data that indicates that a basement is the most common building foundation type in the Midwest. As reported by United States Census Bureau, since 1971, 77% of the residential homes built in the Midwest region were constructed to include a full or a partial basement. Refer to Section 13.4.2.1. This is significantly different than the US reported average indicating 36% of residential homes are constructed with basements. In the Midwest, the remaining 23% of constructed homes consist of crawl spaces (10%) and other types of foundations (13%), which includes slab-on-grade. Data available since the 2000's has identified a decreasing trend in the percentage of the number of homes constructed with a crawlspace.

The MDEQ performed a sensitivity analysis, the results of which identified a slab-on-grade foundation as being the appropriate foundation type for use in the development of the VI Tier 1 screening level and the VI Tier 2 VIAC for soil. Refer to Attachment R. The analysis ensured that the tiered approach aligned with the concepts identified in CSA Report, and developed a better understanding of the relationships between the parameters associated with foundation types.

Modification to the foundation type as part of a VI Tier 3A facility-specific VIAC, adjusts the values to the actual foundation which would account for any actual calculated differences between the groundwater, soil, or vapor. A VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation that the input value is the most representative of actual site and structure conditions, can also be used to account for this difference. Modification of this input value may also require the use of a land or resource use restriction.

13.4.5 Enclosed Space Floor Thickness

An enclosed floor space thickness (L_{crack}), of 15 centimeters (cm) for a structure, is used in the development of the VIAC. A standard concrete floor slab thickness in residential and nonresidential construction is typically between 4-6 inches thick, unless the concrete will receive occasional or regularly occurring heavy loads.

A modification of the enclosed floor space thickness (L_{crack}) is acceptable as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation the input value used is the most representative of actual site and structure conditions. Although, this is typically not a very sensitive parameter, modifying the generic input value can be done, but may require the use of a land or resource use restriction.

13.4.6 Depth of Footings and Utilities below Enclosed Space

The depth of footings and utilities below enclosed space (L_{FF}), of 100 cm, is used in the development of the VIAC.

As discussed in Section 13.4.2.1, the majority of homes in Michigan are constructed with a basement. These structures also include footings, footing drains, sumps, and other utilities that extend the actual depth of the structure that may come into contact with groundwater.

Due to the high percentage of the state where shallow groundwater is present (Refer to Section 13.3.1), most local building codes require the installation of a sump or footing drains to prevent groundwater from entering into habitable spaces. These features (e.g., footings, footing drains, sumps, utilities) may allow vapors to migrate directly into the indoor air without any further diffusion.

The value of 100 cm (1 meter) for all structures takes into the height of a typical basin installed below the lowest level of a structure. This depth would also addresses those structures and their depth a (sumps, footings, and other utilities) that may have been installed beneath the lowest level or floor of a structure. The value of 100 cm is not appropriate when a structure with a larger area (e.g., vault, process pit, root cellar, or elevator area) is present. When such structures exist a site specific evaluation is necessary.

Modification of the depth of footings and utilities below enclosed space (L_{FF}) is acceptable as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation that the input value is the most representative of actual site/structure conditions. Modification of this input value may also require the use of a land or resource use restriction.

13.5 Rise of the Capillary Zone

Lohman (1972) and Fetter (1994) estimated the rise of the capillary zone above the water table using the phenomenon of capillary action. Capillary action describes the spontaneous upward movement of water molecules subject to an attractive force due to surface tension at the air-water interface and the molecular attraction of the liquid and solid phases. The rise of the capillary zone can be estimated using the equation for the height of capillary rise in a bundle of tubes of various diameters equivalent to the diameters between varying soil grain sizes. (Fetter, 1994)

In the development of the VI Tier 1 screening levels, the rise (thickness) of the capillary zone is calculated based on soil-type sand. In the development of the VI Tier 2 and VI Tier 3A generic VIAC, the rise of the capillary zone is calculated based on the soil type documented to be specific to the site, otherwise the use of sand would be appropriate. The value for the rise of the

capillary zone above the water is calculated as part of the equations when groundwater is not in contact[131].

13.6 Distance to a Vapor Source

An exceedance of the screening levels and generic VIAC, indicate the presence of a hazardous substance with the potential for unacceptable exposure via the VIAP. The distance to a vapor source (L_T) for each environmental media (groundwater, soil and vapor) used in the development of the generic screening levels and generic residential and nonresidential VIAC are identified below.

The VI Tier 1 Screening Levels:

- Soil – 1 cm; the use of 1 cm is appropriate for all sites.
- Groundwater – assumed to be in contact with a structure
- Vapor – 1 cm; the use of 1 cm is appropriate for all sites.

The VI Tier 2 generic VIAC:

- Soil – 1 cm, the use of 1 cm is appropriate for all sites.
- Groundwater – at a depth of <3m, groundwater is assumed to be in contact with the structure
- Vapor – 1 cm; the use of 1 cm is appropriate for all sites.

The depth to groundwater (when >3m) may be modified to reflect the actual facility-specific site conditions. The depth to groundwater with consideration of the following will play a key role in establishing whether groundwater is in or not in contact with the structure:

- The height of the capillary fringe (Refer to Section 13.5),
- The depth of the structure (Refer to Section 13.4.4),
- The depth of footings and footing drains, sumps, and all subsurface utilities (Refer to Section 13.4.6).

The VI Tier 3A generic, limited residential and nonresidential VIAC:

- Soil – 1 cm, the use of 1 cm is appropriate for all sites.
- Groundwater – depth to groundwater can be modified to reflect facility-specific conditions.
- Vapor – 1 cm; the use of 1 cm is appropriate for all sites.
- Vapor – 100 cm (1 m); the use of 1m is appropriate only when the known or suspected source of vapors, as verified by sampling is >1m vertically from the structure

Groundwater is considered to be in contact with a structure when either of the following conditions exists:

- The depth of footings and utilities below the enclosed space is less than the depth to groundwater, or
- The depth below grade of the enclosed space is less than the depth to groundwater considering the height of the capillary fringe.

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[131] R 299.27(10)(a) – equations 11 through 13

Though groundwater is considered to be in contact with a foundation, it may not be visible within the structure.

Modification of the distance to source of vapors (L_T) is allowed as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation that the input value used is the most representative of actual site and structure conditions. Supporting documentation must include, but is not limited to:

- Data demonstrating concentrations (groundwater, soil, and vapor) below the VI Tier 1 screening levels or appropriate VI Tier 2 VIAC are defined;
- Data that demonstrates there are no concentrations of hazardous substances or conditions present between the structure and the modified distance to the source of vapors.
- All sampling points are in line with the modified source distance.

Modification to the generic input values may also require the use of a land or resource use restriction.

13.7 Fraction of Organic Carbon

A f_{oc} (soil organic carbon weight fraction) of 0.002 is used in the development of the screening values and residential and nonresidential VIAC. The value of 0.002, is consistent with the value used by USEPA (1996 a and b) for subsurface soils.

Modification of the f_{oc} is acceptable as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site and documentation that the input value used is the most representative of actual site conditions. Supporting documentation should clearly indicate carbon present in any single soil sample represents the natural conditions and is not elevated due to contribution from the hazardous substances released at the site. Refer to Attachment M.

13.8 Q_{soil}

The volumetric flow rate of soil gas entering the closed space of a building is defined as Q_{soil}. A theoretical expression (Nazaroff 1992) is used to estimate the vapor flowrate into a building. The equation is based on the conceptualization that flow to a crack is similar to flow to a cylindrical sink placed at some depth below grade.

Modification of the Q_{soil} is acceptable as part of a VI Tier 3B site-specific evaluation. The advective flow zone is relatively limited in extent, making the soil type adjacent to the building foundation of critical importance. In many cases, coarse-grained fill is placed below foundations and adjacent to the foundation walls; alternatively the foundation is backfilled using disturbed site soils. Even if course grain soils are not placed near the foundation it is usually backfilled with disturbed fill that is from the site. The conservative approach is to assume that soil gas flow will be controlled by coarse-grained soil, and not consider the possible reduction in flow that could be caused by fine-grained soils near the house foundation.

Any modification of the Q_{soil} as part of a VI Tier 3B site-specific evaluation requires information specific to the site, and documentation that the input value used is the most representative of actual site conditions.

Other alternate approaches may be acceptable, but would require additional evaluation and approval by the MDEQ.

13.9 Attenuation Coefficient - Vapor

In the development of the vapor VI Tier 1 screening levels, and vapor and groundwater VI Tier 2 VIAC, an attenuation coefficient (factor) of 0.03 is used. This value represents the attenuation across a concrete slab.

The EPA, in the implementation of the 2014 version of the Vapor Intrusion Screening Level Calculator (USEPA, 2015), identified specific situations that may result in un-attenuated or enhanced transport of vapors towards a receptor, including:

- Very shallow groundwater sources (e.g., depths to groundwater less than 5 feet below the level of the foundation);
- Shallow soil contaminant vapor sources (e.g., presence of contaminated soils within a few feet of the base of the foundation); and
- Buildings with significant openings to the subsurface (e.g., sumps, unlined crawlspaces, earthen floors) or significant preferential pathways, either naturally-occurring or anthropogenic (not including typical utility perforations present in most buildings).

A number of the situations identified above are addressed when consideration is given to groundwater in contact. Refer to Section 13.3. However, shallow sources close to the structure are not addressed. As previously indicated, vapors diffusing directly across the concrete or other openings are likely to contribute to the concentrations in the indoor air. Refer to Section 13.3.2. The Johnson & Ettinger Model only considers contaminant vapors entering a structure through the cracks and openings in the walls and foundation and that have diffused through the soil column.

Research, as well as tests performed by Partner Engineering and Science, Inc., AKT, MDEQ, and others have demonstrated vapors can and do migrate through an intact concrete surface, not just through cracks and other openings. The results of the tests indicate the attenuation rate across the concrete can be as low as 10 or an attenuation factor of 0.1, dependent on the porosity of the flooring material. The actual attenuation rate across the concrete within a given structure is typically not available nor is it likely collected during the initial stages of an investigation. The attenuation rate is also likely to vary significantly for each site.

Modification to the attenuation factor is allowed as part of a VI Tier 3B site-specific evaluation, requiring information specific to the site structure(s) and documentation that the input value used is the most representative of actual site and structure conditions.

13.10 Johnson & Ettinger Model - Algorithm to Derive the Attenuation Coefficient

The steady state attenuation coefficient (α), an important parameter for calculating risk based values for different environmental media (soil, groundwater and vapor), is derived using a modification of the Johnson & Ettinger Vapor Intrusion model[132]. A detailed description of this model, including model inputs may be found in the EPA's User's Guide for Evaluating Subsurface VI (EPA, 2004) and American Petroleum Institute's VI model publication (API, 2002).

13.11 Vertical Separation Distance

Vertical separation distance means the vertical distance from a vapor source to a building foundation[133]. The MDEQ may establish a vertical separation distance for petroleum vapor intrusion that represents the minimum distance between a petroleum vapor source and a structure needed to effectively biodegrade hydrocarbons below a level of concern for a current or planned structure. The distances would be similar to that identified by the ITRC in the document titled Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management (ITRC, 2014). Demonstrating compliance with a vertical separation distance may still require the need for land or resource use restrictions to prevent future exposure.

13.12 VI Tiered Process

The VIAP is evaluated using soil, groundwater, and vapor samples to satisfy the criteria for each media[134]. This evaluation requires the following considerations:

- The conceptual site model (CSM) represents the VIAP.
- The samples collected are aligned with the location of the vapor source and appropriate for evaluating the VIAP.
- When a calculated risk-based VI value is less than the laboratory target detection limit (TDL), the TDL becomes the VI screening level or criterion[135]. When concentrations of hazardous substances in soil or groundwater do not exceed a criterion that is based on the TDL but concentrations exceed the risk based value, a vapor source may be present that represent risk to human health. Therefore, additional evaluation may be necessary.
- When comparing samples that are co-located or are similarly located, vapor samples may be used as the best available information to represent in-situ conditions at the site for evaluating a vapor source and the ability to migrate.

The series of equations and their inputs for calculating the following VI values are:

- Volatilization to indoor air value where groundwater is not in contact with the structure (VIGW) – R 299.27(10)(a) Equations 1 to 20.
- Volatilization to indoor air value where groundwater is in contact with a structure (VIGWIC) – R 299.27(10)(b) Equations 1 to 3.
- Volatilization to indoor air value for soil (VI_{soil}) – R 299.27(10)(c) Equations 1 to 14.

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[132] R 299.27(10)(a) – Equation 6; R 299.27(10)(c) – Equation 6; R 299.27(10)(d) Equation 2
[133] R 299.27(1)(m)
[134] R 299.27(2)(d)
[135] MCL 324.20120a(10); R 299.6(8)(a)

- Volatilization to indoor air value for vapor (VI_{sg}) – R 299.27(10)(d) Equations 1 to 12.
- The acceptable air concentration (AAC), an input to the calculation of VI values – R 299.27(11). The residential AAC is the minimum of the calculated health-based acceptable air values in Equations 1 to 5. The nonresidential AAC is the minimum of the values calculated in Equations 6-8.

If a hazardous substance does not have sufficient generic input values to allow the development of generic criteria using the equations of this rule, VI criteria may be developed for that hazardous substance using the following[136]:

- In place of a generic criterion for groundwater not in contact, the generic criterion for groundwater in contact may be used to evaluate the potential for vapor intrusion. Alternatively, a person may evaluate the VIAP using VI Tier 3B site-specific criteria.
- If a generic criterion for vapor is not available but hazardous substance has sufficient input values to develop an AAC, the generic attenuation factor of 0.03 is be used to develop the VIAC. Alternatively, a person may develop VI Tier 3B site-specific criteria to evaluate the VIAP.

13.12.1 VI Tier 1 Screening Levels Development

The VI Tier 1 screening levels presented in the Criteria Tables are the initial screening levels used to identify a release of a hazardous substance as a source of vapors or a vapor cloud. They are also used to evaluate VIAP without any facility-specific geological or physical-specific information. The VI Tier 1 screening levels may be used as the generic criteria[137] to evaluate the VIAP when no further site data is available. If a concentration of a hazardous substance in any environmental media exceeds the associated VI Tier 1 screening level then a person must evaluate whether additional response activity is required to assess the vapor source for vapor intrusion potential. Action may include:

- Implementation an appropriate response action;
- Evaluation of the VIAP using VI Tier 2 generic unrestricted residential criteria[138] .
- Evaluation of the VIAP using VI Tier 3A criteria[139].
- Evaluation of the VIAP using VI Tier 3B criteria[140].

In addition to the information identified in Sections 13.1 through Section 13.11, the development of the VI Tier 1 screening levels are based on the following:

- Any structure present or planned to be constructed at the site has a concrete block or poured concrete walls and concrete floor;
- Groundwater is in contact with the structure;
- An attenuation factor of 0.03 is used to calculate the acceptable vapor concentration;

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[136] R 299.27(4)
[137] R 299.27(5)(a) to (c)
[138] R 299.27(6)
[139] R 299.27(7)
[140] R 299.27(8)

- All soil-specific inputs are based on the parameters associated with the Natural Resources Conservation Services of the United States Department of Agriculture (NRCS-USDA) soil-type sand with a system temperature of 10 degrees Celsius; and
- Soil is considered to be homogeneous and isotropic.

13.12.2 VI Tier 2 Generic Unrestricted Criterion

In addition to the information identified in Sections 13.1 through Section 13.12.1 the development of the generic VI Tier 2 VIAC are based on the following:

- Any structure present or planned to be constructed at the site has a concrete block or poured concrete walls and concrete floor;
- Groundwater is in contact with the structure, unless it is > 3 meters;
- An attenuation factor of 0.03 is used to calculate the acceptable vapor concentration;
- All soil-specific inputs are based on the parameters associated with the NRCS-USDA soil-type sand;
- System temperature of 10 degrees Celsius; and
- Soil is considered to be homogeneous and isotropic or utilizes the soil type that result in the most restrictive screening value.

The VI Tier 2[141] is the VI Tier 1 screening level that incorporates facility-specific geological and physical site conditions to establish the generic criteria for unrestricted residential use. The input values are identified in Table 2 and Table 10[142]. If concentrations of hazardous substances in any environmental media exceed VI Tier 2 VIAC, a person may:

- Implement an appropriate response action;
- Evaluate the VIAP using VI Tier 3A generic criteria[143]; or
- Evaluate the VIAP using VI Tier 3B site specific criteria[144].

If the concentration of a hazardous substance in environmental media exceeds VI Tier 1 screening level, the VIAP may be evaluated using VI Tier 2 generic unrestricted residential criteria. The VI Tier 2 generic unrestricted residential criteria identify a vapor source and the potential for vapor intrusion and are based on the following:

- MDEQ-approved soil and soil temperature facility-specific input values[145]. When no soil information has been obtained, the facility-specific input values are those listed for sand in Table 2.
- The generic input value for the depth to groundwater is 3 meters and is assumed to be in contact with the structure. A depth to groundwater greater than 3 meters can be established using the shallowest depth of the first encountered groundwater considering seasonal variations based on data specific to the site and MDEQ-approved methodology.

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[141] R 299.27(1)(i)
[142] R 299.7(7) – Table 2; R 299.27(13) – Table 1
[143] R 299.27(7)
[144] R 299.27(8)
[145] R 299.7

- The generic input values for soil criteria assume a residential structure foundation of slab-on grade. The calculated health-based value (HBV) is considered protective of a residential structure with a basement.
- The generic input values for groundwater and vapor assume a residential structure with a basement foundation.
- MDEQ-approved soil type generic input values used to calculate the VI Tier 2 generic criteria are identified in Table 2.
- The calculated value for a hazardous substance based upon groundwater in contact with the structure is considered protective when it is greater than the calculated value of groundwater not in contact with the structure.

As cited above, a soil-type other than sand may be used to develop the VI Tier 2 VIAC. However, MDEQ-approved generic input values must correspond to the soil type specific to the site. The values for the input parameters associated with the soil type are identified in Table 2 and are used to calculate the VI Tier 2 generic criteria. Figure 7 shows the process used for developing the VI HBVs, including values (e.g., TDL, solubility) to be considered to generate the VI Tier 2 VIAC.

13.12.3 VI Tier 3

If concentrations in environmental media exceed VI Tier 1 or the Tier 2 generic criteria, the VIAP may be evaluated using VI Tier 3A generic facility-specific criteria[146] or VI Tier 3B site-specific criteria[147]. The VI Tier 3A criteria represent restricted categorical criteria.

13.12.3.1 Tier 3A Generic Criteria

The VI Tier 3A is defined as the VI Tier 2 generic criterion that incorporates the use of facility-specific land use or building information or both, that requires a land or resource use restriction[148],.

VI Tier 3A generic criteria are based on the use of input values specific to the site based upon the following:

- MDEQ-approved soil and soil temperature facility-specific input values. When no soil information has been obtained during an investigation, the facility-specific input values are those listed for sand in Table 1.
- The shallowest depth of the first encountered groundwater considering seasonal variations based on data specific to the site and MDEQ-approved methodology.
- MDEQ-approved facility-specific inputs values for land use and building information as shown in Table 10.

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[146] R 299.27(7)
[147] R 299.27(8)
[148] R 299.27(1)(j)

13.12.3.2 Tier 3B Site-Specific Criteria

The VI Tier 3B[149] is a criterion developed using an alternate method or model approved by the MDEQ. The data collected from the facility used in the evaluation must be demonstrated to be representative of site-specific conditions and undergone a sensitivity and validation analysis that will determine and evaluate:

- The parameters that require additional information to reduce output uncertainty.
- The inputs that contribute most to output variability.
- The parameters that are most highly correlated with the output.
- The change in the output that results from changing a given input parameter.
- The expected reliability of the identified parameters.

The building parameters used, including the exchange rate, enclosed-space floor thickness, enclosed-space floor length, enclosed-space floor width, and enclosed-space height, must undergo an analysis that includes:

- An evaluation of the smaller areas contained within the structure.
- An evaluation of how the footings, walls, air exchange patterns impact the data.
- An evaluation of whether the inputs used are representative of the actual site conditions.

13.12.4 Different Models or Methods

The MDEQ may approve the use of different models or methods[150]. To determine if the model or method is appropriate to evaluate vapor intrusion risks, a person include an analysis for the inputs similar to what is identified in Section 13.13.3.2 above. Models that are available and may be proposed for review include models that assess:

- Heterogeneous or multilayer soil present at a property.
- A vapor source that consists solely of dissolved phase petroleum.
  - A NAPL vapor source.
  - A finite vapor source in unsaturated soil for circumstances where the vertical and horizontal extent of a vapor source throughout the facility has been defined based upon all applicable VI Tier 2 generic criteria.

13.12.5 Acceptable Air Concentrations (AAC)

The acceptable air concentrations (AAC) represent the acceptable health-based concentration of volatile hazardous substances in indoor air. The calculated health-based acceptable air values (AAV) of a volatile hazardous substance consider the risk level (target risk or hazard quotient), acceptable inhalation toxicity endpoint for different health effects (e.g., cancer and non-cancer), and generic exposure conditions (exposure duration and averaging time). The AAC is the risk-based component of the VIAC for different environmental media.

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[149] R 299.27(1)(k)
[150] R 299.27(8)(c)

The equations and inputs for calculating the residential and nonresidential AAVs for cancer, non-cancer and developmental effects are presented in Rule 27[151]. The residential AAC is the minimum of the health risk-based AAVs calculated according to equations 1 to 5 of R 299(11)(a). The nonresidential AAC is the minimum of the health risk-based AAVs calculated according to equations 6 to 8 of R 299(11)(b).

13.13 Final VIAC Determination

The final criterion for each medium is based on considerations of the calculated health-based value (HBV), appropriate TDL, solubility (for groundwater criteria) and maximum soil ceiling levels and C_{sat} for soil VIAC. Figure 7 presents the decision-making process used in determining the final value that will become the VIAC. Briefly,

- The health-based value (HBV) for groundwater, soil or vapor is calculated using the generic AAC and the medium-based generic attenuation coefficients.
- The HBV is compared to the TDL. When the HBV is lower than the TDL value, the TDL becomes the VIAC.
- The groundwater HBV is also compared to solubility[152]. Where solubility is lower than HBV, solubility becomes the VIAC.
- For soil, in addition to the TDL, the soil HBV is compared to the maximum ceiling soil concentration. When the HBV is greater than the maximum soil ceiling concentration, the maximum soil ceiling concentration becomes the criterion.

The soil VIAC is evaluated using C_{sat}[153]. When the VIAC exceeds C_{sat}, the VIAC value in Table 4 is followed by Footnote (C).

13.14 Petroleum Vapor Intrusion[154]

The MDEQ may establish a vertical separation distance for petroleum vapor intrusion. The use of a vertical separation distance will aid in identifying those sites where vapor intrusion is occurring.

A VI Tier 3B allows the use of a model (Refer to Section 13.12.4) that considers a vapor source that consists solely of dissolved phase petroleum or a NAPL vapor source. The use of such models requires the collection of data generally not collected as part of the typical investigative process. For the VIAP, the use of an MDEQ-approved model, the results of which are reviewed and approved by the MDEQ, may allow a party to obtain an unrestricted land use closure.

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[151] R 299.27(11)
[152] R 299.6(6); Refer to Section 6.1
[153] R 299.4(9); R 299.49(C); Refer to Section 9.1
[154] R 299.27(9)

14.0 HAZARDOUS SUBSTANCES WITH SPECIAL CONSIDERATIONS[155]

Special considerations for hazardous substances with similar toxicity characteristics, and individual hazardous are footnoted[156] throughout the Criteria Tables. A summary of these considerations is provided in the following Sections.

14.1 Groups of Hazardous Substances with Similar Toxicity Characteristics

Health-based values for certain groups of hazardous substances with similar toxicity characteristics are developed with special considerations[157].When 2 or more hazardous substances are present and known to result in toxicological interaction, then the interactive effects, including additivity, are considered in establishing levels that are protective of the public health, safety, and welfare and the environment.

14.1.1 Carcinogenic PAH (cPAH) and Toxicity Equivalence Factor (TEF)[158] -

Carcinogenic polynuclear aromatic hydrocarbons [cPAH] are evaluated as a single hazardous substance and environmental concentrations are expressed as an equivalent concentration of benzo(a)pyrene based upon the relative potency and concentration of the carcinogenic polynuclear aromatic hydrocarbons present at the facility. All carcinogenic polynuclear aromatic hydrocarbons that have documented carcinogenic activity that is additive to that of benzo(z)pyrene and have relative potency factors recognized by the USEPA are evaluated as a single hazardous substance and environmental concentrations calculated on the basis of the relative potencies and chemical-specific concentrations present at the facility. The adjusted environmental concentrations are summed and the resulting total equivalent concentration compared to the criteria for benzo(a)pyrene.

The cPAH and their benzo(a)pyrene associated toxicity equivalence factor (TEF) are:

Hazardous Substance	CAS Number	TEF
Benzo(a)pyrene	50328	1.0
Benzo(a)anthracene	56553	0.1
Benzo(b)fluoranthene	205992	0.1
Benzo(k)fluoranthene	207089	0.01
Chrysene	218019	0.001
Dibenz(a,h)anthracene	53703	1.0
Indeno(1,2,3-c,d)pyrene	193395	0.1

A Footnote (Q)[159] follows the name of each cPAH in the Criteria Tables. The Footnote (Q) appears in place of the criterion values to indicate the need for comparing total TEF-adjusted concentration to the benzo(a)pyrene criteria. Refer to Attachment N for further information.

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[155] R 299.34
[156] R 299.49(1)
[157] R 299.34(1)
[158] R 299.34(1)(b); R 299.49(1)(Q)

14.1.2 Polychlorinated and Polybrominated Dibenzodioxins and Dibenzofurans and Dioxin-like Polychlorinated Biphenyls (Dioxins, Furans, and Dioxin-like PCBs)[160]

All polychlorinated and polybrominated dibenzodioxins and dibenzofurans and dioxin-like PCBs are evaluated as a single hazardous substance and environmental concentrations are expressed as an equivalent concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin based upon the relative potency and concentration of the dioxin-like chemicals present at the facility. All classes of hazardous substances that have documented dioxin-like activity and have toxicity equivalent factors (TEFs) or other relative potency factors recognized by the USEPA are evaluated as a single hazardous substance and environmental concentrations are calculated on the basis of the relative potencies and chemical-specific concentrations present at the facility. The adjusted environmental concentrations shall be summed and the resulting total equivalent concentration compared to the criterion for 2,3,7,8-tetrachlorodibenzo-p-dioxin. The Criteria Tables include a Footnote (O)[161] after the name of each dioxin, furan and dioxin-like PCBs and is included in place of cleanup values to indicate the need to adjust and add all Footnote (O) substances that are present in the facility. Polybrominated dibenzodioxins and dibenzofurans are assumed to have the same relative potency as the congener with chlorines substituted at the same locations until chemical specific TEFs are developed for these brominated hazardous substances. Soil direct contact criteria for these hazardous substances are not protective for the human consumption of eggs from chickens with access to soil at these concentrations. In addition, the soil direct contact criteria may not be protective for other livestock products raised or produced on soils at these concentrations. Exposure from livestock products is an injury which requires consideration[162].

TEFs for dibenzodioxins, dibenzofurans and dioxin-like PCBs are identified as follows:

Dioxin Congener	CAS Number	TEF
2,3,7,8-TCDD	1746016	1.0
1,2,3,7,8-PeCDD	40321764	1.0 (0.5)*
1,2,3,4,7,8-HxCDD	39227286	0.1
1,2,3,6,7,8-HxCDD	57653857	0.1
1,2,3,7,8,9-HxCDD	19408743	0.1
1,2,3,4,6,7,8-HpCDD	35822469	0.01

[159] R 299.49(1)(Q): The concentration of each carcinogenic polynuclear aromatic hydrocarbon (cPAH) detected at a facility shall be expressed as its equivalent concentration of benzo(a)pyrene by multiplying the concentration by its respective toxicity equivalent factor (TEF). All TEF-adjusted cPAH concentrations shall then be added together and the total TEF-adjusted concentration compared to the relevant criteria for benzo(a)pyrene.
[160] R 299.34(1)(a)
[161] R 299.49(1)(O): The concentration of all polychlorinated and polybrominated dibenzodioxin and dibenzofuran and polychlorinated biphenyl congeners listed in the table below present at a facility, expressed as an equivalent concentration of 2,3,7,8-tetrachlorodibenzo-p-dioxin based upon their toxicity equivalence factors (TEF), shall be added together and compared to the criteria for 2,3,7,8-tetrachlorodibenzo-p-dioxin. Soil direct contact criteria for these hazardous substances are not protective for the human consumption of eggs from chickens with access to soil at these concentrations. In addition, the soil direct contact criteria may not be protective for other livestock products raised or produced on soils at these concentrations. Exposure from livestock products is an injury which requires consideration pursuant to R 299.28.
[162] R 299.28

Dioxin Congener	CAS Number	TEF
1,2,3,4,6,7,8,9-OCDD	3268879	0.0003 (0.001)*

Furan Congener	CAS Number	TEF
2,3,7,8-TCDF	51207319	0.1
1,2,3,7,8-PeCDF	57117416	0.03 (0.05)*
2,3,4,7,8-PeCDF	57117314	0.3 (0.05)*
1,2,3,4,7,8-HxCDF	70648269	0.1
1,2,3,6,7,8-HxCDF	57117449	0.1
1,2,3,7,8,9-HxCDF	72918219	0.1
2,3,4,6,7,8-HxCDF	60851345	0.1
1,2,3,4,6,7,8-HpCDF	67562394	0.01
1,2,3,4,7,8,9-HpCDF	55673897	0.01
1,2,3,4,5,7,7,9-OCDF	39001020	0.0003 (0.001)*

* For comparison of groundwater samples to GSI criteria, use the TEF in parentheses and do not include dioxin-like PCB congeners (R 323.1209).

PCB Congener	CAS Number	TEF
3,3,4,4'-TCB (77)	32598133	0.0001
3,4,4',5-TCB (81)	70362604	0.0003
3,3',4,4',5-PeCB (126)	57465288	0.1
3,3',4,4',5,5',-HxCB (169)	32774166	0.03
2,3,3',4,4'-PeCB (105)	32598144	0.00003
2,3,4,4',5-PeCB (114)	74472370	0.00003
2,3,4,4',5-PeCB (118)	31508006	0.00003
2',3,4,4'5-PeCB (123),	65510443	0.00003
2,3,3',4,4',5-HxCB (156)	38380084	0.00003
2,3,3',4,4',5-HxCB (157)	69782907	0.00003
2,3,4,4',5,5'-HxCB (167)	52663726	0.00003
2,3,3',4,4',5,5',-HxCB (189)	39635319	0.00003

14.1.3 Polychlorinated Biphenyls (PCBs) and Toxic Substances Control Act (TSCA)

In evaluating PCB levels, consideration of federal laws is required by statute[163]. In determining the adequacy of a land-use based response activity to address sites contaminated by PCBs, the MDEQ does not require response activity in addition to that which is subject to and complies with applicable federal regulations and policies that implement the TSCA. Rule 34[164] provides further information regarding this requirement.

[163] MCL 324.20120a(12)
[164] R 299.34(4): When PCBs are present, refer to the federal TSCA, 40 C.F.R. 761 to determine the applicability of the TSCA cleanup standards.

The Criteria Tables show a Footnote (T)[165] following the PCB name. This footnote includes a reference to the federal TSCA, 40 C.F.R. §761, Subpart D and Subpart G, to determine the applicability of TSCA cleanup standards. If TSCA standards are not applicable, the following soil direct contact criteria may be used:

Land Use Category	TSCA, Subpart D Cleanup Standards	Part 201 Soil Direct Contact Cleanup Criteria
Residential	1,000 ppb, or 10,000 ppb if capped	1,900 ppb
Nonresidential	1,000 ppb, or 10,000 ppb if capped	20,000 ppb

14.1.4 Trihalomethanes[166]

The trihalomethanes (THMs) includes the following Part 201 hazardous substances:

- Bromodichloromethane (CAS No. 75274),
- Bromoform (CAS No. 75252),
- Chloroform (CAS No. 67663), and
- Dibromochloromethane (CAS No. 74953).

The Footnote (W) follows the hazardous substance name of these THMs in the Criteria Tables. Footnote (W) requires concentrations of trihalomethanes disinfection by-products in groundwater to be added together to determine compliance with the Michigan drinking water standard of 80 µg/L. Concentrations of trihalomethanes in soil are added together to determine compliance with the drinking water protection criterion of 1,600 µg/kg. The Footnote (W) shown in place of criteria values indicates the need to add all concentrations of THMs in groundwater or soil.

14.1.5 Ammonia, Nitrites and Nitrates[167]

The concentrations of all potential sources of nitrate-nitrogen (e.g., ammonia-N, nitrite-N, and nitrate-N) in groundwater that is used as a source of drinking water cannot, when added together, exceed the nitrate drinking water criterion of 10,000 µg/L. Where leaching to groundwater is a relevant pathway, soil concentrations of all potential sources of nitrate-nitrogen cannot, when added together, exceed the nitrate drinking water protection criterion of 2.0E+5 µg/kg. Nitrite has a separate drinking water criterion of 1,000 µg/L, nitrite concentrations cannot exceed the nitrite criterion. Footnote (N) follows the hazardous substance name and the criteria for these in the Groundwater Criteria Table.

14.1.6 Isomers[168]

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[165] R 299.49(1)(T): Alternatives to compliance with the TSCA standards listed below are possible under 40 C.F.R. §761 Subpart D. New releases may be subject to the standards identified in 40 C.F.R. §761, Subpart G. Use Part 201 soil direct contact cleanup criteria in the following table if TSCA standards are not applicable.
[166] R 299.49(1)(W)
[167] R 299.49(1)(N)
[168] R 299.4(11); R 299.49(1)(J)

Some hazardous substances (e.g., xylenes) may be present in several chemical isomer forms. The MDEQ may identify specific isomers of hazardous substances which must be added together and the sum compared to an identified chemical compound-specific or class-specific criterion for a given environmental medium. If analytical data detects a single isomer, additional analytical evaluation for the total of the isomers is necessary for comparison to the identified criterion.

The Footnote (J) is shown in the Criteria Tables after the name of those hazardous substances that may exist as isomers to indicate this requirement for isomer-specific concentrations to be added together for comparison to criteria.

14.2 Hazardous Waste Characteristics Defined Under Part 111 of NREPA[169]

Hazardous substances that exhibit the characteristics of ignitability, reactivity, corrosivity, or toxicity as defined under Part 111 are footnoted in the Criteria Tables as follow:

- Hazardous substances that may exhibit the characteristic of ignitability as defined under Part 111 of NREPA in R 299.9212(1) are designated with Footnote (I).
- Hazardous substances that may exhibit the characteristic of reactivity as defined under Part 111 of NREPA in R 299.9212(3) are designated with Footnote (R).
- Hazardous substances that may exhibit the characteristic of corrosivity as defined under Part 111 of NREPA in R 299.9212(2) are designated with Footnote (U). These substances may result in an aqueous mixture that has a pH less than or equal to 2 or greater than or equal to 12.5.
- Hazardous substances that may exhibit the characteristic of toxicity as defined as defined under Part 111 of NREPA in R 299.9212(4) are designated with Footnote (KK).

A list of these hazardous substances is shown in Footnote (KK) of the Criteria Tables.

14.3 Individual Hazardous Substances with Special Considerations

The following individual hazardous substances have either special considerations in the development of the criteria, or special considerations in the application of the criteria.

14.3.1 Ammonia[170]

The Footnote (CC) is shown in the Criteria Tables for the ammonia generic GSI criteria. The generic GSI groundwater criteria are based on the toxicity of unionized ammonia (NH_3); the criteria are 29 µg/L and 53 µg/L for cold water and warm water surface water, respectively. As a result, the GSI criterion is compared to the percent of the total ammonia concentration in the groundwater that will become NH_3 in the surface water. This percent NH_3 is a function of the pH and temperature of the receiving surface water and can be estimated using Footnote (CC)'s table. The generic approach for estimating NH_3 assumes a pH of 8 and temperatures of 68°F and 85°F for cold water and warm water receiving surface waters, respectively. The resulting percent NH_3 is 3.8 percent and 7.2 percent for cold water and warm water, respectively. This

[169] R 299.4(12)
[170] R 299.49(1)(CC)

percentage is multiplied by the total ammonia-nitrogen (NH_3-N) concentration in the groundwater and the resulting NH_3 concentration compared to the applicable GSI criterion. As an alternative, the maximum pH and temperature data from the specific receiving surface water can be used to estimate, using Footnote (CC)'s table, a percent unionized ammonia concentration for comparison to the generic GSI. The generic GSI soil protection criteria for unionized ammonia are 580 µg/kg and 1,100 µg/kg for cold water and warm water surface water, respectively.

14.3.2 Asbestos[171]

The state drinking water standard for asbestos (fibers greater than 10 micrometers in length) is in units of million fibers per liter of water (MFL). Soil concentrations of asbestos must be evaluated on a site-specific basis. USEPA asbestos technical resources provide applicable information for a site specific evaluation at USEPA's Web site: https://www.epa.gov/superfund/superfund-asbestos-technical-resources.

14.3.3 Boron[172]

The boron drinking water criteria (DWC) shown in the Criteria Tables are health-based values and do not protect for adverse impacts to plant life and phytotoxicity from irrigation water. When irrigation water is a reasonable and relevant use of groundwater the potential for phytotoxicity and injury to the groundwater resource that may impair its use for irrigation require consideration[173]. The MDEQ has determined 500 ppb is necessary to address the risks to plant life and groundwater resources not otherwise accounted for with the generic criterion. Data in the literature indicate that several important agricultural crops species in Michigan such as fruit trees, grapes, beans and onions, exhibit toxicity at irrigation water concentrations of boron between 0.5 to 1.0 ppm (MDEQ, 1998). Boron soil criteria protective of drinking water (GWPC) are based upon adverse impacts to plant life and phytotoxicity from soil conditions as boron concentrations in soil will increase over time. The residential and nonresidential drinking water criteria are followed by Footnote (F) to designate the need to consider the phytotoxicity-based value for drinking water. The soil protection of drinking water criteria is followed by Footnote (F) to indicate that it is based on phytotoxicity rather than the HBV.

14.3.4 Chromium III and VI[174]

Valence-specific chromium data, trivalent chromium (Cr III) and hexavalent chromium (Cr VI) are compared to the corresponding valence-specific criteria for soil and GSI. For the drinking water pathway, the total concentration of both Cr III and CR VI cannot exceed the drinking water criterion of 100 µg/L. If analytical data are provided for total chromium only, the data are compared to the criteria for Cr VI.

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[171] R 299.49(1)(AA)
[172] R 299.49(1)(F)
[173] MCL 324.20120a(16); R 299.28
[174] R 299.49(1)(H)

14.3.5 Cyanide [175]

The residential direct contact criterion for cyanide is protective of acute toxicity resulting in fatality; therefore, the concentrations of individual discrete samples are required for comparison to this criterion. The nonresidential direct contact criterion may not be protective of the potential for release of hydrogen cyanide gas with acidic conditions. Additional response activity or land or resource use restrictions may be necessary to be protective for the acute inhalation concerns associated with hydrogen cyanide gas. Additional information regarding cyanide sampling is available in the MDEQ Application of Target Detection Limits and Designated Analytical Methods, Appendix C. While the document's references to Footnote (P) do not reflect the revisions, the information that is provided remains applicable. Refer to Attachment O for the criteria derivation.

14.3.6 Ethylenediaminetetraacetic Acid (EDTA)[176]

This hazardous substance belongs to a class of chemicals known as chelating agents. The MDEQ's experience with the behavior of chelating agents in the environment comes from EDTA and the sodium and calcium salts of EDTA. The ability of EDTA and other chelating agents to mobilize more toxic hazardous substances, such as, inorganics in soil and groundwater, poses a greater concern than the toxicity of the individual chelating agents. As such, generic groundwater criteria are not presented for hazardous substances in this class. Rather, inorganic concentrations in groundwater must be evaluated at sites where chelating agents are known or suspected to have been released. Concentrations of inorganics in groundwater must satisfy applicable criteria.

14.3.7 Lead[177]

Criteria for lead are derived using biologically based models[178] and are not calculated using the equations and generic input values in pathway-specific rules. More details regarding the lead criteria are available in the Lead Background Document (Refer to Attachment O). Total lead and both fine and coarse lead fractions analysis may be required for comparison to lead soil criteria. Additional information regarding fine and coarse lead fraction analysis is available in the MDEQ Application of Target Detection Limits and Designated Analytical Methods, Appendix D.

14.3.8 Methane

Methane is designated with Footnote (K) as a hazardous substance that may be flammable or explosive, or both.

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[175] R 299.49(1)(P)
[176] R 299.49(1)(II)
[177] MCL 324.20120a(9); R 299.1(L)
[178] MCL 324.20120a(9): The MDEQ may establish cleanup criteria for a hazardous substance using a biologically based model developed or identified as appropriate by the USEPA if the MDEQ determines all of the following:
(a) That application of the model results in a criterion that more accurately reflects the risk posed.
(b) That data of sufficient quantity and quality are available for a specified hazardous substance to allow the scientifically valid application of the model.
(c) The United States environmental protection agency has determined that application of the model is appropriate for the hazardous substance in question.

Health-based criteria are not available for methane dissolved in groundwater due to insufficient toxicity data. The MDEQ derived an acceptable FESL[179] of 10,000 µg/L to evaluate potential explosive risks when the following conditions do not exist:

- Methane dissolved in groundwater is under pressure;
- Groundwater is entering a structure or confined space;
- Methane is present in a drinking water well; and/or
- There is an additional source of methane.

Concentrations that exceed 10,000 µg/L or the existence of any of the above conditions require further evaluation. Refer to FESL discussion at Section 7.0 for information regarding further evaluation.

Health-based criteria are not available for methane for volatilization to indoor air screening levels due to insufficient toxicity data [180]. An acceptable soil gas concentration to address methane's flammability and explosivity was derived utilizing 25 percent of the lower explosive limit for methane. This equates to 1.25 percent by volume or 8.4E+6 µg/m^3.

Additional information regarding the derivation of the screening levels is available in the Methane Background Document (Attachment Q).

14.3.9 Total Mercury and Mercury Species[181]

The criteria are based on data for different species of mercury; however, total mercury analytical results are compared to criteria.

14.3.10 3-Methylphenol and 4-Methylphenol[182]

3-Methylpenol and 4-methylphenol cannot be analyzed separately. Environmental concentrations are reported as 3- and 4-methylphenol. As a result, both isomers are listed together as a single hazardous substance, methylphenols, in the Criteria Tables. To protect for the adverse effects of both isomers, the criteria presented in the tables represents the lower of the criteria generated for each isomer. 2-Methylphenol is analyzed separately and compared to the criteria listed separately in the Criteria Tables.

14.3.11 Sodium[183]

The residential criterion for sodium is 230,000 µg/L pursuant to the MDEQ's Sodium Advisory Council recommendation and revised Groundwater Discharge Standards.

14.3.12 Trichloroethylene (TCE)[184]

The health-based values for trichloroethylene mutagenic effects are calculated using cancer adjustment factors (CAF) and mutagenic adjustment factors (MAF) to adjust the cancer potency

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[179] R 299.49(1)(AA)
[180] R 299.49(1)(GG)
[181] R 299.49(1)(Z)
[182] R 299.49(1)(JJ)
[183] R 299.49(1)(HH)
[184] R 299.49(1)(NN)

values for combined risk for mutagenic and non-mutagenic cancer effects. The modified cancer potency values are shown below:

Mutagenic health-based values:	**CAF**	**MAF**	**Adult-based cancer potency values**
Ingestion and dermal (Drinking Water Value; Direct Contact Value)	0.804	0.202	Cancer Slope Factor (CSF) = 4.6E-2 ((mg/kg-day)$^{-1}$)
Inhalation (Acceptable Air Value; Volatilization to Indoor Air Value; Particulate Soil Inhalation Value)	0.756	0.244	Inhalation Unit Risk Factor (IURF) = 4.1E-6 ((µg/kg-day)$^{-1}$)

TCE is carcinogenic at multiple sites in the body. For kidney tumors, TCE acts via a mutagenic mode of action (MOA). For liver and other TCE-induced tumors, the MOA is not clear. Increased early-life susceptibility is assumed for kidney cancer and therefore, the ADAFs should be applied to the kidney cancer component of the total cancer risk. For liver and non-Hodgkin lymphoma (NHL), the cancer risk is calculated without ADAF. The MDEQ adopted the USEPA (2016) generated adjustment factors for cancer and cancer-mutagenic effects to facilitate calculating exposure risk. The CAF and MAF are based on the ratio of the NHL and liver-based CSF/IURF or kidney-based CSF/IURF to the adult-based CSF as follows:

- IRIS adult-based CSF = 4.6E-2 (mg/kg-day)$^{-1}$; CSF = 3.7E-2 for liver and NHL (non-mutagenic cancer); and CSF = 9.3E-3 for kidney (mutagenic).
- IRIS adult-based IURF = 4.1E-6 (µg/m^3)$^{-1}$; IURF = 3.1E-6 for liver and NHL nonmutagenic tumors; and IURF = 1.0E-6 for kidney (mutagenic).

14.3.13 Vinyl Chloride[185]

The health-based values for vinyl chloride are calculated using two different cancer potency values to protect for continuous lifetime exposure from birth and for continuous lifetime exposure during adulthood. Chemical-specific two-fold adjustment to the cancer potency factors are used for calculating the health-based value for mutagenic effect to account for greater sensitivity to vinyl chloride exposure during early life.

Cancer Potency Values	**Residential**	**Nonresidential**
Cancer Slope Factor, (mg/kg-day)-1	1.4E+00	7.2E-01
Inhalation Unit Risk Factor, (µg/m^3)-1	8.8E-06	4.4E-06

[185] R 299.49(1)(LL)

15.0 CONCERNS NOT ADDRESSED BY GENERIC CLEANUP CRITERIA

There are concerns that have not been addressed with generic criteria, and as a result, they must be considered[186] when relevant to a specific facility. Several of these concerns are listed and discussed below.

15.1 Contaminated Soil Runoff to Surface Waters

Consideration must be given to the potential for contaminated soil to erode into surface water, and if the potential exists, what response activity may be appropriate[187]. This concern is relevant for all land uses. It is applicable to facilities where significant potential exists for contaminated soil to reach surface water via direct transport or runoff. The following should be considered in determining whether the transport of contaminated soil to surface waters is a relevant pathway:

- The proximity to surface waters.
- The extent of exposed and/or erodable soils.
- The extent of erodable contamination.
- The transport or erosion potential based on soil types, compaction, and slope.
- The presence in soil of metals or persistent bioaccumulative chemicals.

If this pathway is determined to be relevant, then the following should be considered in determining if the pathway is or will be adequately controlled:

- Whether vegetation is adequate and not expected to require maintenance (this would not require a restricted closure).
- Whether an impervious surface or another engineering measure is required to provide adequate control of potential runoff (this would require a restricted closure).

15.2 Surface Water Sediments

Contaminated surface water sediments can cause adverse impacts to aquatic flora or fauna, the food chain, or aesthetics. If this potential exists, the pathway is relevant. This pathway has the potential to be relevant for all land uses. Response or corrective actions to address sediments must include site-specific criteria based on the evaluation of bulk sediment chemistry, sediment toxicity, and benthic community populations. Development of the site-specific criteria must also include consideration of the following use impairments such that those impairments are eliminated or mitigated following implementation of the criteria[188].

- Restrictions on fish or wildlife consumption.
- Tainting of fish and wildlife flavor.
- Degraded fish or wildlife populations.
- Fish tumors or other deformities.
- Bird or animal deformities or reproductive problems.
- Degradation of benthos.

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[186] MCL 324.20120a(16)
[187] R 299.28(1)(f)
[188] R 299.30

- Restrictions on dredging activities.
- Eutrophication or undesirable algae.
- Restrictions on drinking water consumption, taste, or odor problems.
- Beach closings.
- Degradation of aesthetics.
- Added costs to agriculture or industry, or a local unit of government.
- Degradation of phytoplankton or zooplankton populations.
- Loss of fish and wildlife habitat.
- Unacceptable risk through human contact as a result of absorption of hazardous substances through the skin or by incidental ingestion.
- Other unacceptable risks to human receptors exposed to hazardous substances.

15.3 Acute Toxicity and Physical Hazards

Acute toxicity and physical hazards need to be considered on a case-by-case basis at every facility[189]. Flammability and/or explosivity potential has been addressed via development of FESLs for a limited number of hazardous substances where sufficient chemical-specific information is available (FESL discussed at 6.0). When FESLs cannot be developed, an evaluation for flammability and/or explosivity will need to be conducted. Since FESLs have not been developed for soil, it may be necessary to give special consideration to these hazards in soil.

Hazardous substances that exhibit the characteristics as defined under Part 111 of NREPA[190] of ignitability, reactivity, corrosivity, or toxicity are footnoted in the Criteria Tables. These substances are designated in the Criteria Tables with Footnotes (I), (U), or (R), respectively. Hazardous substances that are ignitable may present a combustion hazard under normal environmental conditions (i.e., standard temperature and pressure) and/or may be strong oxidizers capable of exacerbating a fire once ignited. Corrosive substances have either a very high or a very low pH, destroy living tissue upon direct contact, corrode or destroy building materials or other equipment, and mobilize other hazardous substances. Reactive substances may explode under normal environmental conditions when exposed to moisture or when subject to an initiating force. Reactive substances may also generate toxic fumes as is the case for cyanide or sulfide containing substances. Special attention and caution must be exercised when these hazardous substances are known or expected to be present in soil and/or groundwater.

If a hazardous substance has a potential for acute inhalation toxicity, further evaluation of acute inhalation toxicity will need to be conducted. Acute toxicity to aquatic organisms must also be considered. Specific response activities are required if there is a release to surface waters, either directly or through venting groundwater that is acutely toxic[191]. Contaminant-specific

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[189] MCL 324.20120a(16); R 299.4(3); R 299.28
[190] R 299.9212
[191] MCL 324. 20120e(13)]

values for acute toxicity to aquatic life are developed as part of the Surface Water Quality Standards[192].

Additional hazardous substances listed in the criteria tables may also pose acute or physical hazards that may need to be evaluated. All physical and acute hazards need to be evaluated on a case-by-case basis.

15.4 Ecological and Aesthetic Impacts

Additional impacts not accounted for in the generic criteria that need to be considered are aesthetics, food chain contamination, adverse impacts to soil organisms, and adverse impacts to aquatic and terrestrial wildlife[193].

Observable evidence of an aesthetic impact including, but not limited to, groundwater or soil discoloration, taste or odors, or stressed vegetation requires further evaluation. Only a few drinking water criteria account for known adverse aesthetic impacts[194]. Aesthetic impacts are further complicated by the fact that the presence of multiple contaminants may result in impacts that would not otherwise be accounted for. A taste or odor threshold concentration, or a concentration adversely affecting appearance may be determined in accordance with standard USEPA methods.

The generic criteria for soil do not fully address aesthetic impacts. Soils which are in compliance with the appropriate health-based chemical-specific criteria, yet still exhibit adverse aesthetic impacts, must be addressed on a case-by-case basis. In determining if additional action is required for soils with adverse aesthetic impacts, consideration will be given to the intended use of the property, the depth of the impacted soils, the source of the contamination, and the specific aesthetic impacts exhibited in the soil.

Certain hazardous substances such as dioxins, furans, and polychlorinated biphenyl (PCB) present their greatest ecological impacts in reduced reproductive success, embryo survival, and contaminant biomagnification through the food web. The presence of bioaccumulative contaminants is of particular concern. These contaminants include, but are not limited to, chlordane, 4-4'-DDD, 4,4'-DDE, 4,4'-DDT, dieldrin, hexachlorobenzene, hexachlorobutadiene, hexachlorocyclohexanes, alpha-hexachlorobenzene, beta-hexachlorocyclohexane, delta-hexachlorocyclohexane, lindane, mercury, mirex, octachlorostyrene, PCBs, pentachlorobenzene, photomirex, dioxins (2,3,7,8-tetrachlorodibenzo-p-dioxin being the most toxic congener), furans (2,3,7,8-tetrachlorodibenzo-p-furans being the most toxic congener), 1,2,3,4-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, and toxaphene. This food chain contamination is generally not visibly evident, but these ecological impacts are very significant

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[192] R 323.1057 Water Quality Values Refer to MDEQ Groundwater-Surface Water Interface Pathway Compliance Options Resource Materials for further information
[193] R 299.28; R 299.30
[194] R 299.9

and need to be evaluated to ensure that the proposed remedy is adequately protective of the environment when hazardous substance known to biomagnify or bioaccumulate are present.

The GSI criteria do consider certain impacts to some aquatic organisms and wildlife, in addition to human health effects. However, generic criteria for groundwater do not fully address ecological impacts. Generic ecologic-based soil or sediment criteria have not been established by the MDEQ. Nonetheless, it is important that all facilities consider the need for conducting an ecological risk assessment. Ecological risk assessments are useful to define the risks to aquatic and/or terrestrial wildlife that are posed by the contaminant concentrations present at the facility. Human health remediation targets may not be protective for aquatic and terrestrial wildlife because the wildlife may be exposed to greater concentrations of contaminants than humans or may be more sensitive to contaminants than humans. In addition the presence of threatened or endangered species needs to be evaluated.

In most cases, some form of ecological risk assessment needs to be conducted when aquatic and/or terrestrial habitat(s) will remain at a facility after completion of the remedial or corrective action construction activities. If habitat exists and there is observable evidence such as wildlife death or deformities immediate evaluation is needed to confirm that the injury is related to the conditions at the facility. Interim actions should be implemented to eliminate the threat to wildlife. If threatened and/or endangered species exist at a facility actions must be adjusted to ensure that there is not damage to the population. In most instances there will not be observable evidence and the initial form of this assessment effort will be what is generally referred to as a prescreening, or screening level, ecological risk assessment. A prescreening risk assessment must examine whether there will be an unacceptable risk to organisms expected to live in habitats located at or near the facility. If unacceptable, ecological risks cannot be ruled out at the facility, then some additional action will be necessary. This additional action could lead to the completion of a more detailed ecological risk assessment involving definition of habitats, identification of receptor species, review of available ecological risk data, food chain modeling, and potentially the collection and analysis of biological samples. This additional assessment effort could eventually lead to the development of ecologically-based criteria at the facility. Alternatively, presumptive actions can be implemented to prevent unacceptable ecological exposures at the facility (e.g., capping or otherwise isolating the contaminants from ecological exposure, or removal of the contaminant). It may be more cost effective to implement presumptive remedies than to conduct a detailed ecological risk assessment.

To assist in conducting or evaluating screening level ecological assessments, the ecological screening level guidance document, dated August 22, 2003, prepared for the USEPA Region 5 RCRA Corrective Action Program office (https://www3.epa.gov/region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf) is recommended. The document provides comparison concentration values for a variety of chemical compounds in air, water, sediment, and soil. Further useful documents for ecological screening may include U.S. EPA Interim Ecological Soil Screening Levels (https://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents) and Los Alamos National Laboratory Ecological Screening Levels found in the ECORISK database

(http://www.lanl.gov/environment/protection/eco-risk-assessment.php). If concentrations at a facility clearly and consistently exceed these comparison values for the environmental media of concern, then unacceptable ecological risk cannot be ruled out at the facility.

For those facilities regulated under Part 111, Hazardous Waste Management, of NREPA, additional response activities to address ecological risk may be required to assure consistency with the Federal RCRA Program. Please contact the Office of Waste Management and Radiological Protection, Hazardous Waste Section for additional information.

16.0 MDEQ UPDATES TO GENERIC CLEANUP CRITERIA TABLES

Rule provisions have allowed the update of information in the promulgated Criteria Tables under limited circumstances. These circumstances include:

16.1 Hazardous Substances Not Included in the Criteria Tables

The absence of a hazardous substance in the Criteria Tables means the MDEQ has not conducted an evaluation for that substance; it does not mean the MDEQ has determined it is not a hazardous substance or not a contaminant that poses an unacceptable risk. For a substance that is not listed in the Criteria Tables, the MDEQ may determine if it is a hazardous substance using best available information about the toxicological and physical-chemical properties of that substance and use that information to develop generic or site-specific criteria[195].

16.2 Hazardous Substances with "NA" in Place of a Criterion or Screening Level

For a hazardous substance that the Criteria Tables designated NA for a criterion or screening level, if the MDEQ obtains sufficient information to support calculation of a criterion, the MDEQ will use best available information to calculate a criterion for the hazardous substance[196]. The NA shown in the Criteria Tables indicates any of the following:

- Insufficient chemical-specific data (chemical-physical or toxicity data) to support calculation of HBVs;
- An HBV is not available because the pathway is not relevant to the hazardous substance; i.e., the substance does not belong to the category for which a value should be calculated (e.g., FESLs are not calculated for substance having a flash point greater than 60°C; the hazardous substance is not classified as a volatile).

16.3 Chemical-Specific, Toxicological, and Chemical-Physical Data Sources

Toxicological, chemical-specific, and chemical-physical data, if available, in tables of Rule 50 will be used in conjunction with the equations and generic input values that appear in these rules for the development of additional criteria[197].

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[195] R 299.6(13)
[196] R 299.6(14)
[197] R 299.6(12)

16.4 Newly Developed or Revisions to State Drinking Water Standards or Surface Water Quality Standards

The statute directs that the state drinking water standards[198] and surface water quality standards are used as generic criteria[199]. If a state drinking water standard or surface water quality standard is established or an existing standard is changed, the standard becomes the criterion and the criterion value is revised in the Criteria Tables[200].

16.5 Revisions to Target Detection Limits (TDL)

If a TDL used to establish a criteria is revised during an update[201] of the MDEQ Published List of TDLs and Analytical Methods such that the calculated health-based value is no longer less than the TDL for a hazardous substance in given environmental medium, then the comparison of the HBV to the appropriate provisions (e.g., solubility, soil maximum ceiling concentration) is conducted to establish a revised criterion[202]. The Criteria Tables will be revised to incorporate changes from this review.

16.6 Notice of Revisions

The MDEQ will make available the new toxicological, chemical-specific and chemical-physical data and criteria by announcing it on the MDEQ's Web site, publishing notice of the change in the MDEQ calendar, or other means that effectively notify interested persons. The new criteria take effect when published and announced[203].

17.0 SITE-SPECIFIC CRITERIA

The CSA report (CSA, 2014) indicates that encouraging site-specific cleanups and expanding opportunities for site-specific cleanups can address many of the concerns and issues related to Michigan's generic cleanup criteria. To encourage the use of information specific to the location of a site, the MDEQ has developed a process that allows the use of MDEQ-approved facility-specific inputs to the generic soil criteria equations. In addition to the CSA recommendations for use of the process for the Vapor Intrusion to Indoor Air Pathway, the MDEQ applies this approach to other soil pathways. Use of the facility-specific provisions may be self-implemented as it does not require further MDEQ review and approval. Where appropriate, the MDEQ has also identified site-specific inputs that may allow MDEQ approval of an unrestricted residential use; and has identified alternative methods or models where available to address conditions that do not allow for generic assumptions.

17.1 Site-Specific Health Based Values and Exposure Assumptions

Site-specific criteria with MDEQ approval may be used to replace generic criteria when evaluating hazardous substances at the site[204]. Where appropriate, the MDEQ has identified

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[198] MCL 324.20120a(5)
[199] MCL 324.20120e(1)(a)
[200] R 299.6(16) and (17)
[201] MCL 324.20101(1)(bbb): Target detection limits for a hazardous substance in a given environmental medium are specified by the MDEQ in a list that it publishes not more than once a year.
[202] R 299.6(18)
[203] R 299.6(19)
[204] MCL 324.20120a(2) and MCL 324.20120b

site-specific inputs (e.g., fraction of organic carbon, wind speed) that may allow MDEQ approval of an unrestricted residential use; and has identified alternative methods or models where available to address conditions that do not allow for generic assumptions (e.g., heterogeneous or multilayer soils).

17.2 Equations and Site-Specific Inputs

In accordance with statutory requirements for the MDEQ to approve numeric or nonnumeric site-specific criteria, it must be determined that such criteria, in comparison to generic criteria, better reflect best available information[205] concerning the toxicity or exposure risk posed by the hazardous substance or other factors[206]. Site-specific criteria may, as appropriate:

(a) Use the algorithms for calculating generic criteria established by rule or propose and use different algorithms.

(b) Alter any value, parameter, or assumption used to calculate generic criteria, with the exception of the risk targets specified in section 20120a(4).

(c) Take into consideration the depth below the ground surface of contamination, which may reduce the potential for exposure and serve as an exposure barrier.

(d) Be based on information related to the specific facility or information of general applicability, including peer-reviewed scientific literature.

(e) Use probabilistic methods of calculation.

(f) Use nonlinear-threshold-based calculations where scientifically justified.

(g) Take into account a land use or resource use restriction.

[205] Refer to Section 3.1.3
[206] MCL 324.20120b

REFERENCES:

American Petroleum Institute. 2002. Practical Guidance for Assessing the "Groundwater to Indoor Air" Vapor Migration Pathway at Petroleum Hydrocarbon Sites..

American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE). 1985. ASHRAE Handbook (1985) Fundamentals. Chapter 22. Atlanta, GA.

American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE). 2010. ASHRAE, ANSI/ASHRAE Standard 62.1-2010. Ventilation for acceptable indoor air quality. Atlanta, GA.

Cowherd, C., G.E. Muleski, P.J. Englehard, and D.A. Gillette. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. EPA/600/8-85/002. U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Washington, DC. February, 1985.

CSA (Criteria Stakeholder Advisory Workgroup), 2014. Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria. Lansing, Michigan: Public Sector Consultants for the Michigan Department of Environmental Quality. (accessed August 2015).

Fellin, P.; Otson, R. 1996. The Effectiveness of Selected Materials in Moderation of Indoor VOC Levels. In Volatile Organic Compounds in the Environment; Wang, W., Schnoor, J., Doi, J., Eds.; ASTM STP 1261; American Society for Testing and Materials: West Conshohocken, PA 1996; pp 135-146.

Fetter, C. W. 1994. Applied Hydrogeology, 3rd Ed., Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Gusdorf, J.; Hamlin, T. Indoor Air Quality and Ventilation Rates in R-2000 Houses; Call-Up No. 23440-95-1037; Buildings Group, Residential Programs, Energy Technology Branch, CANMET, Department of Natural Resources Canada: Ottawa, Ontario, Canada, 1995.

Hers, I. June 3, 2002 Technical Memorandum to Debbie Newberry, USEPA OSW. Input Parameters for OSWER Wide Guidance for Vapor Intrusion Pathway.

Hers, Ian; Zapf-Gilje, Reidar; and Atwater, Loretta Li & Jim. 2001. The Use of Indoor Air Measurements To Evaluate Intrusion of Subsurface VOC Vapors into Buildings, Journal of the Air & Waste Management Association, 51:9, 1318-1331, DOI:10.1080/10473289.2001.104643

Howe, G.B., Mullins, M.E., and Rogers, T.N., 1987. Evaluation and Prediction of Henry's Law Constants and Aqueous Solubilities for Solvents and Hydrocarbon Fuel Components,Volume1: Technical Discussion-Final Report. Research Triangle Institute

ITRC (Interstate Technology & Regulatory Council). 2014. Petroleum Vapor Intrusion: Fundamentals of Screening, Investigation, and Management. PVI-1. Washington, D.C.: Interstate Technology & Regulatory Council, Petroleum Vapor Intrusion Team.

Koontz, M.D. and H.E. Rector. 1995. Estimation of Distributions for Residential Air Exchange Rates. EPA Contract No. 68-D9-0166, Work Assignment No. 3-19. USEPA Office of Pollution Prevention and Toxics. Washington, D.C.

Lavinia. 2013. Surprising Trends in House Plans and Building Sizes in America Identifying infographic developed by the team at Alan Mascord Design Associates Inc.

Lohman, S. W. 1972. Ground-Water Hydraulics. Geological Survey Professional Paper 708, U.S. Department of the Interior, Washington, DC.

Martí, V.; De Pablo, J.; Jubany, I.; Rovira, M.; and Orejudo,E. 2014. Water-Air Volatilization Factors to Determine Volatile Organic Compound (VOC) Reference Levels in Water Toxics 2014, 2, 276-290; doi:10.3390/toxics2020276, ISSN 2305-6304,

MDEQ. 1998. Irrigation Water Limit Justification for Boron CAS# 7440-42-8. February 11, 1998.

MDEQ. 2002. DEQ Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria. (S^3TM) August 2002.

MDEQ. 2007. Technical Support Document – Attachment 7. Part 201 Generic Soil Inhalation Criteria for Ambient Air/Part 213 Tier I Soil Inhalation Risk-based Screening Levels for Ambient Air. July 2007. (accessed on 3/2016)

MDEQ. 2015A. Generic Exposure Assumptions Values Update Technical Support Document on Body Weight. October, 2015. (unpublished).

MDEQ. 2015B. Generic Exposure Assumptions Values Update Technical Support Document on Drinking Water Intake Rate. September, 2015. (unpublished).

MDEQ. 2015C. Generic Exposure Assumptions Values Update Technical Support Document on Exposure Duration and Averaging Time. September, 2015. (unpublished).

MDEQ. 2015D. Generic Exposure Assumptions Values Update Technical Support Document on Skin Surface Area. October, 2015. (unpublished).

MDEQ. 2015E. Generic Exposure Assumptions Values Update Technical Support Document on Soil and Dust Ingestion. September, 2015. (unpublished).

MDEQ. 2015F. Generic Exposure Assumptions Values Update Technical Support Document on Soil Dermal Adherence Factor. October, 2015. (unpublished).

MDEQ. 2015G. Generic Exposure Assumptions Values Update Technical Support Document on Soil Direct Contact Exposure Frequency. September, 2015. (unpublished).

MDEQ. 2015H. Generic Exposure Assumptions Values Update Technical Support Document on Parameters Related to Particulate Emissions Factor. October, 2015. (unpublished).

MDEQ. 2015I. Generic Exposure Assumptions Values Update Technical Support Document on Parameters Related to Soil-to-Air Volatilization Factor. October, 2015. (unpublished).

MDEQ. 2015J. MDEQ Response to Recommendations Criteria Stakeholders Advisory Group Final Report. MDEQ, Lansing, Michigan.

MDEQ. 2016. Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria. Toxics Steering Group, Children's Environmental Health Subcommittee, Lansing, Michigan. (unpublished).

Murray, D.M. and D.E. Burmaster. 1995. Residential Air Exchange Rates in the United States: Empirical and Estimated Parametric Distributions by Season and Climactic Region. Risk Analysis. 15. 459-465.

Nazaroff, W.W. Radon Transport from Soil to Air; Rev. Geophys. 1992, 30 (2), 137-160.

Nielson, K. K., and V. C. Rogers. 1990. Radon transport properties of soil classes for estimating indoor radon entry. In: F. T. Cross (ed), Proceedings of the 29th Hanford Symposium of Health and the Environment. Indoor Radon and Lung Cancer: Reality or Myth? Part 1. Battelle Press, Richland, Washington.

NRC (National Research Council), 2009. Science and decisions: advancing risk assessment. Washington, DC: National Academies Press. Available from http://www.nap.edu/catalog/12209/science-and-decisions-advancing-risk-assessment (accessed November 2015)

Sherman, MH. (1989). Analysis of errors associated with passive ventilation measurement techniques. Build Environ 24: 131-139. http://dx.doi.org/10.1016/03601323(89)90002-4.

Turk, BH; Brown, JT; Geisling-Sobotka, K; Froehlich, DA; Grimsrud, DT; Harrison, J; Koonce, JF; Prill, RJ; Revzan, KL. (1987). Indoor air quality and ventilation measurements in 38 Pacific Northwest commercial buildings: Volume I: Measurement results and interpretation: Final report. (LBL22315 1/2). Berkeley, CA: Lawrence Berkeley National Laboratory. http://www.ntis.gov/search/product.aspx?A BBR=DE88014064.

USEPA (U.S. Environmental Protection Agency). 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. (accessed August 2015).

USEPA. 1991a. Guidelines for Developmental Toxicity Risk Assessment. Fed Reg 56(234):63798-63826. (accessed August 2015).

USEPA. 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 Response. EPA/540/R-92/003. (accessed August 2015).

USEPA. 1992. Guidance to Protect POTW Workers from Toxic and Reactive Gases and Vapors. Office of Water. EPA812-B-92-001. June 1992.

USEPA. 1996a. Guidelines for reproductive toxicity risk assessment. Risk Assessment Forum, Washington, DC; EPA/630/R-96/009. Available online at: http://cfpub.epa.gov/ncea/raf/pdfs/repro51.pdf (accessed August 2015).

USEPA. 1996b. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-23. (accessed August 2015).

USEPA. 1996c. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-17A. Available online at: http://www.epa.gov/superfund/health/conmedia/soil/introtbd.htm (accessed August 2015).

USEPA. 2001. Risk assessment guidance for superfund (RAGS): Volume I - Human health evaluation manual (Part D, standardized planning, reporting and review of superfund risk assessments). Office of Emergency and Remedial Response, Washington, DC; 9285.7-01D. (accessed August 2015).

USEPA. 2002c. Supplemental guidance for developing soil screening levels for superfund sites. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-24. (accessed August 2015).

USEPA. 2002. EMSOFT User's Guide and Modeling Software (2002 Update). U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office, Washington, DC, NCEA/W-0073, NCEA/W-0073, 2002.

USEPA. 2004. User's Guide for Evaluating Vapor Intrusion into Buildings. Prepared by Environmental Quality Management, Inc. Contract No. 68-W-02-33. Revised February 22, 2004.

USEPA. 2005a. Guidelines for carcinogen risk assessment. Risk Assessment Forum. EPA/630/P-03/001F, March, 2005.

USEPA. 2005b. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. EPA/630/R-03/003F.

USEPA. 2006a. Emission Factors 2006 Update. AP-42 section 13.2.2 Unpaved Roads (November, 2006).

USEPA. 2006b. A Framework for Assessing Health Risk of Environmental Exposures to Children. National Center for Environmental Assessment, Office of Research and Development, Washington, DC; EPA/600/R-05/093F

USEPA. 2011. Exposure factors handbook – 2011 edition. Office of Research and Development, Washington, D.C. EPA/600/R-090/052F. (accessed August 2015).

USEPA. 2014a. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors" (2014). OSWER Directive 9200.1-120.

USEPA. 2014b. Framework for Human Health Risk Assessment to Inform Decision Making. Risk Assessment Forum, Office of the Science Advisor, Washington, D.C. EPA/100/R-14/001. (accessed August 2015).

USEPA. 2015. Vapor Intrusion Screening Level (VISL) Calculator, User's Guide.

USEPA. 2016. Regional Screening Table. (accessed March, 2016)

Zhou, H., Hu, D., Wang, X., Han, F., Li, Y., Wu, X., and Ma, S. 2016. Horizontal Heat Impact of Urban Structures on the Surface Soil Layer and Its Diurnal Patterns under Different Micrometeorological Conditions. Sci. Rep. 6, 18790; doi: 10.1038/srep18790

TABLES:

1. Appropriate Selection of Soil Type
2. Generic Input Values for USDA Soil Texture Classifications
3. List of Mutagenic Chemicals
4. List of Development or Reproductive Toxicants
5. Residential Exposure Factors
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TABLE 1 – Appropriate Selection of Soil Type

Soil texture classification and corresponding predominant soil types are identified in Table 1.

Table 1. Soil Type Determination

Boring log indicates that the following materials are the predominant soil types:	**Appropriate texture classification:**
Sand or Gravel or Sand and Gravel, with less than approximately 12% fines, where “fines” are smaller than 0.075 mm in size.	Sand
Sand or Silty Sand, with approximately 12 % to 25 % fines	Loamy Sand
Silty Sand, with approximately 20 % to 50 % fines	Sandy Loam
Silt and Sand or Silty Sand or Clayey, Silty Sand or Sandy Silt or Clayey, Sandy Silt, with approximately 45 to 75 % fines; Sandy Silt, Silt, Clay and soils with greater than 50% fines	Loam
Soil types not otherwise listed or Non-native materials pursuant to subrule (3)(iv) of this rule	Sand
Bedrock	Requires a site-specific evaluation

R 299.7(7) - Table 1

TABLE 2 - Soil Texture (Soil Type) and the Generic Input Values for Soil Parameters for Each Soil Type.

Table 2. Generic Input Values for USDA Soil Textural Classifications

Soil Texture (USDA)	Soil Texture Abbreviation (USDA)	Soil Total Porosity[A,B] n (cm^3/cm^3)	Saturated Water Content[A,C] θ_s (cm^3/cm^3)	Residual Water Content[A,B] θ_r (cm^3/cm^3)	Soil Water-Filled Porosity[A] θ_w (cm^3/cm^3)	Soil Air-Filled Porosity[A,D] θ_a (cm^3/cm^3)	van Genuchten parameters[A,B]			Mean Particle Diameter[A,E] (cm)	Dry Bulk Density[A,E] ρ_b (g/cm^3)	Saturated Hydraulic Conductivity[A] K_s (cm/h)
							α_1 (1/cm)	N	M			
Clay	C	0.459	0.459	0.098	0.215	0.244	0.01496	1.253	0.2019	0.0092	1.43	0.61
Clay loam	CL	0.442	0.442	0.079	0.168	0.274	0.01581	1.416	0.2938	0.016	1.48	0.34
Loam	L	0.399	0.399	0.061	0.148	0.251	0.01112	1.472	0.3207	0.02	1.59	0.5
Loamy sand	LS	0.39	0.39	0.049	0.076	0.314	0.03475	1.746	0.4273	0.04	1.62	4.38
Silt	SI	0.489	0.489	0.05	0.167	0.322	0.00658	1.679	0.4044	0.0046	1.35	1.82
Silty loam	SIL	0.439	0.439	0.065	0.18	0.259	0.00506	1.663	0.3987	0.011	1.49	0.76
Silty clay	SIC	0.481	0.481	0.111	0.216	0.265	0.01622	1.321	0.243	0.0039	1.38	0.4
Silty clay loam	SICL	0.482	0.482	0.09	0.198	0.284	0.00839	1.521	0.3425	0.0056	1.63	0.46
Sand	S	0.375	0.375	0.053	0.054	0.321	0.03524	3.177	0.6852	0.044	1.66	26.78
Sandy clay	SC	0.385	0.385	0.117	0.197	0.188	0.03342	1.208	0.1722	0.025	1.63	0.47
Sandy clay loam	SCL	0.384	0.384	0.063	0.146	0.238	0.02109	1.33	0.2481	0.029	1.63	0.55
Sandy loam	SL	0.387	0.387	0.039	0.103	0.284	0.02667	1.449	0.3099	0.03	1.62	1.6

A - From USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. United States Environmental Protection Agency, Office of Emergency and Remedial Response. February 22, 2004.

B - Hers, I. June 3, 2002 Technical Memorandum to Debbie Newberry, USEPA OSW. Input Parameters for OSWER Wide Guidance for Vapor Intrusion Pathway.

C - Saturated water content is assumed to be equal to the water soil total porosity. The saturated water between drainage and wetting conditions varies but is always less than the fully saturated water content which is equal to the soil total porosity.

D - The air-filled porosity is calculated as the total porosity minus soil water-filled porosity.

E - Nielson, K. K., and V. C. Rogers. 1990. Radon transport properties of soil classes for estimating indoor radon entry. In: F. T. Cross (ed), Proceedings of the 29th Hanford Symposium of Health and the Environment. Indoor Radon and Lung Cancer: Reality or Myth? Part 1. Battelle Press, Richland, Washington.

R 299.7(7) – Table 2

TABLE 3 List of Mutagenic Chemicals (Footnote MM)

The Footnote (MM) identifies the hazardous substances that are carcinogens with a mutagenic mode of action. The cancer potency values used in calculating health-based values are modified using age-dependent adjustment factors for those carcinogenic chemicals identified as mutagenic. The hazardous substances designated with Footnote (MM) in the Criteria Tables are listed below:

Table 3. Carcinogens with Mutagenic Mode of Action

CHEMICAL/COMPOUND	CAS #
Acylamide	79061
Benzidine	92875
Benzo(a)pyrene (BaP) and carcinogenic polychlorinated aromatic hydrocarbons (cPAH)*.	50328
*cPAH: Benzo(a)anthracene Benzo(b)fluoranthene Benzo(k)fluoranthene Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene	 56553 205992 207089 218019 53703 193395
Chromium (VI)	18540299
Dibenz[a,h]anthracene	53703
Dichlorvos	62737
Methylene chloride (Dichloromethane)	75092
4,4'-Methylene-bis-2-chloroaniline	101144
Dibromochloromethane (DBCM)	124481
Dibromochloropropane	96128
Formaldehyde	50000
Trichloroethylene	79016
1,2,3-Trichloropropane	96184
Vinyl chloride	75014

*cPAH toxicity are evaluated relative to BaP (R 299.49(1)(Q)).

R 299.49(1)(MM); R 299.38(2)(c)

TABLE 4 List of Developmental-Reproductive Toxicants (Footnote DD)

Prenatal developmental effects may occur after a single exposure (SE) or full-term (FT) exposure. Oral exposure pathways are drinking water and soil direct contact. Inhalation exposure pathways are ambient air and volatilization to indoor air. Individual discrete sample concentrations are compared to criteria, without temporal or spatial averaging, for those hazardous substances categorized as "SE" in the following table and having final criteria for relevant pathways that are based on developmental effects (dev). If the final criterion for an "SE" categorized hazardous substance is not based on developmental effects, discrete samples are not required where the use of statistics is appropriate.

Table 4. Developmental Toxicants and Categories
[Full-term (FT) or Single event (SE) exposure]

Hazardous Substance	CAS Number	Oral Exposure Pathways	Inhalation Exposure Pathways
Acetophenone	98862	SE	SE
Acrylic acid	79107	FT	
Aluminum	7429905	SE	
Benzo(a)pyrene	50328	SE	SE
bis(2-Ethylhexyl)phthalate	117817	SE	
Boron	7440428	SE	
Bromodichloromethane	75274	SE	
2-Butanone (MEK)	78933	FT	SE
Butyl benzyl phthalate	85687	SE	
Caprolactam	105602	FT	
Carbaryl	63252	SE	
Carbofuran	1563662	SE	
Carbon Disulfide	75150	SE	
Chloroethane	75003		FT
4-Chloro-3-methylphenol	59507	SE	
2-Chlorophenol	95578	SE	SE
Chlorpyrifos	2921882	SE	
Cyanide	57125	FT	
Cyclohexane	110827		FT
4-4'-DDT	50293	SE	
Decabromodiphenyl ether	1163195	SE	SE
Di-n-butyl phthalate	84742	SE	SE
Di(2-ethylhexyl) adipate	103231	SE	
Dicamba	1918009	FT	
2,4-Dichlorophenol	120832	SE	

Table 4. Developmental Toxicants and Categories
[Full-term (FT) or Single event (SE) exposure]

Hazardous Substance	CAS Number	Oral Exposure Pathways	Inhalation Exposure Pathways
Diisopropyl ether	108203	SE	SE
Dinoseb	88857	FT	FT
Ethanol	64175	SE	
Ethylene glycol	107211	SE	
Fluorine (soluble fluoride)	7782414	FT	
Formaldehyde	50000		FT
1-Formylpiperidine	2591868	SE	
Glyphosate	1071836	SE	
Heptachlor	76448	SE	
Isophorone	78591		SE
Isopropyl alcohol	67630	FT	
Lead	7439921	FT	FT
Lithium	7439932	SE	FT
Mercury , organic (CH3Hg)	22967926	SE	
Methanol	67561	SE	SE
Methoxychlor	72435	SE	
2-Methoxyethanol	109864	SE	
4-Methyl-2-pentanone (MIBK)	108101		SE
2-Methylphenol	95487	SE	
Nitrate	14797558	FT	
Nitrite	14797650	FT	
Pendimethalin	40487421	SE	
Perchlorate	14797730	FT	
Perfluorooctane sulfonic acid	1763231	SE	
Phenol	108952	FT	
Phenytoin	57410	SE	
Phosphorus, White	7723140	SE	
Polybrominated biphenyls	67774327	FT	
Polychlorinated biphenyls (PCBs)	1336363	FT	
Propyl alcohol	71238	SE	SE
n-Propylbenzene	103651		SE
Strontium	7440246	FT	
Tebuthiuron	34014181	FT	
1,2,4,5-Tetrachlorobenzene	95943	SE	

Table 4. Developmental Toxicants and Categories
[Full-term (FT) or Single event (SE) exposure]

Hazardous Substance	CAS Number	Oral Exposure Pathways	Inhalation Exposure Pathways
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	FT	FT
Tetrahydrofuran	109999	FT	
Triallate	2303175		SE
Trichloroethylene	79016	SE	SE
2,4,6-Trichlorophenol	88062	SE	
Triethylene glycol	112276	FT	
3-Trifluoromethyl-4-nitrophenol	88302	FT	
Vinyl acetate	108054	SE	

R 299.49(1)(DD); R 299.34(2)

TABLE 5 and 6 - List of Generic Exposure Assumptions

Table 5 and 6 shows the residential and nonresidential exposure factors and the values used for each receptor including the basis used for the value.

Table 5: Residential Exposure Factors

Exposure Factors			Residential Values									Basis for Values[d]			Data Sources[e]
			Child (ages <1-6)[a]	Adult (ages 7-32)	Children (ages <2)[b]	Children (ages <2-6)[b]	Children (ages <6-16)[b]	Adult (ages 16-32)[b]	Child and adult	Pregnant Resident - full term (FT)[c]	Pregnant Resident - single exposure (SE)[c]	Child and other children ages	Adult	Pregnant Resident[c]	
Drinking Water Values[f] for carcinogens, mutagens, DR toxicants (R 299.10(6))															
Drinking water Ingestion Rate	L-water/day	**IR_{dw}**	0.78	2.5	0.82	0.76	1.3	2.3	NA	1.8	1.8	age-weighted upper bound	age-weighted upper bound	upper-bound	USEPA (2011); MDEQ (2015B)
Exposure Frequency	days/year	**EF**	350	NA	NA	NA	NA	NA	350	280	1 day/day	upper-bound	upper-bound	FT - mid-range SE- upper bound	MDEQ (2015G)
Exposure Duration	years	**ED**	6	26	2	4	10	16	32	0.767	1 day	upper-bound	upper-bound	FT – lower bound SE- upper bound	MDEQ (2015C)
Relative Source Contribution	unitless	**RSC**	0.2	NA	NA	NA	NA	NA	0.2	0.2	0.2	upper-bound	upper-bound	upper-bound	MCL 324.20120a (4)
Body Weight	kg	**BW**	15	80	9.6	17	44	77	NA	75	75	age-weighted mid-range	age-weighted mid-range	mid-range	USEPA (2011); MDEQ (2015A)
Averaging Time, cancer	days	**AT_{ca}**	28,470	NA	NA	NA	NA	NA	28,470	NA	NA	mid-range	mid-range	mid-range	MDEQ (2015C)

Table 5: Residential Exposure Factors

Exposure Factors			Residential Values									Basis for Values[d]			Data Sources[e]
			Child (ages <1-6)[a]	Adult (ages 7-32)	Children (ages <2)[b]	Children (ages <2-6)[b]	Children (ages <6-16)[b]	Adult (ages 16-32)[b]	Child and adult	Pregnant Resident - full term (FT)[c]	Pregnant Resident - single exposure (SE)[c]	Child and other children ages	Adult	Pregnant Resident[c]	
Averaging Time, noncancer	days	**AT_{nc}**	2,190	NA	NA	NA	NA	NA	11,680	280	1	mid-range	mid-range	FT - mid-range SE- upper bound	MDEQ (2015C)
Age-dependent adjustment factors for cancer potency	days	**ADAF**	NA	NA	10	3	3	1	NA	NA	NA	NA	NA	NA	USEPA (2005); CSA (2015)
Soil Ingestion and Dermal Contact (R 299.20(4)															
Soil Ingestion Rate	mg-soil/day	**IR_s**	179	89	179	179	89	90	NA	89	89	upper-bound	upper-bound	upper-bound	USEPA (2011); MDEQ (2015E)
Exposure Frequency, Ingestion	days/year	**EF_i**	350	NA	NA	NA	NA	NA	350	280	1 day/day	upper-bound	upper-bound	FT – mid-range SE- upper bound	MDEQ (2015G)
Exposure Duration	years	**ED**	6	26	2	4	10	16	32	0.767	1 day	upper-bound	upper-bound	FT – lower bound SE- upper bound	MDEQ (2015C)
Relative Source Contribution	unitless	**RSC**	1	NA	NA	NA	NA	NA	1	1	1	lower-bound	lower-bound	lower-bound	MCL 324.20120a (4)
Body Weight	kg	**BW**	15	80	9.6	17	44	77	NA	75	75	Age-weighted mid-range	Age-weighted mid-range	mid-range	MDEQ (2015A)

Table 5: Residential Exposure Factors

Exposure Factors			Residential Values									Basis for Values[d]			Data Sources[e]
			Child (ages <1-6)[a]	Adult (ages 7-32)	Children (ages <2)[b]	Children (ages <2-6)[b]	Children (ages <6-16)[b]	Adult (ages 16-32)[b]	Child and adult	Pregnant Resident - full term (FT)[c]	Pregnant Resident - single exposure (SE)[c]	Child and other children ages	Adult	Pregnant Resident[c]	
Exposure Frequency, Dermal Contact	days/year	**EF_d**	275	NA	NA	NA	NA	NA	350	280	1 day/day	upper-bound	upper-bound	FT – mid-range SE- upper bound	MDEQ (2015G)
Adherence Factor	mg-soil/cm^2	**AF**	0.3	0.07	0.3	0.3	0.07	0.07	NA	0.07	0.07	Skin surface area-weighted[f]	Skin surface area-weighted[f]	Skin surface area-weighted[f]	MDEQ (2015F)
Skin Surface Area	cm^2/day	**SA**	2,400	6,000	2,000	2,600	3,700	5,700	NA	5,500	5,500	Age-weighted mid-range	Age-weighted mid-range	mid-range	MDEQ (2015D)
Averaging Time, cancer	days	**AT_c**	28,470	NA	NA	NA	NA	NA	28,470	NA	NA	mid-range	mid-range	NA	MDEQ (2015C)
Averaging Time, noncancer	days	**AT_{nc}**	2,190	NA	NA	NA	NA	NA	11,680	280	1	mid-range	mid-range	FT - mid-range SE- upper bound	MDEQ (2015C)
Age-dependent adjustment factors for cancer potency	days	**ADAF**	NA	NA	10	3	3	1	NA	NA	NA	NA	NA	NA	USEPA (2005); CSA (2015); MDEQ (2015)
Ambient Air Inhalation of Soil Volatiles and Particulates (R 299.26)															
Exposure Frequency	days/year	**EF**	350	NA	NA	NA	NA	NA	350	268.5	1 day/day	upper-bound	upper-bound	upper-bound	MDEQ (2015G)
Exposure Duration	years	**ED**	6	26	2	4	10	16	32	0.767	1 day	upper-bound	upper-bound	upper-bound	MDEQ (2015C)

Table 5: Residential Exposure Factors

Exposure Factors			Residential Values									Basis for Values[d]			Data Sources[e]
			Child (ages <1-6)[a]	Adult (ages 7-32)	Children (ages <2)[b]	Children (ages <2-6)[b]	Children (ages <6-16)[b]	Adult (ages 16-32)[b]	Child and adult	Pregnant Resident - full term (FT)[c]	Pregnant Resident - single exposure (SE)[c]	Child and other children ages	Adult	Pregnant Resident[c]	
Relative Source Contribution	unitless	**RSC**	1	NA	NA	NA	NA	NA	1	1	1	lower-bound	lower-bound	lower-bound	MCL 324.20120a (4)
Averaging Time, cancer	days	**AT_c**	28,470	NA	NA	NA	NA	NA	28,470	NA	NA	mid-range	mid-range	NA	MDEQ (2015C)
Averaging Time, noncancer	days	**AT_{nc}**	2,190	NA	NA	NA	NA	NA	11,680	280	1	mid-range	mid-range	FT - mid-range SE- upper bound	MDEQ (2015C)
Age-dependent adjustment factors for cancer potency	days	**ADAF**	NA	NA	10	3	3	1	NA	NA	NA	NA	NA	NA	USEPA (2005); CSA (2015); MDEQ (2015)

[a] Child ages <1-6 years old is the basis for calculating residential health-based values for developmental-reproductive toxicants

[b] These age groups are used for adjusting the cancer potency values (CSF and IURF) for carcinogens with mutagenic mode of action

[c] The criteria for developmental chemicals are calculated for a pregnant resident receptor using the chemical-specific assumptions based on full-term (FT) or single event (SE) exposure during pregnancy.

[d] The values presented may be based on mid-range statistics (mean, median) or upper bound (90th or 95th perecentile) values.

[e] The data sources used in developing the values for the exposure assumptions are described in MDEQ 2015 TSDs (Attachment H) or MDEQ Background Documents (Attachment I-M)

[f] The AF is based on the mid-range value for skin surface and age-weighted AF of receptors in a high-end soil activity

Table 6. Nonresidential Exposure Factors

Exposure Factors			Nonresidential Values			Basis for Values			Data Sources
			Adult	Pregnant Worker - full term[a]	Pregnant Worker - single exposure[a]	Adult	Pregnant Worker - full term	Pregnant Worker - single exposure	
Drinking Water Values for carcinogens, mutagens, DR toxicants (R 299.10(6))									
Drinking water Ingestion Rate	L-water/day	**IR_{dw}**	1.3	0.9	0.9	age-weighted upper bound	upper-bound	upper-bound	USEPA (2011); MDEQ (2015B)
Exposure Frequency	days/year	**EF**	238	183	1 day/day	upper-bound	mid-range	upper-bound	MDEQ, (2015G)
Exposure Duration	years	**ED**	20	0.767	1 day	upper-bound	lower-bound	upper-bound	MDEQ, (2015C)
Relative Source Contribution	unitless	**RSC**	NA	0.2	0.2	lower-bound	lower-bound	lower-bound	MCL 324.20120a(4)
Body Weight	kg	**BW**	80	75	75	Age-weighted mid-range	mid-range	mid-range	USEPA (2011); MDEQ (2015)
Averaging Time, cancer	days	**AT_{ca}**	28,470	NA	NA	mid-range	NA	NA	MDEQ, (2015A)
Averaging Time, noncancer	days	**AT_{nc}**	7,300	280	1	mid-range	mid-range	upper bound	MDEQ, (2015C)
Soil Ingestion and Dermal Contact (R 299.20(4))									
Soil Ingestion Rate	mg-soil/day	**IR_s**	89	89	89	age-weighted upper bound	upper-bound	upper-bound	USEPA (2011); MDEQ (2015E)
Exposure Frequency, Ingestion	days/year	**EF_i**	238	268.5	1 day/day	upper-bound	mid-range	upper-bound	MDEQ, (2015G)
Exposure Duration	years	**ED**	20	0.767	1 day	upper-bound	lower-bound	upper-bound	MDEQ, (2015C)
Relative Source Contribution	unitless	**RSC**	NA	1	1	lower-bound	lower-bound	lower-bound	MCL 324.20120a(4)
Body Weight	kg	**BW**	80	75	75	mid-range	mid-range	mid-range	USEPA (2011); MDEQ (2015A)
Exposure Frequency, Dermal Contact	days/year	**EF_d**	188	268.5	1 day/day	upper-bound	lower-bound	upper-bound	MDEQ, (2015G)
Adherence Factor	mg-soil/cm2	**AD**	0.20	0.20	0.20	Skin surface area-weighted[d]	Skin surface area-weighted[d]	Skin surface area-weighted[d]	USEPA (2011); MDEQ (2015F)

Table 6. Nonresidential Exposure Factors

Exposure Factors			Nonresidential Values			Basis for Values			Data Sources
			Adult	Pregnant Worker - full term[a]	Pregnant Worker - single exposure[a]	Adult	Pregnant Worker - full term	Pregnant Worker - single exposure	
Skin Surface Area	cm^2/day	**SA**	3,500	3,100	3,100	age-weighted average; mid-range	mid-range	mid-range	MDEQ, (2015D)
Averaging Time, cancer	days	**AT_{ca}**	28,470	NA	NA	mid-range	NA	NA	MDEQ, (2015C)
Averaging Time, noncancer	days	**AT_{nc}**	7,300	280	1	mid-range	mid-range	upper bound	MDEQ, (2015C)
Ambient Air Inhalation of Soil Volatiles and Particulates (R 299.26)									
Exposure Frequency	days/year	**EF**	238	268.5	1 day/day	upper-bound	mid-range	upper bound	MDEQ, (2015G)
Exposure Duration	years	**ED**	20	0.767	1 day	upper-bound	mid-range	upper bound	MDEQ, (2015C)
Relative Source Contribution	unitless	**RSC**	NA	1	1	lower-bound	lower-bound	lower-bound	MCL 324.20120a(4)
Averaging Time, cancer	days	**AT_{ca}**	28,470	NA	NA	mid-range	NA	NA	MDEQ, (2015C)
Averaging Time, noncancer	days	**AT_{nc}**	7,300	280	1	mid-range	mid-range	upper bound	MDEQ, (2015C)

[a] The criteria for developmental chemicals are calculated for a pregnant worker using the chemical-specific assumptions based on full-term (FT) or single event (SE) exposure during pregnancy.
[b] The values presented may be based on mid-range statistics (mean, median) or upper bound (90th or 95th perecentile) values.
[c] The data sources used in developing the values for the exposure assumptions are described in MDEQ 2015 TSDs (Attachment H) or MDEQ Background Documents (Attachment I-M)
[d] The AF is based on the mid-range value for skin surface and age-weighted AF of receptors in a high-end soil activity

TABLE 7 - List of Fate and Transport Generic Factors

Table 7 presents the inputs/parameters and the values used for calculating the fate and transport factors and other parameters (SWPV, VF, PEF, and Csat).

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Inputs for determining Soil-Water Partitioning Value (SWPV)							
Soil-water partitioning value	µg/kg (ppb)	**SWPV**	Calculated	Calculated	Calculated	Calculated	R 299.22
Target soil leachate concentration; applicable Part 201 groundwater value x 16)	µg/L (ppb)	**Cw**	Calculated	Calculated	Calculated	Calculated	DWC and GSI values in Criteria Tables (R 299.46)
Soil-water partition coefficient: 1) Kd for inorganics or 2) Kd for organics = Koc × foc	cm^3/g or L/kg	**Kd**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Kd for organics – calculated Kd for inorganics – Refer to Table 3 (R 299.50(5) and (6))
Soil organic carbon partition coefficient	cm^3/g	**Koc**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Fraction of organic carbon content of soil	g/g	**foc**	0.002 g/g	0.002 g/g	0.002 g/g	0.002 g/g	Refer to Attachment M
Total soil porosity (Lpore/Lsoil)	unitless	**η**	0.375	0.375	0.375	0.375	R 299.7
Soil water-filled porosity (Lwater/Lsoil)	unitless	**$\theta\omega$**	0.054	0.054	0.054	0.054	R 299.7
Soil air-filled porosity (Lair/ Lsoil)	unitless	**$\theta\alpha$**	0.321	0.321	0.321	0.321	R 299.7
Dimensionless Henry's law constant	unitless	**H'**	Calculated	Calculated	Calculated	Calculated	R 299.18
Temperature adjustment factor	unitless	**TAF**	0.5	0.5	0.5	0.5	MDEQ (2015l)

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Dry soil bulk density	g/cm^3	ρ_b	1.66	1.66	1.66	1.66	R 299.7
Henry's law constant at 25°C	atm-m^3/mol	**HLC**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Ideal gas constant	atm-L/mol-K	**R**	8.206E-2	8.206E-2	8.206E-2	8.206E-2	CRC (2014-2015)
Temperature at 25ºC	K	**T**	298.15	298.15	298.15	298.15	R 299.7
Inputs for determining the Theoretical saturated soil concentration (Csat) (R 299.20)							
Soil saturation concentration	µg/kg (ppb)	**Csat**	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	R 299.18
Solubility in water	µg/L (ppb)	**S**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Dry soil bulk density	1.66 g/cm^3	**ρb**	1.66	1.66	1.66	1.66	R 299.7
Soil-water partition coefficient	cm^3/g	**Kd**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
For organic compounds	Koc (cm^3/g) x foc (g/g)	**Kd**					Varies; Refer to Table 3 (R 299.50(5) and (6))
Soil organic carbon partition coefficient	cm^3/g	**Koc**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Organic carbon content of soil	0.002 g/g	**foc**	0.002 g/g	0.002 g/g	0.002 g/g	0.002 g/g	R 299.7
Soil water-filled porosity (Lwater/Lsoil)	unitless	**θω**	0.054	0.054	0.054	0.054	R 299.7
Soil air-filled porosity (Lair/ Lsoil)	unitless	**θα**	0.321	0.321	0.321	0.321	R 299.7

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Dimensionless Henry's law constant	unitless	**H'**	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	R 299.18
Temperature adjustment factor	unitless	**TAF**	0.50	0.50	0.50	0.50	MDEQ (2015I); Refer to Attachment I
Inputs for determining Volatilization Factor for infinite source (R 299.26)							
Volatilization factor for infinite source	m^3/kg	**VFinf**	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	R 299.26(10) Equations 9(a) to (c)
Dispersion factor for 1/2 acre	g/m2-second per kg/m3	**Q/C**	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	Refer to Attachment K
Normalized average flux for infinite source in soil	g/m^2-second	$J_{s,inf}^{ave}$	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	R 299.26 Equations 9(b) to (c)
Dry soil bulk density	1.66 g/cm^3	**ρb**	1.66	1.66	1.66	1.66	R 299.7
Apparent diffusivity	cm^2/second	**DA**	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	NA
Pi	unitless	**π**	3.14159	3.14159	3.14159	3.14159	NA
Exposure time:	seconds	**t**	1.01E+09 (32 years x 3.1536E+7 seconds/year)	1.01E+09 (32 years x 3.1536E+7 seconds/year)	6.31E+08 (20 years x 3.1536E+7 seconds/year)	6.31E+08 (20 years x 3.1536E+7 seconds/year)	MDEQ (2015C)
Total soil porosity (Lpore/Lsoil)	unitless	**η**	0.375	0.375	0.375	0.375	R 299.7

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Soil water-filled porosity (Lwater/Lsoil)	unitless	$\theta\omega$	0.054	0.054	0.054	0.054	R 299.7
Soil air-filled porosity (Lair/ Lsoil)	unitless	$\theta\alpha$	0.321	0.321	0.321	0.321	R 299.7
Diffusivity in air	cm^2/second	**Da**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Diffusivity in water	cm^2/second	**Dw**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Dimensionless Henry's law constant	unitless	**H'**	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	NA
Temperature adjustment factor	unitless	**TAF**	0.50	0.50	0.50	0.50	MDEQ (2015l)
Soil-water partition coefficient: 1) Kd for inorganics or 2) Kd for organics = Koc × foc	chemical-specific, cm^3/g	**Kd**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Soil organic carbon partition coefficient	cm^3/g	**Koc**	chemical-specific	chemical-specific	chemical-specific	chemical-specific	Varies; Refer to Table 3 (R 299.50(5) and (6))
Organic carbon content of soil	0.002 g/g	**foc**	0.002 g/g	0.002 g/g	0.002 g/g	0.002 g/g	Refer to Attachment M
Inputs for determining Volatilization Factor for finite source (2 or 5 meter depth) (R 299.26)							
Volatilization factor for infinite source	m^3/kg	VF_{fin}	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	Calculated; chemical- and source size-specific	R 299.26 Equation 9
Dispersion factor for 1/2 acre; Refer to Table of Dispersion Factor Values for Q/C of other source area sizes	42.45 g/m2-second per kg/m3	**Q/C**	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	R 299.49 Footnote (Y); Refer to Attachment K

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	**Developmental (Child or Pregnant Resident)**	**Worker**	**Pregnant Worker**	
Normalized average flux for 2- or 5-meter finite source derived using EMSOFT model	g/m^2-second	$J^{ave}_{s,fin}$	Calculated; chemical- specific	Calculated; chemical- specific	Calculated; chemical-specific	Calculated; chemical-specific	R 299.26 Equation 10; Refer to Section 12.1
Paramaters for Determining Particulate Emission Factor (PEF) (R 299.26)							
Dispersion factor for 1/2 acre; See Table of Dispersion Factor Values for Q/C of other source area sizes	g/m^2-second per kg/m^3	**Q/C**	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	42.45 (for ½ acre source size)	MDEQ (2015); Refer to Attachment K
Emissions due to Wind Erosions (Ew)							
Annual Emissions due to Wind Erosions (Ew)	g/m^2 per sec	**Ew**	Calculated: 8.466E-07	Calculated: 8.466E-07	Calculated: 8.466E-07	Calculated: 8.466E-07	R 299.26 Equations 21(a) to (d)
Vegetative cover	unitless	**V**	0.5 (50%)	0.5 (50%)	0.5 (50%)	0.5 (50%)	MDEQ (2015H); Refer to Attachment H
Michigan annual wind speed adjusted to 7.0 meters	m/sec	**Umz**	6.56	6.56	6.56	6.56	Refer to Attachment K
Equivalent threshold friction value of wind speed at 7.0 m	m/sec	**Utadj**	11.319	11.319	11.319	11.319	Refer to Attachment H
Function of x based on Cowherd, 1985	unitless	**F(*x*)**	0.87	0.87	0.87	0.87	Cowherd (1985)
Michigan annual wind speed at measurement height	m/sec	**Um**	6.92	6.92	6.92	6.92	Refer to Attachment K
Michigan wind speed measurement height	m	**h**	10	10	10	10	Refer to Attachment K
Height above test surface	m	**z**	7	7	7	7	Cowherd (1985); EPA (2002)
Threshold friction value of wind speed based on a soil aggregate size	m/sec	**Ut**	0.5	0.5	0.5	0.5	Refer to Attachment H
Soil aggregate size	mm		0.5	0.5	0.5	0.5	Refer to Attachment H

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Correction factor for non-erodible elements	unitless	Cf	1.25	1.25	1.25	1.25	Refer to Attachment H
Height above test surface	m	**z**	7	7	7	7	Cowherd (1985); USEPA (2002)
Roughness height	m	**z0**	0.005	0.005	0.005	0.005	MDEQ (2015H); Refer to Attachment H
Cowherd derived *x; x*=0.886 (Utadj/ Umz)	unitless	***x***	Calculated: 1.529	Calculated; 1.529	Calculated; 1.529	Calculated; 1.529	Cowherd (1985); USEPA (2002)
Emissions due to Vehicle Traffic on Unpaved Roads (Ev)							
Annual average vehicle emissions on unpaved road	g/m^2-s	**Ev**	Calculated: 1.871E-08	Calculated: 1.871E-08	Calculated: 4.192E-08	Calculated; 4.192E-08	R 299.26 Equations 22(a)
Annual PM10 vehicle emissions on unpaved road	g/year	**E**	Calculated: 1,112	Calculated: 1,112	Calculated: 1,694	Calculated: 1,694	R 299.26 Equations 22(b)
Area of a ½ acre site excluding house/building area	m^2	**A**	1,965	1,965	1,965	1,965	MDEQ (2015)
Area of house or building	m^2		58.06	58.06	58.06	58.06	MDEQ (2015H)
PM10 emission per vehicle-kilometer traveled (VeKT)	VeKT	**E10**	7.94	7.94	3.163	3.163	R 299.26 Equations 23 (a) and (b)
Length of unpaved driveway or road or kilometer traveled (KT)	Km	**L**	0.02	0.02	0.045	0.045	MDEQ (2015)
One-way trips or vehicles/day	vehicles/day	**Ve**	20	20	50	50	MDEQ (2015H)
Frequency of travel	days/year	**F**	350	350	238	238	MDEQ (2015G)
Emissions due to Vehicle Traffic on Unpaved Roads (Ev)							

Table 7. Fate and Transport Factors/Inputs

Input Parameters			Residential Values		Nonresidential Values		Data Basis and Sources
			Resident (Child and Adult)	Developmental (Child or Pregnant Resident)	Worker	Pregnant Worker	
Particle size multiplier for unpaved road, PM10 in pounds/vehicle-miles traveled (VeMT)	lb/VeMT	**k**	1.8	1.8	NA	NA	USEPA (2006)
Surface material silt content	%	**s**	11%	11%	8.30%	8.30%	MDEQ (2015H)
Mean vehicle speed	miles/hour	**S**	25	25	NA	NA	MDEQ (2015H)
Constant for PM10	unitless	**a**	1	1	NA	NA	USEPA (2006)
Constant for PM10	unitless	**c**	0.2	0.2	NA	NA	USEPA (2006)
Constant for PM10	unitless	**d**	0.5	0.5	NA	NA	USEPA (2006)
Mean number of days with at least 0.01 inch of precipitation	days	**p**	135	135	135	135	MDEQ (2015H)
Surface material moisture content	unitless	**M**	0.20%	0.20%	NA	NA	MDEQ (2015)
Emission factor for 1980's vehicle fleet exhaust, brake wear and tire tear	lb/VeMT	**C**	4.7E-4	4.7E-4	NA	NA	USEPA (2006)
Conversion factor [g/vehicle-km traveled per lb/vehicle-miles traveled]	(g/VeKT)/(lb/VeMT)	**CF**	281.9	281.9	281.9	281.9	USEPA (2006)
Particle size multiplier for PM10	1.5 lb/VeMT	**k**	NA	NA	1.5	1.5	USEPA (2006)
Mean vehicle weight	3.3 tons	**W**	NA	NA	3.3	3.3	MDEQ (2015H)
Constant for PM10	0.9, unitless	**a**	NA	NA	0.9	0.9	USEPA (2006)
Constant for PM10	0.45, unitless	**b**	NA	NA	0.45	0.45	USEPA (2006)

TABLE 8 - Statewide Default Soil Background Levels

Table 8 shows the Michigan soil background levels for some metals. The method used to develop the statewide default soil background concentrations is described in Attachment J.

TABLE 8. 2015 Statewide Default Soil Background Levels

METAL	Number of Samples	Number of Sites	% Non-detect	Distribution of 2015 Site Mean Data	Mean[a] (mg/kg)	Standard Deviation[b]	Default Value (mg/kg)
Aluminum (Al)	508	171	0%	Lognormal	2619	2.170	5,700
Arsenic (As)	1795	490	6.3%	Lognormal	2.1	2.599	5.5
Barium (Ba)	1241	401	2.0%	Lognormal	17.1	2.63	45
Beryllium (Be)	390	155	71.3%	Non-parametric	--	--	1.0
Cadmium (Cd)	1347	413	69.9%	Non-parametric	--	--	2.0
Chromium (Cr)	861	247	12.5%	Lognormal	5.5	2.793	15
Cobalt (Co)	1161	426	18.4%	Lognormal	5.2	2.006	10
Copper (Cu)	1393	437	7.4%	Lognormal	5.4	2.543	14
Iron (Fe)	568	197	0%	Lognormal	4775	2.356	11,250
Lead (Pb)	1619	482	18.0%	Lognormal	4.7	2.399	11
Lithium (Li)	312	124	28.5%	Lognormal	4.6	2.359	11
Manganese (Mn)	574	209	0%	Lognormal	113	3.184	360
Nickel (Ni)	850	255	18.8%	Lognormal	6.9	2.095	15
Selenium (Se)	1209	420	77.3%	Non-parametric	--	--	0.61
Strontium (Sr)	81	51	0%	Normal	78.3	50.3	129
Vanadium (V)	406	167	1.7%	Lognormal	11.2	2.403	27
Zinc (Zn)	1392	433	2.2%	Lognormal	16.1	2.424	39

[a]For normal distributions this represents the arithmetic mean. For lognormal distributions, this represents the geometric mean. The mean was not estimated for data with non-parametric distributions (greater than 50% non-detect).
[b]For lognormal distributions, this represents the geometric standard deviation. The standard deviation is not estimated for nonparametric data.

MCL 324.20101((1)(e); R 299.6(8)(b); R 299,46 – Table 2 and Table 3

TABLE 9 List of Volatiles with Footnote (OO)

When available information indicate that a hazardous substance is or may become volatile, the MDEQ may categorize the chemical as a volatile and calculate VIAC or VSIC for that hazardous substance. Table 9 lists hazardous substances that are considered volatile based on vapor pressure; i.e. substances with vapor pressure > 1 mmHg is or may become volatile, consistent with USEPA's definition of volatile.

Table 9. Volatiles Designated with Footnote (OO)

Chemical Name	CAS Number	HLC at 25°C (atm-m^3/mol)	Vapor Pressure (mmHg)
Acetic acid	64197	1.00E-07	1.57E+01
Acrylic acid	79107	3.70E-07	3.97E+00
n-Butanol	71363	8.81E-06	6.70E+00
t-Butyl alcohol	75650	9.05E-06	4.07E+01
Cyclohexanone	108941	9.00E-06	4.33E+00
Diacetone alcohol	123422	2.61E-07	1.71E+00
N,N-Dimethylacetamide	127195	1.31E-08	2.00E+00
Dimethylformamide	68122	7.39E-08	3.87E+00
1,4-Dioxane	123911	4.80E-06	3.81E+01
Ethanol	64175	5.00E-06	5.93E+01
Formaldehyde	50000	3.37E-07	3.89E+03
Formic acid	64186	1.67E-07	4.26E+01
Isobutyl alcohol	78831	9.78E-06	1.05E+01
Isopropyl alcohol	67630	8.10E-06	4.54E+01
Methanol	67561	4.55E-06	1.27E+02
2-Methoxyethanol	109864	3.30E-07	9.50E+00
N-Methyl-morpholine	109024	2.50E-07	1.32E+01
Oxo-hexyl acetate	88230357	NA	1.32E+00
Piperidine	110894	4.45E-06	3.21E+01
Propionic acid	79094	4.45E-07	3.53E+00
Propyl alcohol	71238	7.41E-06	2.10E+01
1,1,3,3-Tetramethylurea	632224	8.48E-09	1.39E+01

R 299.49(1)(OO); R 299.26(2); R 299.27(2)

Table 10 VI Generic Input Values for Volatilization to Indoor Air Equations

Table 10 shows the variables or inputs that must be used when developing calculated HBVs for VI Tier 1 screening levels, VI Tier 2 generic criteria and VI Tier 3A generic criteria.

Table 10 Generic Input Values to VI Tier 1, 2, and 3A HBVs

Variable		VI Tier 1 Screening Levels	VI Tier 2 Generic criteria	VI Tier 3A Generic criteria
--	**Exposure scenario category**	**Unrestricted Residential**	**Unrestricted Residential**	**Limited Residential & Limited Nonresidential**
--	Soil type input values (Tables 1 and 2 of R 299.7)	Sand	No info available: Sand Observation: Sand, sandy loam, loamy sand, or loam Via approved method: 12 classifications identified by the NRCS	VI Tier 2 values
T_S	Source temperature (Table 3 of R 299.7)	10°C or 283.15K	For sand: 10°C or 283.15K For all other soil types: County-specific value	VI Tier 2 values
--	Depth to groundwater (in contact definition in subrule (3) of this rule)	3 m or 300 cm and in contact with the structure	3 m or 300 cm and in contact unless actual depth to groundwater > depth of building considering capillary fringe, depth of footings, and subsurface utilities	Actual depth unless in contact
--	Soil source type	Infinite	VI Tier 1 value	VI Tier 1 value
L_T	Distance to a vapor source (in contact defined in subrule (3) of this rule)	Soil and Vapor: 1 cm or 0.01 m Groundwater: Assumed to be in contact with structure	Soil and Vapor: 1 cm or 0.01 m Groundwater: In contact unless actual depth to groundwater > depth of building considering capillary fringe, depth of footings, and subsurface utilities	Soil: 1 cm or 0.01 m Vapor : 1 cm or 0.01 m when the vapor source is ≤ to 1 m vertically from the structure 100 cm or 1 m when the vapor source is > 1 m vertically from the structure Groundwater: Actual depth unless in contact
--	Basis of Capillary Fringe or Zone	Calculated based on sand	Calculated based on soil type	VI Tier 2 values
f_{oc}	Soil organic carbon weight fraction	0.002	VI Tier 1 value	VI Tier 1 value
--	Building Type	Groundwater and vapor: Residential house with occupied basement SOIL: Residential house with a slab-on-grade foundation	VI Tier 1 value	Residential: House, Apartment Nonresidential: Office, Manufacturing

Table 10 Generic Input Values to VI Tier 1, 2, and 3A HBVs

Variable		VI Tier 1 Screening Levels	VI Tier 2 Generic criteria	VI Tier 3A Generic criteria
--	**Exposure scenario category**	**Unrestricted Residential**	**Unrestricted Residential**	**Limited Residential & Limited Nonresidential**
ER	Air Exchange Rate	0.25 hr^{1}	VI Tier 1 value	Residential: House: 0.25 hr^{-1} Apartment: 0.61 hr^{-1} Nonresidential: Office: 1.0 hr^{-1} Manufacturing: 1.5 hr^{-1} Other approved values
--	Foundation Type	Groundwater and vapor: Basement Soil: slab-on-grade	VI Tier 1 value	Basement Slab-on-grade
L_{FF}	Depth of footings and utilities below enclosed space	100 cm; 1 m	VI Tier 1 value	VI Tier 1 value
L_F, Z_{crack}	Depth below grade and crack depth below grade	Groundwater and vapor: 200 cm or 2 m Soil: 15cm or 0.15m	VI Tier 1 Value	Residential or Nonresidential: Basement: 200 cm or 2 m Slab-on-grade: 15 cm or 0.15 m
L_{crack}	Enclosed space floor thickness	15 cm or 0.15m	VI Tier 1 value	Residential or Nonresidential: 15 cm or; 0.15 m
L_B	Enclosed space floor length	1,000 cm or 10 m	VI Tier 1 value	Residential: 1,000 cm or 10 m Nonresidential: 1,500 cm or 15 m
W_B	Enclosed space floor width	1,000 cm or 10 m	VI Tier 1 value	Residential: 1,000 cm or 10 m Nonresidential: 1,500 cm or; 15 m
H_B	Enclosed space height (mixing height)	244 cm or 2.44 m	VI Tier 1 value	Residential: Basement (occupied): 244 cm or 2.44 m Basement (unoccupied): 366 cm or 3.66 m Slab-on-grade: 244 cm or 2.44 m Nonresidential: Basement: 366 cm Slab-on-grade: 366 cm
w	Floor-wall seam crack width	0.1 cm or 0.001 m	VI Tier 1 value	VI Tier 1 value
ΔP	Soil-bldg. differential pressure, Residential or Nonresidential	40 g/cm-s^2	VI Tier 1 value	VI Tier 1 value
$VF_{G\ Win}$	Volatilization factor	Groundwater in contact: Calculated	VI Tier 1 value	VI Tier 1 value

Table 10 Generic Input Values to VI Tier 1, 2, and 3A HBVs

Variable		VI Tier 1 Screening Levels	VI Tier 2 Generic criteria	VI Tier 3A Generic criteria
--	**Exposure scenario category**	**Unrestricted Residential**	**Unrestricted Residential**	**Limited Residential & Limited Nonresidential**
α	Attenuation coefficient	Soil: Calculated Vapor:0.03	Soil: Calculated Vapor: 0.03 Groundwater in contact: 0.03 Groundwater not in contact: Calculated	Soil: Calculated Vapor: Source <1 m: 0.03 Source and sampling location is >1 m: Calculated Groundwater: Calculated

R 299.27(13) – Table 1

FIGURES:

1. Physical-Chemical Value Decision Framework
2. Toxicity Value Decision Framework
3. Framework for Determination of Exposure Value
4. Decision Process for Developing Generic Drinking Water Criteria
5. Decision Process for Developing Generic Soil Criteria
6. VI Tier Process
7. Decision Process for Developing Generic Volatilization to Indoor Air Criteria
8 USDA Soil Texture Classifications

FIGURE 1 - Physical-chemical Value Decision Framework and Data Quality Objectives

The MDEQ used the following framework and data quality objectives (DQOs) for identifying data sources and determining the values for physical and chemical characteristics of hazardous substances. Refer to Table 4 (R 299.50) or the Chemical Update Worksheets (Attachment E) for chemical-specific physical-chemical values and their respective basis. DQOs are presented in the CSA report (CSA, 2015).

Figure 1. Physical-Chemical Value Decision Framework

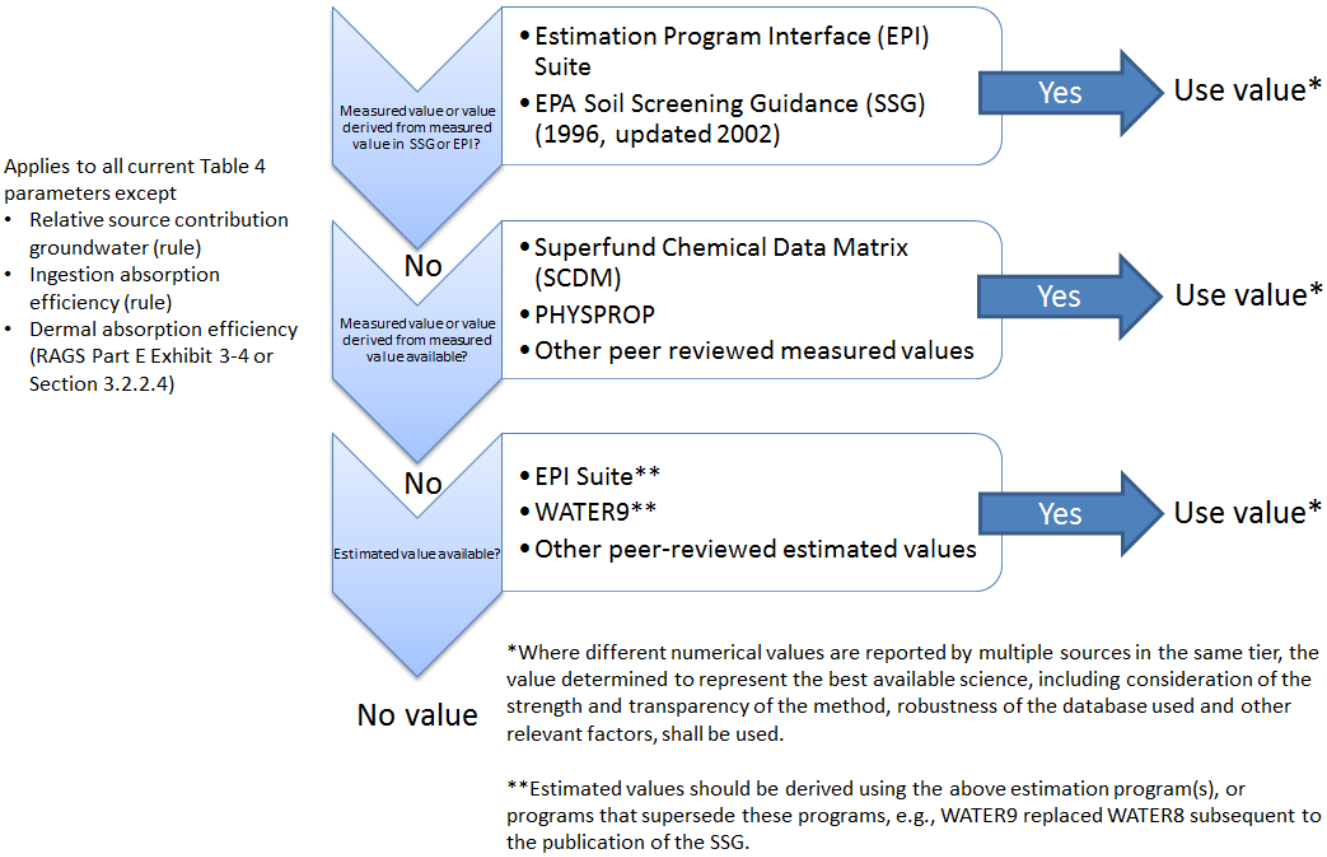


FIGURE 2 Toxicity Value Decision Framework and DQOs

The MDEQ used the following framework and DQOs for identifying data sources and determining oral and inhalation toxicity values for cancer, noncancer, developmental, and other effects. Refer to Table 4 (R 299.50) or the Chemical Update Worksheets (Attachment E) for toxicity values and their respective basis.

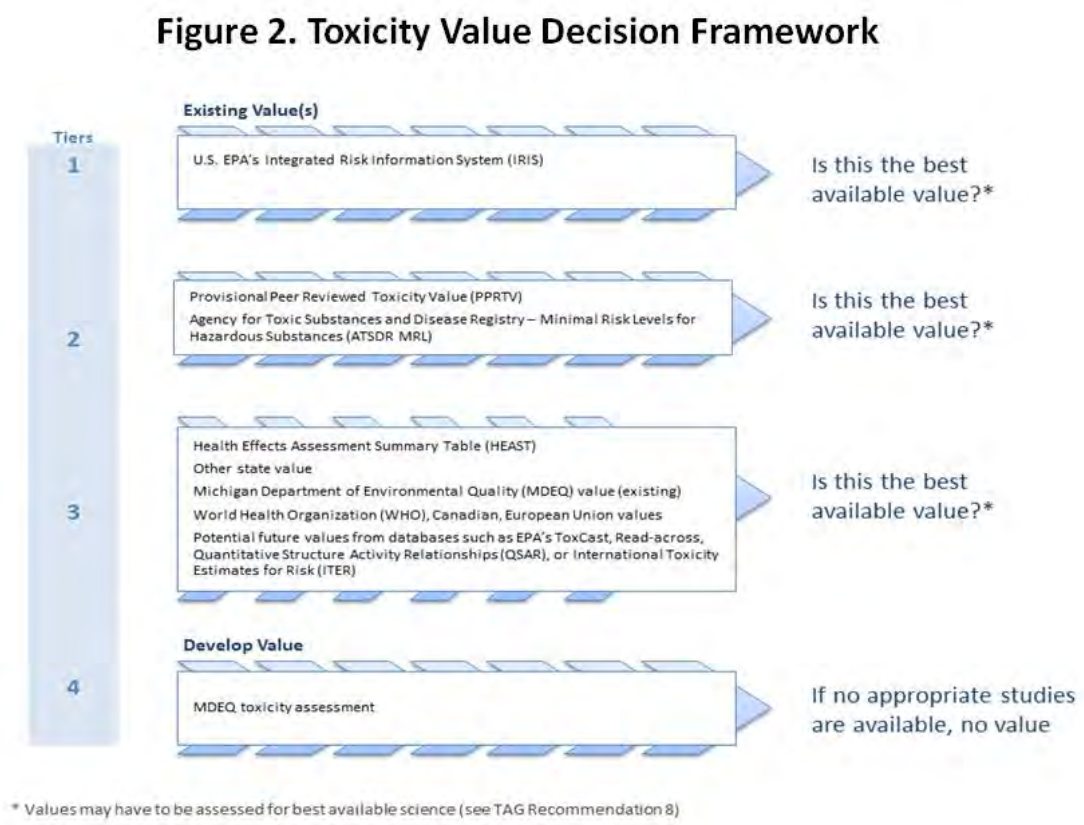


FIGURE 3 Decision Framework for Determination of Exposure Factors and Fate and Transport Inputs, and Data Quality Objectives

The MDEQ used the following framework and date quality objectives (DQOs)for identifying data sources and determining values for exposure factors, and fate and transports inputs. The MDEQ contracted with SRC, Inc. to research and recommend values using this Framework. When Michigan-specific data are available, the MDEQ developed values using this Framework. Michigan data-based values include dispersion factor, wind speed and soil type characteristics (e.g., soil bulk density, porosities). Refer to MDEQ Exposure TSDs – Attachment H for details.

Figure 3. Framework for Determination of Exposure Values

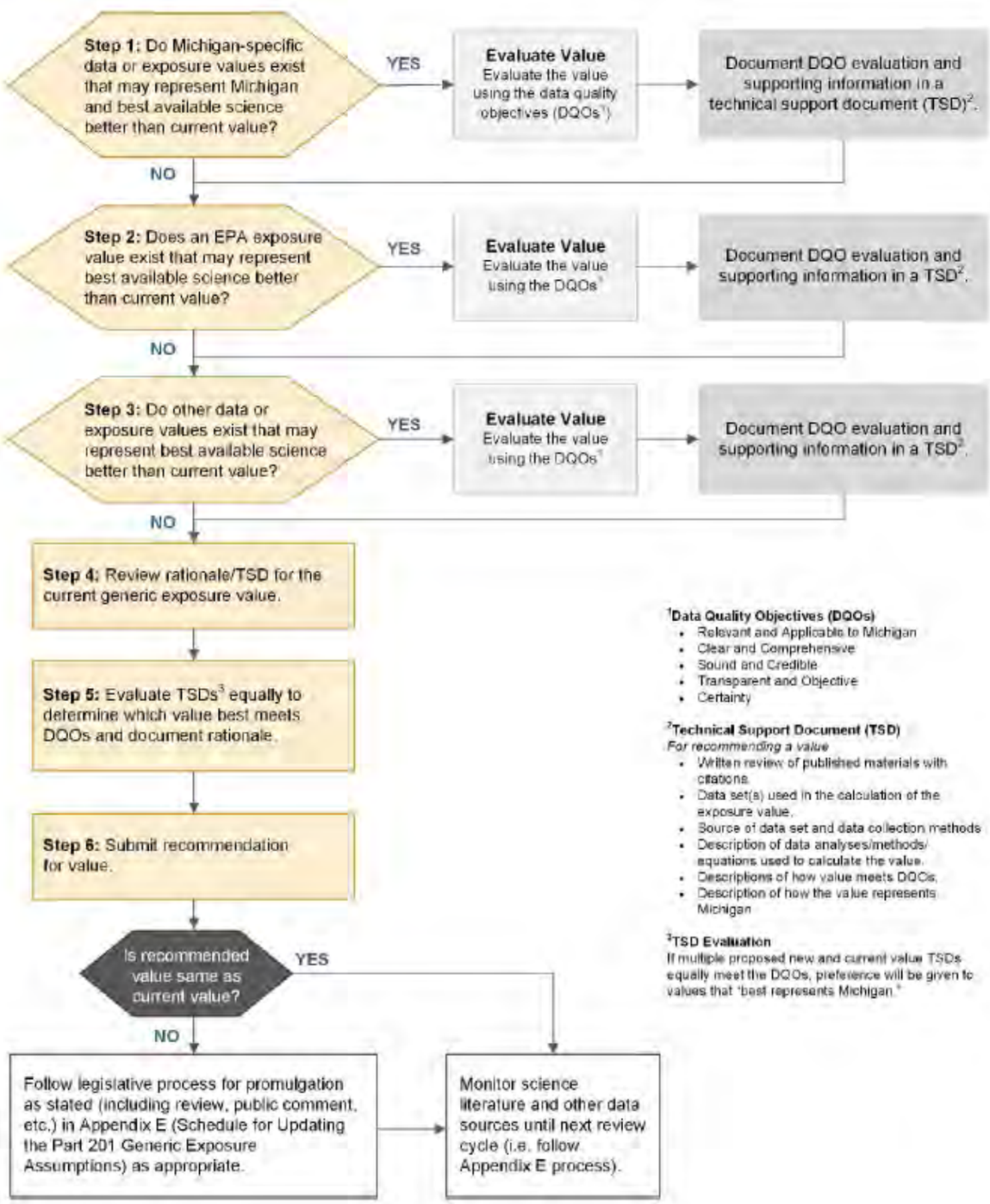
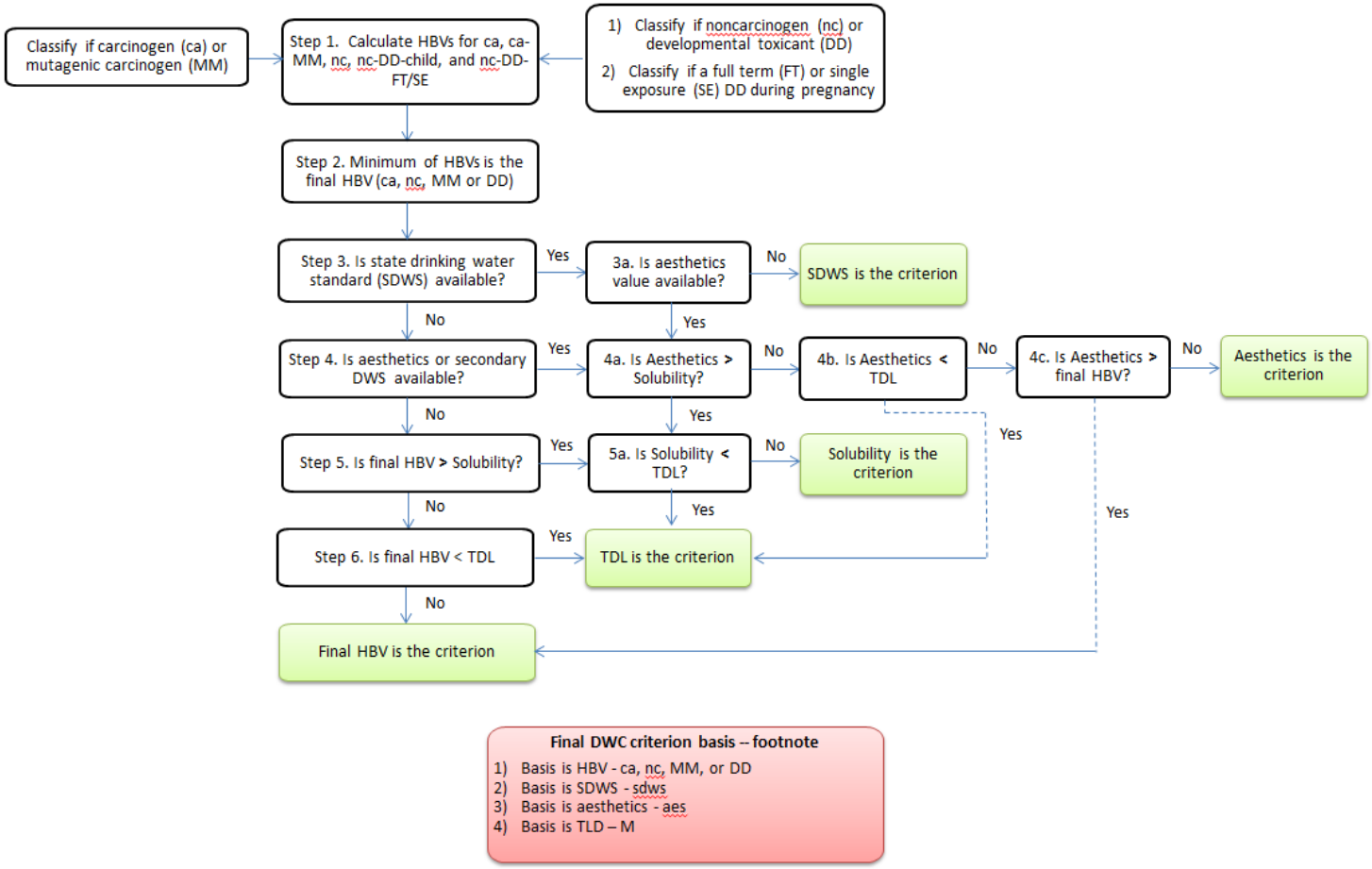


FIGURE 4 Decision Process - Generic Drinking Water Criteria

The DWC is based on state drinking water standards, aesthetics value or calculated HBV including considerations of solubility and TDL. The figure below shows the steps used by the MDEQ to develop the final generic DWC.

Figure 4. Decision Process for Developing Generic DWC

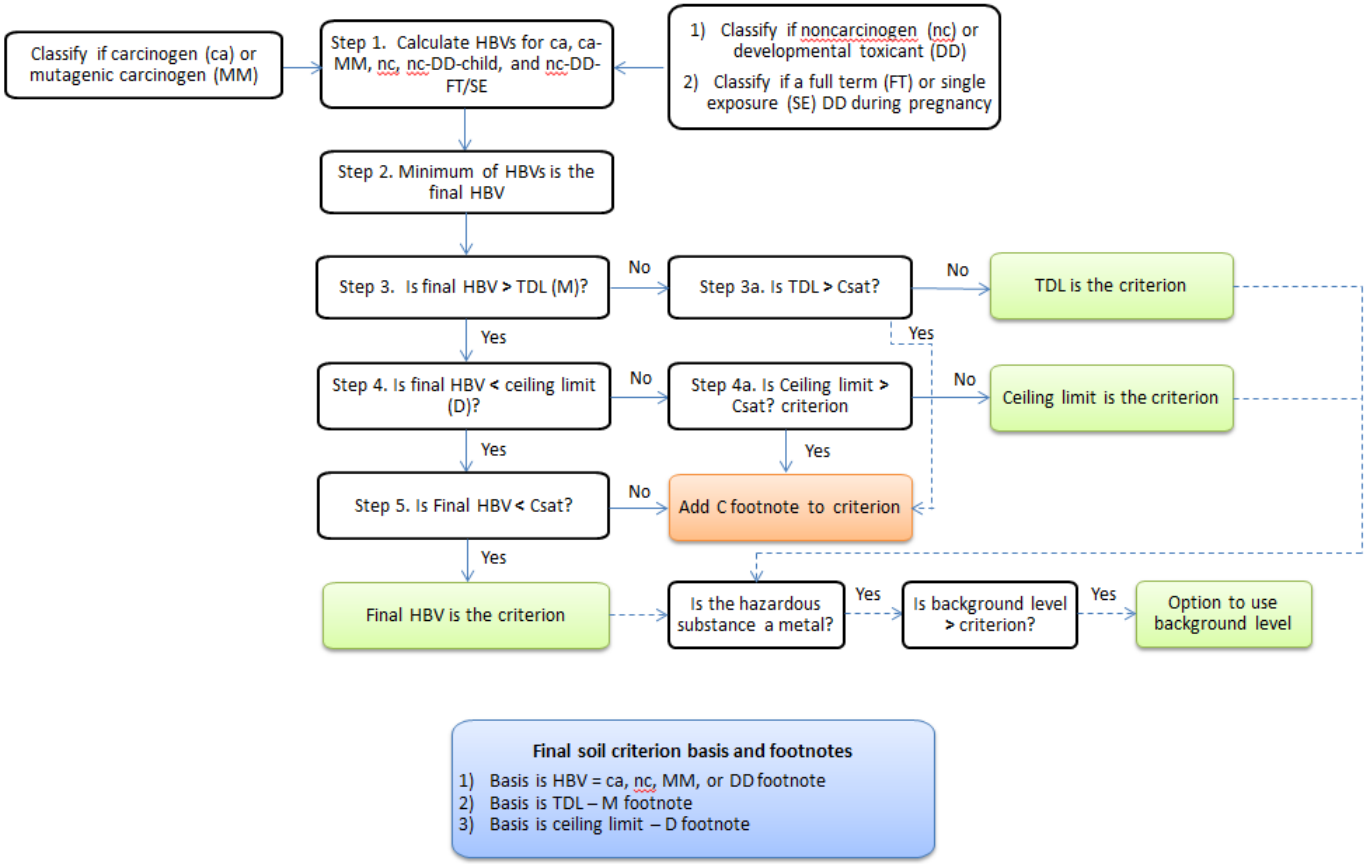


R 299.6; R 299.9; R 299.10

FIGURE 5 Decision Process - Soil criteria

The calculated HBVs are compared to the TDL and soil ceiling concentration to develop the final criteria. In addition, comparison to Csat is required while background concentration is an option to consider when evaluating the final criteria. The figure below shows the steps used by the MDEQ to develop the final soil criteria.

Figure 5. Decision Process for Developing Generic Soil Criteria

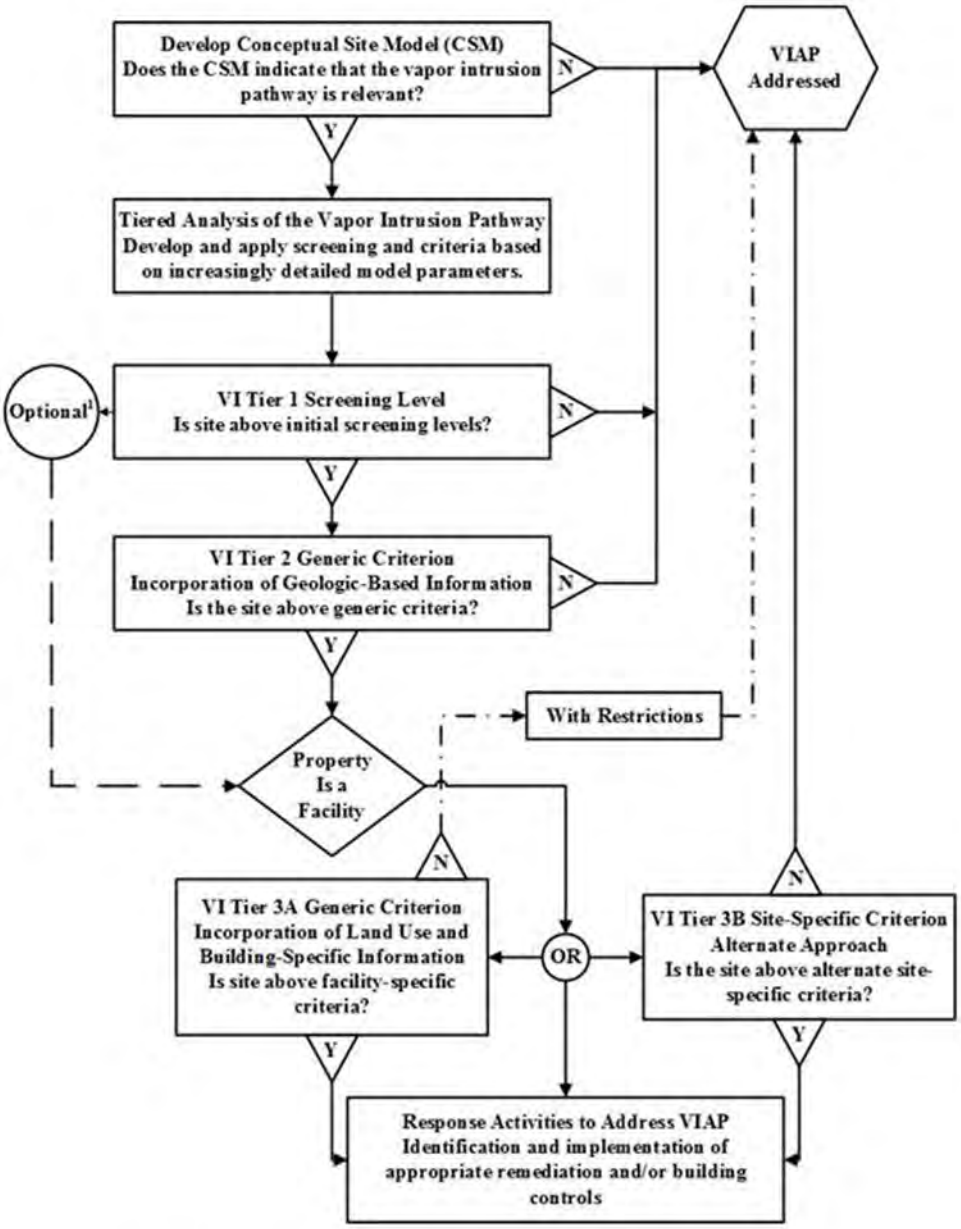


R 299.6; R 299.20; R 299.22; R 299.26

FIGURE 6 VI Tier Process

The figure shows the Figure 1 VI Tier Process and illustrates the process to access the volatilization to indoor air pathway. The process is presented as a sequential step-by-step approach; parties may skip tiers as appropriate to the conditions at a site, or the circumstances of an investigation.

Figure 6. VI Tier Process



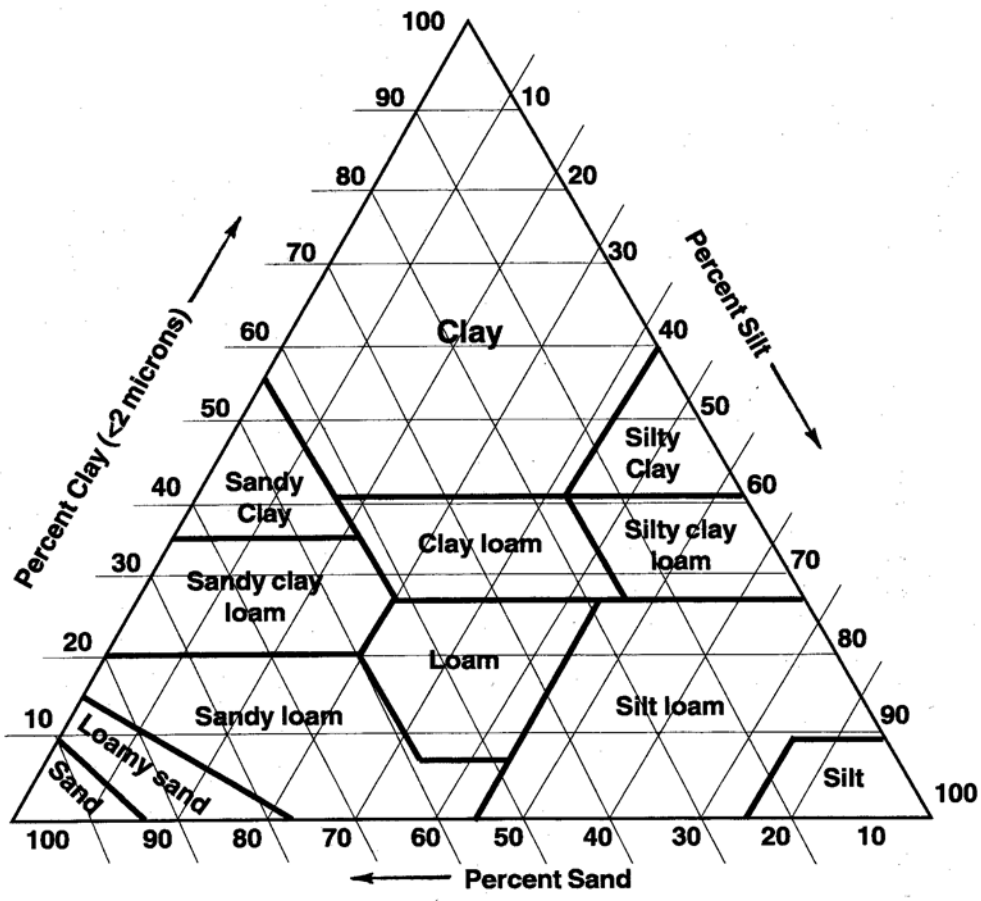
1. R 299.27(3)(a)(i)

R 299.27(2)(c); R 299.27(12) – Figure 1

Figure 7 Figure showing the different soil textural classes (soil types)

The figure below shows the different soil types identified by the USDA.

Figure 7. USDA Soil Textural Classification

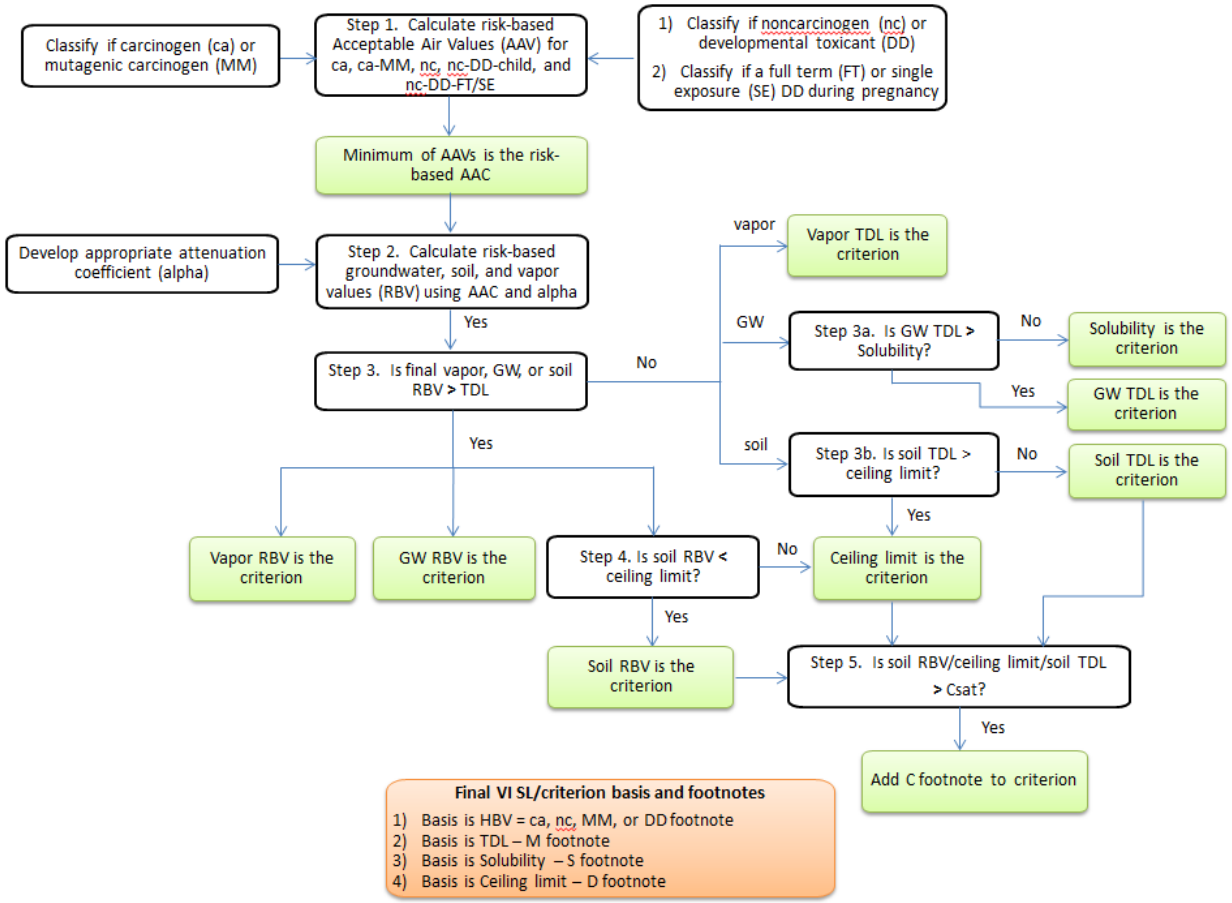


R 299.7(6) – Figure 1

Figure 8 Decision Process - VIAC

The calculated VI values are compared to the appropriate TDL to determine the final criteria. For groundwater values, comparison to solubility is also required. For soil values, comparison to ceiling concentration and Csat are required; background concentration is shown as an option to consider. The figure below shows the steps used to develop the final VIAC.

Figure 8. Decision Process for Developing Generic VIAC



R 299.6; R 299.27

APPENDIX 1

GLOSSARY

Age-adjusted dermal factor (DF): DF is an estimate of the soil dermal exposure that an individual is assumed to have while residing at the same residence spanning both the childhood and adulthood years of the exposure duration.

Age-adjusted soil ingestion factor (IF): IF represents an estimate of the drinking water or soil ingestion exposure that an individual is assumed to have while residing at the same residence spanning both the childhood and adulthood years of the exposure duration.

Averaging time (AT): AT represents the number of days over which an exposure is averaged and differs for carcinogens, non-carcinogens, and developmental toxicants.

Dermal absorption efficiency (AEd): AEd represents the fraction of hazardous substance that is assumed to penetrate the skin or dermal barrier exchange boundaries upon soil contact.

Dispersion factor (Q/C): The Q/C represents dispersion of airborne contaminants.

Exposure duration (ED): ED represents the number of years that individuals may be exposed to contaminants at their residences or workplaces.

Exposure frequency for ingestion (EFi): EFi represents the number of days per year that individuals may be exposed to soil/dust through ingestion at their residences or workplaces.

Exposure frequency for dermal contact (EFd): EFd represents the number of days per year that individuals may be exposed to soil/dust through contact at their residences or workplaces.

Gastrointestinal absorption factor (ABSgi): ABSgi represents the fraction of an ingested hazardous substance which is absorbed into the body. This factor is used to extrapolate dermal reference dose or dermal slope factor estimates from oral reference dose or slope factor, respectively, when dermal toxicity endpoints are not available.

Hazard Quotient (HQ): HQ represents the ratio of the chronic daily dose of a hazardous substance (reasonable maximum exposure) divided by the chronic reference dose for that substance.

Ingestion absorption efficiency (AEi): AEi represents the fraction of hazardous substance orally ingested that is assumed to pass through the gastrointestinal tract into the circulatory system.

Lowest-observed-adverse-effect level (LOAEL): The LOAEL represents the lowest exposure dose level of a hazardous substance at which there are biologically significant increases in

frequency or severity of adverse effects observe between an exposed population and an appropriate control group.

No-observed-adverse-effect level (NOAEL): The NOAEL represents the highest exposure dose level of a hazardous substance at which there are no biologically significant increases in the frequency or severity of adverse effect between an exposed population and an appropriate control group.

Particulate Emission Factor (PEF): The PEF relates the concentration of a particulate contaminant in ambient air to the corresponding concentration of contaminant in soil.

Relative Source Contribution (RSC): RSC represents the assumed portion of a person's total daily intake of a noncarcinogenic hazardous substance that comes from the environmental medium being addressed by the criterion.

Skin surface area (SA): SA represents the surface area of skin that assumed to be in contact with soil during soil-related activities.

Soil Adherence Factor (AF): AF represents the amount of soil assumed to adhere to the exposed skin surface during soil-related activities.

Soil ingestion rate (IRs): IRs represents the amount of soil/dust intake per day during a soil exposure event.

Target Risk (TR): TR represents the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogenic hazardous substance.

Temperature adjustment factor (TAF): TAF represents a numeric multiplier used to adjust the Henry's law constant for the lower average annual Michigan soil temperature.

Volatilization Factor (VF): The VF relates the concentration of a volatile contaminant in ambient air to the corresponding concentration of contaminant in soil.

APPENDIX 2

ABBREVIATIONS and ACRONYMS

AAC: acceptable air concentration
ADAF: age-dependent adjustment factor
AEd: dermal absorption efficiency
AEH: air exchange per hour
AEi: absorption efficiency
AER: air exchange rate
AERMOD: atmospheric dispersion modeling system
AF: adherence factor
API: American Petroleum Institute
ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers
AT: averaging time
B(a)P: benzo(a)pyrene
BW: body weight
CAF: cancer adjustment factor
CAS: Chemical Abstract Service
cPAH: carcinogenic polynuclear aromatic hydrocarbons
CN: cyanide
CSA: Criteria Stakeholder Advisory group
CSM: conceptual site model
Csat: theoretical saturation concentration
CSFd: dermal cancer slope factor
CSFo: oral cancer slope factor
DNA: deoxyribonucleic acid
DCC/V: direct contact criteria/values
DR: developmental reproductive toxicant
DQOs: data quality objectives
DWC/V: drinking water criteria/values
DWPC: drinking water protection criteria
ED: exposure duration
EDTA: ethylene diamine tetraacetic acid
EF: exposure frequency
EMSOFT: Exposure Model for Soil-Organic Fate and Transport
EV: event frequency
Ew: wind speed
FCV: final chronic value
FESL/V: Flammability explosivity screening level/value
Foc: fraction of organic carbon in soil
FT: full-term developmental toxicant category
GSI: groundwater surface water interface pathway
GSIC: groundwater surface water interface
GSIPC: groundwater surface water interface protection criteria
GVIIC: groundwater volatilization to indoor air inhalation criteria
GWPC: groundwater protection criteria
GWPV: groundwater protection value
H': dimensionless Henry's law constant
H_B: enclosed space or mixing height
Hg: mercury

HBV: health based value
HDV: human drinking water value
HLC: Henry's law constant
HNDV: human non-drinking water value
HVAC: heating, ventilation, and air conditioning
IR: ingestion rate
IRIS: Integrated Risk Information System
ITRC: Interstate Technology & Regulatory Council
IURF: Inhalation unit risk factor
J&E: Johnson & Ettinger
L_B: length
LEL: lower explosive limit
L_{FF}: depth of footings/utilities below enclosed space
L_T: distance to vapor source
MAF: mutagenic adjustment factors
MBSS: Michigan background soil survey
MDEQ: Michigan Department of Environmental Quality
MFL: million fibers per liter of water
MIBK: methyl isobutyl ketone
MMOA: mutagenic mode of action
MOA: mode of action
MW: molecular weight
NAPL: non-aqueous phase liquid
NRCS: Natural Resources Conservation Services
NREPA: The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended
PAH: polycyclic aromatic hydrocarbon
Part 201: Environmental Remediation, of NREPA
Part 213: Leaking Underground Storage Tanks, of NREPA
PCBs: polychlorinated biphenyls
PEF: particulate emission factor
POTW: public owned treatment works
PSIC/PSIV: particulate soil inhalation criteria/values
Q/C: dispersion factor
Qsoil: volumetric flow rate of soil gas entering the closed space of a building
RCRA: Resource Conservation and Recovery Act
RfC: inhalation reference concentration
RfDd: dermal reference dose
RfDo: oral reference dose
RfV: reference value
RSC: relative source contribution factor
RME: reasonable maximum exposure
S^3TM: Sampling Strategies and Statistics Training Manual for Part 201 Cleanup Criteria
SDWS: state drinking water standard
SE: single event developmental toxicant category
SIC: soil inhalation criteria
SRC: SRC, Inc.
SVIIC: soil volatilization to indoor air inhalation criteria
SWPC/SWPV: soil-water partitioning criteria/value
TAF: temperature adjustment factor
TAG: Technical Advisory Group
TCE: trichloroethylene

TEF: toxicity equivalent factor
TDL: target detection level
TSCA: the federal Toxic Substances Control Act
TSG: Toxics Steering Group
THMs: trihalomethanes
TSD: technical support document
UCL: upper confidence limit
USCS: United Soil Classification System
USEPA: United States Environmental Protection Agency
VC: vinyl chloride
VF: volatilization factor
VI: volatilization to indoor air
VIAC/P: volatilization to indoor air criteria/pathway
VOC: volatile organic compound
VSIC/VSIV: volatile soil inhalation criteria/values
USDA: United States Department of Agriculture
W_B: enclosed floor space - width
WHO: World Health Organization
WV: wildlife value

ATTACHMENTS AND LINKS:

A. PART 201 and PART 213 Statutes
B. PART 201 Rules
C. CSA Final Report
D. MDEQ Response to CSA Recommendations
E. Chemical Update Worksheets and Users Guide
F. MDEQ Toxics Steering Group (TSG) Developmental-Reproductive Criteria Development Process Report
G. Generic Assumptions for Soil Type, County Based Soil Temperature, and Depth to Groundwater
H. MDEQ Exposure Technical Support Documents (TSDs)
   - Exposure duration and averaging time
   - Exposure frequency
   - Drinking water ingestion rate
   - Body weight
   - Soil ingestion rate
   - Skin surface area
   - Adherence factor
   - Particulate emission factor variables
   - Volatilization factor parameters
I. Temperature Adjustment Factor (TAF) Background Document
J. Statewide Default Soil Background Levels Background Document
K. Dispersion Factor and Wind Speed Background Document
L. Source Area Size and Generic Soil Inhalation Criteria Determination
M. Fraction of Organic Carbon Content
N. Carcinogenic PAHs Background Document
O. Cyanide Background Document
P. Lead Background Document
Q. Methane Background Document
R. Volatilization to Indoor Air Foundation Type Sensitivity Analysis

ATTACHMENT A

STATUTES

PART 201, Environmental Remediation, of NREPA

Part 213, Leaking Underground Storage Tanks, of NREPA

Available online at:

http://www.michigan.gov/deqrrd
Select Act and Rules from bottom- right column

Part 201 Current direct link:
http://www.legislature.mi.gov/(S(oboizqgzh2ewxpps3vtr5fxb))/mileg.aspx?page=getObject&objectName=mcl-451-1994-II-7-201

Part 213 Current direct link:
http://www.legislature.mi.gov/(S(aei3ms5zmgw4lw40kfblvyre))/mileg.aspx?page=getObject&objectName=mcl-451-1994-II-8-213

ATTACHMENT B

PART 201 RULES

Available online at: Generic Cleanup Criteria Proposed Rules Revisions Webpage:
http://www.michigan.gov/deqrrd criteria:
Select: ADMINISTRATIVE RULES FOR PART 201, ENVIRONMENTAL CONTAMINATION RESPONSE ACTIVITY

Current direct link to the Generic Cleanup Criteria Proposed Rules Revisions Webpage:
http://www.michigan.gov/deq/0,4561,7-135-3311_4109_9846-384981--,00.html

Proposed Rules are also available on online directly from LARA/ORR at:

http://w3.lara.state.mi.us/orr/Files/ORR/1604_2015-094EQ_orr-draft.pdf

ATTACHMENT C

CRITERIA STAKEHOLDER ADVISORY (CSA) REPORT

Available online at:

Criteria Stakeholder Advisory Workgroup:
http://www.michigan.gov/deq/0,4561,7-135-3311_4109_9846_30022-325789--,00.html

Select: **CSA Workgroup Final Report and Recommendations to the DEQ**

- **TAG 1: Chemical-Physical Parameters and Toxicity Data Final Report and Recommendations to the CSA**
- **TAG 2: Generic Exposure Assumptions Final Report and Recommendations to the CSA**
- **TAG 3: Vapor Intrusion Pathway Final Report and Recommendations to the CSA**
- **TAG 4: Legal Issues Final Report and Recommendations to the CSA**

Current direct links are:

CSA Workgroup Final Report and Recommendations to the DEQ:
http://www.michigan.gov/documents/deq/deq-rrdCSAFinalReport-11-26-14_475701_7.pdf

TAG 1: Chemical-Physical Parameters and Toxicity Data Final Report and Recommendations to the CSA:
http://www.michigan.gov//documents/deq/deq-rrd-TAG1FinalReport-8-15-14_465863_7.pdf

TAG 2: Generic Exposure Assumptions Final Report and Recommendations to the CSA
http://www.michigan.gov/documents/deq/deq-rrd-TAG2ReportFINAL10-11-14_472076_7.pdf

TAG 3: Vapor Intrusion Pathway Final Report and Recommendations to the CSA:
http://www.michigan.gov/documents/deq/deq-rrd-TAG3-InvestigatingTheVaporIntrusionRisk9-22-2014_472054_7.pdf

TAG 4: Legal Issues Final Report and Recommendations to the CSA
http://www.michigan.gov/documents/deq/deq-rrd-CSA-Part201FinalReport-Tag4_479176_7.pdf

ATTACHMENT D

MDEQ RESPONSE TO CSA RECOMMENDATIONS

Available online at: Criteria Stakeholder Advisory Workgroup:
http://www.michigan.gov/deq/0,4561,7-135-3311_4109_9846_30022-325789--,00.html
Select: DEQ Response to the CSA Workgroup Recommendations is available here

Current direct link:
http://www.michigan.gov/documents/deq/deq-rrd-CSA-DEQRRDResponseToCSAReport_495689_7.pdf

ATTACHMENT E

CHEMICAL UPDATE WORKSHEETS AND USERS GUIDE

I. MDEQ CHEMICAL UPDATE WORKSHEET USER GUIDE

Section (A): Chemical-physical properties
The chemical-specific chemical-physical properties are presented in Section (A) of the Chemical Update Worksheets. Updated values and reference sources were identified consistent with the decision framework and data quality objectives presented in the Criteria Stakeholder Advisory Report (CSA Report) and MDEQ Response to CSA Recommendations[1].

The data presented in the column labeled "Part 201 Value" represents the parameter values promulgated in 2013. The data presented in the column labeled "Updated Value" represent the parameter values used in the 2016 Criteria rule package. The information presented in the column labeled "Reference Source" represents the source MDEQ used to obtain the "Updated Value," which may represent the original reference or a compiled reference resource. The scientific basis and details of the "Updated Value" is presented in the area beneath the "Updated Value" and Source/Reference/Date. All source and basis abbreviations are defined at the end of each worksheet.

General information:

- Numeric values are generally reported in the Chemical Update Worksheets as they were presented in their respective reference source.
- Where appropriate, the numeric format of some parameter values was changed for convenience and clarity of presentation in the Chemical Update Worksheet (e.g., decimal to scientific format for very large or small numbers).
- Numeric conversion was performed where it was necessary to harmonize the units of measure for a given parameter as used in the criteria equations.

Parameter-specific information:

- In general, molecular weight values for inorganic hazardous substances are reported for the elemental form of the substance, when appropriate.
- Physical state was determined using the following definitions:
  - If a hazardous substance has a melting point > 20 °C, it is considered a solid.
  - If a hazardous substance has a melting point < 20 °C, it is considered a liquid.
  - If a hazardous substance has a boiling point < 20 °C, it is considered a gas.
  - If a hazardous substance is not an organic chemical, it is considered an inorganic.
  - Physical state is relevant to calculating the theoretical Csat.

[1] Refer to CSA Report and MDEQ Response Attachments C & D

- Physical state is not relevant to the reported water quality standards.

- In general, the order of preference for the soil organic carbon-water partition coefficient for organic compounds (Koc) was as follows:
  - Estimated Koc values from EPI Suite (USEPA, 2012), where the reported MCI method values are preferred over the LogKow method values
  - Estimated Koc values from the USEPA Soil Screening Guidance (USEPA, 1996)
  - Experimental (measured) Koc values from EPI Suite (USEPA, 2012)
- The soil organic carbon-water partition coefficient for ionizing organic compounds (Koc) represent the value reported in the USEPA Soil Screening Guidance (EPA-SSG) (USEPA, 1996) at pH =6.8.
- The reported soil-water distribution coefficient (Kd) for inorganic compounds were obtained from the EPA-SSG with the exception of lead and copper. MDEQ contracted the development of Kd values for lead and copper using the same methodology presented in the EPA-SSG. Air and water diffusivity values were calculated using the equations 17-5 and 17-6, respectively, presented in the WATER9 Software User Guide (USEPA, 2001).

Section (B): Toxicity Values/Benchmarks

Data presentation:

Chemical-specific toxicity information is presented in Section (B) of the Chemical Update Worksheets. The reporting structure of this section of the Chemical Update Worksheet is as follows:

- The column labeled “Part 201 Value” represents the toxicity data used to develop the associated criteria promulgated in 2002.
- The information presented in the column labeled “Updated Value” represents the updated toxicity values and other supporting toxicity data proposed for the 2016 criteria rule update package.
- The toxicity value reference source and its respective publication date are presented in the column labeled “Source/Reference/Date”.
- As part of the update, any general MDEQ reviewer comments regarding the toxicity value or supporting toxicity data are reported in the column labeled “Comments/Notes/Issues”. However, these comments were resolved and removed as each Chemical Update Worksheet was finalized.

Toxicity values were developed consistent with the decision framework and data quality objectives presented in the CSA Report and MEDQ Response to Recommendations[1] (CSA, 2015), with the exception of the CSA’s Tier 4 recommendation for MDEQ de novo toxicity endpoints. Due to time limitations associated with the preparation of the proposed criteria rule package, only existing toxicity values from Tier 1-3 reference sources were evaluated for carcinogenic, mutagenic, non-carcinogenic, developmental, and reproductive endpoints. Tier 4 toxicity assessments were not conducted for this update.

Reference Sources:
In order to make the determination of "best available value", toxicity values were evaluated across Tiers 1-3 as presented in the CSA decision framework. Where available, all candidate toxicity values from Tier 1 (USEPA Integrated Risk Information System (IRIS) and Office of Pesticide Programs (OPP) and Tier 2 sources (Agency for Toxic Substances and Disease Registry (ATSDR) and USEPA's Provisional Peer Reviewed Toxicity Values (PPRTV) are summarized in each toxicity value section for comparison. Where Tier 1 and Tier 2 candidate toxicity values are not available, an extensive Tier 3 evaluation for other existing toxicity values was conducted. Tier 3 search sources included websites and environmental databases from the following state, federal, and international agencies:

- Michigan Department of Environmental Quality Chemical Criteria Database
- California Environmental Protection Agency
- Massachusetts Department of Environmental Protection
- Minnesota Department of Health
- New Jersey Department of Environmental Protection
- New York State Department of Environmental Conservation
- Texas Commission on Environmental Quality
- USEPA Health Effects Summary Tables (HEAST) database
- National Toxicology Program Report on Carcinogens (RoC)
- World Health Organization International Agency for Research on Cancer (IARC)
- World Health Organization International Programme on Chemical Safety (IPCS)
- Health Canada
- National Institute for Public Health and the Environment, RIVM
- European Chemicals Agency REACH database
- Organisation for Economic Co-Operation and Development (OECD)

For brevity and clarity within the Chemical Update Worksheet, only the "best available" among the Tier 3 toxicity values is included in each toxicity value section. The complete Tier 3 search results are presented in the Tier 3 Chemical Update Worksheets, and the additional Tier 3 information is available upon request.

Carcinogens with mutagenic mode of action (MMOA):
The datasheets presents information if a hazardous substances is a carcinogen with a mutagenic mode of action (MMOA). These substances are identified using USEPA assessments including MMOA listing in the Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens (USEPA, 2005) and those identified by IRIS assessments. The reference sources including IRIS justification are presented in the datasheet.

Noncarcinogens with developmental and reproductive effects:
A noncancer hazardous substance with oral or inhalation toxicity that is developmental and/or reproductive is identified in the chemical datasheet. Developmental toxicity justification is also presented in the datasheet. Prenatal developmental effects may occur after a single exposure (SE) or full-term (FT) exposure. The SE or FT category is presented in the datasheet. Further explanation on developmental and reproductive toxicity identification is available in the MDEQ Toxics Steering Group report (MDEQ, 2016).

State drinking water standards, national secondary drinking water regulations (secondary maximum contaminant levels), and aesthetic groundwater values:
The state drinking water standard, the national secondary drinking water regulation for a contaminant, and any aesthetic groundwater value determined by the MDEQ[2] are reported in this section of the Chemical Update Worksheet. State drinking water standards are established pursuant to section 5 of the Safe Drinking Water Act, 1976 PA 399, MCL 325.1005, and are reported in the *Supplying Water to the Public* rules that were accessed online at http://w3.lara.state.mi.us/orr/Files/AdminCode/1346_2014-023EQ_AdminCode.pdf
The national secondary drinking water standards were accessed online at https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals Aesthetic groundwater values that were previously developed by the MDEQ are available upon request. No aesthetic groundwater values were revised or established for the criteria rule package due to time limitations.

Phytotoxicity values:
Previously developed phytotoxicity values are reported in this section of the Chemical Update Worksheet. No phytoxicity values were revised or established for the updated criteria rule package due to time limitations.

Section (C): Chemical-specific Exposure Factors
The criteria for identifying the generic absorption factor values are presented in R 299.20(3)(b). Chemical-specific gastrointestinal (ABSgi) and dermal (AEd) absorption factors were obtained from USEPA's *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment),* July, 2004, when available. The values used by MDEQ for AEd and ingestion absorption factor (AEi) for organic and inorganic hazardous substances in previous criteria calculations were retained. The MDEQ did not evaluate alternative resources or attempt to develop de novo absorption factors for the 2016 criteria rule package due to time limitations.

Section (D): Water Quality Standards and GSI Criteria
The groundwater surface water interface (GSI) values were developed using the December 1, 2015 version of the Rule 57 water quality values published by the MDEQ and accessible online at: http://www.michigan.gov/deq/0,4561,7-135-3313_3681_3686_3728-11383--,00.html. These data are evaluated and potentially revised one or more times per year. Additional water quality standards are also included.

The methodology applied in deriving the values and GSI criteria entered into this section of the Chemical Update Worksheet is described in the text of Footnote (G) presented in Rule 299.49(1). Briefly, the generic GSI value is the lesser of the calculated final chronic value (FCV), the wildlife value (WV), and the surface water human non-drinking water value (HNV). Where the GSI criterion is not protective for surface water that is used as a drinking water

[2] MCL 324.20120a(5)

source, the Rule 57 human drinking water values (HDV) are presented in the table of Footnote (X). These water quality terms are defined in Part 4, Water Quality Standards, of Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended(http://www.michigan.gov/documents/deq/wrd-rules-part4_521508_7.pdf)

Section (E): Target Detection Limits

Hazardous substance analytical target detection limits (TDLs) in soil and water have been established by the MDEQ for hazardous substances with generic criteria. The MDEQ published list of TDLs and Designated Analytical Methods for 2016 was used to establish criteria. In establishing TDLs, the MDEQ considered the need to be able to measure the hazardous substances at concentrations at or below cleanup criteria. The TDLs were derived by reviewing the low-level capabilities of state laboratories and methods published by government agencies and referenced in the above referenced document.

References:

Criteria Stakeholders Advisory (CSA) Workgroup, Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria. 2014.

MDEQ, 2015: Response to Recommendations, Criteria Stakeholder Advisory Group Final Report, July 2015.

MDEQ. List of Target Detection Limits and Designated Analytical Methods. 2016.

MDEQ, 2015. Process to address developmental and/or reproductive toxicity in the derivation of generic cleanup criteria. Toxics Steering Group, Children's Environmental Health Subcommittee, Lansing, Michigan. (unpublished)

United States Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). July, 2004

United States Environmental Protection Agency (USEPA), Estimation Programs Interface SUITE 4.1, copyright 2002-2012.

USEPA, Soil Screening Guidance: Technical Background Document, Second Edition, 1996.

USEPA, 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. EPA/630/R-03/003F.

USEPA, User Guide for WATER9 Software, Version 2.0.0, 2001.

II. CHEMICAL UPDATE WORKSHEETS

	CHEMICAL NAME	CAS NUMBER
1	Acenaphthene	83329
2	Acenaphthylene	208968
3	Acetaldehyde	75070
4	Acetate	71501
5	Acetic acid	64197
6	Acetone	67641
7	Acetonitrile	75058
8	Acetophenone	98862
9	Acrolein	107028
10	Acrylamide	79061
11	Acrylic acid	79107
12	Acrylonitrile	107131
13	Alachlor	15972608
14	Aldicarb	116063
15	Aldicarb sulfone	1646884
16	Aldicarb sulfoxide	1646873
17	Aldrin	309002
18	Aluminum	7429905
19	Ammonia	7664417
20	t-Amyl methyl ether (TAME)	994058
21	Aniline	62533
22	Anthracene	120127
23	Antimony	7440360
24	Arsenic	7440382
25	Asbestos	1332214
26	Atrazine	1912249
27	Azobenzene	103333
28	Barium	7440393
29	Benzene	71432
30	Benzidine	92875
31	Benz(a)anthracene	56553
32	Benzo(b)fluoranthene	205992
33	Benzo(k)fluoranthene	207089
34	Benzo(g,h,i)perylene	191242
35	Benzo(a)pyrene	50328
36	Benzoic acid	65850
37	Benzyl alcohol	100516
38	Benzyl chloride	100447
39	Beryllium	7440417
40	bis(2-Chloroethoxy)ethane	112265
41	bis-2-Chloroethylether	111444
42	bis(2-Ethylhexyl) phthalate	117817

	CHEMICAL NAME	CAS NUMBER
43	Boron	7440428
44	Bromate	15541454
45	Bromobenzene	108861
46	Bromodichloromethane	75274
47	Bromoform	75252
48	Bromomethane	74839
49	n-Butanol	71363
50	2-Butanone (MEK)	78933
51	n-Butyl acetate	123864
52	t-Butyl alcohol	75650
53	Butyl benzyl phthalate	85687
54	n-Butylbenzene	104518
55	sec-Butylbenzene	135988
56	t-Butylbenzene	98066
57	Cadmium	7440439
58	Camphene	79925
59	Caprolactam	105602
60	Carbaryl	63252
61	Carbazole	86748
62	Carbofuran	1563662
63	Carbon disulfide	75150
64	Carbon tetrachloride	56235
65	Chlordane	57749
66	Chloride	16887006
67	2-Chloroaniline	95512
68	4-Chloroaniline	106478
69	Chlorobenzene	108907
70	p-Chlorobenzene sulfonic acid	98668
71	1-Chloro-1,1-difluoroethane	75683
72	Chloroethane	75003
73	2-Chloroethyl vinyl ether	110758
74	Chloroform	67663
75	Chloromethane	74873
76	4-Chloro-3-methylphenol	59507
77	beta-Chloronaphthalene	91587
78	2-Chlorophenol	95578
79	o-Chlorotoluene	95498
80	Chlorpyrifos	2921882
81	Chromium (III)	16065831
82	Chromium (VI)	18540299
83	Chrysene	218019
84	Cobalt	7440484
85	Copper	7440508

	CHEMICAL NAME	CAS NUMBER
86	Cyanazine	21725462
87	Cyanide	57125
88	Cyclohexane	110827
89	Cyclohexanone	108941
90	Dacthal	1861321
91	Dalapon	75990
92	4-4'-DDD	72548
93	4-4'-DDE	72559
94	4-4'-DDT	50293
95	Decabromodiphenyl ether	1163195
96	Di-n-butyl phthalate	84742
97	Di(2-ethylhexyl) adipate	103231
98	Di-n-octyl phthalate	117840
99	Diacetone alcohol	123422
100	Diazinon	333415
101	Dibenzo(a,h)anthracene	53703
102	Dibenzofuran	132649
103	Dibromochloromethane	124481
104	Dibromochloropropane	96128
105	Dibromomethane	74953
106	Dicamba	1918009
107	1,2-Dichlorobenzene	95501
108	1,3-Dichlorobenzene	541731
109	1,4-Dichlorobenzene	106467
110	3,3'-Dichlorobenzidine	91941
111	Dichlorodifluoromethane	75718
112	1,1-Dichloroethane	75343
113	1,2-Dichloroethane	107062
114	1,1-Dichloroethylene	75354
115	cis-1,2-Dichloroethylene	156592
116	trans-1,2-Dichloroethylene	156605
117	2,6-Dichloro-4-nitroaniline	99309
118	2,4-Dichlorophenol	120832
119	2,4-Dichlorophenoxyacetic acid	94757
120	1,2-Dichloropropane	78875
121	1,3-Dichloropropene	542756
122	Dichlorvos	62737
123	Dicyclohexyl phthalate	84617
124	Dieldrin	60571
125	Diethyl ether	60297
126	Diethyl phthalate	84662
127	Diethylene glycol monobutyl ether	112345
128	Diisopropyl ether	108203

	CHEMICAL NAME	CAS NUMBER
129	Diisopropylamine	108189
130	Dimethyl phthalate	131113
131	N,N-Dimethylacetamide	127195
132	N,N-Dimethylaniline	121697
133	Dimethylformamide	68122
134	2,4-Dimethylphenol	105679
135	2,6-Dimethylphenol	576261
136	3,4-Dimethylphenol	95658
137	Dimethylsulfoxide	67685
138	2,4-Dinitrophenol	51285
139	2,4-Dinitrotoluene	121142
140	Dinoseb	88857
141	1,4-Dioxane	123911
142	Diquat	85007
143	Dissolved oxygen (DO)	NA
144	Diuron	330541
145	Endosulfan	115297
146	Endothall	145733
147	Endrin	72208
148	Epichlorohydrin	106898
149	Ethanol	64175
150	Ethyl acetate	141786
151	Ethyl-tert-butyl ether (ETBE)	637923
152	Ethylbenzene	100414
153	Ethylene dibromide	106934
154	Ethylene glycol	107211
155	Ethylene glycol monobutyl ether	111762
156	Ethylenediaminetetraacetic acid (EDTA)	60004
157	Fluoranthene	206440
158	Fluorene	86737
159	Fluorine (soluble fluoride)	7782414
160	Formaldehyde	50000
161	Formic acid	64186
162	1-Formylpiperidine	2591868
163	Gentian violet	548629
164	Glyphosate	1071836
165	Heptachlor	76448
166	Heptachlor epoxide	1024573
167	n-Heptane	142825
168	Hexabromobenzene	87821
169	Hexachlorobenzene (C-66)	118741
170	Hexachlorobutadiene (C-46)	87683
171	alpha-Hexachlorocyclohexane	319846

	CHEMICAL NAME	CAS NUMBER
172	beta-Hexachlorocyclohexane	319857
173	Hexachlorocyclopentadiene (C-56)	77474
174	Hexachloroethane	67721
175	n-Hexane	110543
176	2-Hexanone	591786
177	Indeno(1,2,3-cd)pyrene	193395
178	Iron	7439896
179	Isobutyl alcohol	78831
180	Isophorone	78591
181	Isopropyl alcohol	67630
182	Isopropyl benzene	98828
183	Lead	7439921
184	Lindane	58899
185	Lithium	7439932
186	Magnesium	7439954
187	Manganese	7439965
188	Mercury (Total)	Varies
189	Mercury, elemental	7439976
190	Mercuric chloride	7487947
191	Methyl Mercury	22967926
192	Methane	74828
193	Methanol	67561
194	Methoxychlor	72435
195	2-Methoxyethanol	109864
196	2-Methyl-4-chlorophenoxyacetic acid	94746
197	2-Methyl-4,6-dinitrophenol	534521
198	N-Methyl-morpholine	109024
199	Methyl parathion	298000
200	4-Methyl-2-pentanone (MIBK)	108101
201	Methyl-tert-butyl ether (MTBE)	1634044
202	N-methylaniline	100618
203	Methylcyclopentane	96377
204	4,4'-Methylene-bis-2- chloroaniline (MBOCA)	101144
205	Methylene chloride	75092
206	2-Methylnaphthalene	91576
207	Methylphenols	Varies
208	2-Methylphenol	95487
209	3-Methylphenol	108394
210	4-Methylphenol	106445
211	Metolachlor	51218452
212	Metribuzin	21087649
213	Mirex	2385855

	CHEMICAL NAME	CAS NUMBER
214	Molybdenum	7439987
215	Naphthalene	91203
216	Nickel	7440020
217	Nitrate	14797558
218	Nitrite	14797650
219	Nitrobenzene	98953
220	2-Nitrophenol	88755
221	n-Nitroso-di-n-propylamine	621647
222	N-Nitrosodiphenylamine	86306
223	Oxamyl	23135220
224	Oxo-hexyl acetate	88230357
225	Pendimethalin	40487421
226	Pentachlorobenzene	608935
227	Pentachloronitrobenzene	82688
228	Pentachlorophenol	87865
229	Pentane	109660
230	2-Pentene	109682
231	Perchlorate	14797730
232	Perfluorooctanoic acid	335671
233	Perfluorooctane sulfonic acid	1763231
234	pH	NA
235	Phenanthrene	85018
236	Phenol	108952
237	Phenytoin	57410
238	Phosphorus, Total	Varies
239	Phosphorus, White	7723140
240	o-Phthalic acid	88993
241	Phthalic anhydride	85449
242	Picloram	1918021
243	Piperidine	110894
244	Polybrominated biphenyls	67774327
245	Polychlorinated biphenyls (PCBs)	1336363
246	Prometon	1610180
247	Propachlor	1918167
248	Propazine	139402
249	Propionic acid	79094
250	Propyl alcohol	71238
251	n-Propylbenzene	103651
252	Propylene glycol	57556
253	Pyrene	129000
254	Pyridine	110861
255	Selenium	7782492
256	Silver	7440224

	CHEMICAL NAME	CAS NUMBER
257	Silvex (2,4,5-TP)	93721
258	Simazine	122349
259	Sodium	17341252
260	Sodium azide	26628228
261	Sodium bromide	7647156
262	Strontium	7440246
263	Styrene	100425
264	Sulfate	14808798
265	Tebuthiuron	34014181
266	2,3,7,8-Tetrabromodibenzo-p-dioxin	50585416
267	1,2,4,5-Tetrachlorobenzene	95943
268	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016
269	1,1,1,2-Tetrachloroethane	630206
270	1,1,2,2-Tetrachloroethane	79345
271	Tetrachloroethylene	127184
272	Tetrahydrofuran	109999
273	1,1,3,3-Tetramethylurea	632224
274	Tetranitromethane	509148
275	Thallium	7440280
276	Toluene	108883
277	p-Toluidine	106490
278	Total dissolved solids (TDS)	NA
279	Toxaphene	8001352
280	Triallate	2303175
281	Tributylamine	102829
282	1,2,3-Trichlorobenzene	87616
283	1,2,4-Trichlorobenzene	120821
284	1,1,1-Trichloroethane	71556
285	1,1,2-Trichloroethane	79005
286	Trichloroethylene	79016
287	Trichlorofluoromethane	75694
288	2,4,5-Trichlorophenol	95954
289	2,4,6-Trichlorophenol	88062
290	1,2,3-Trichloropropane	96184
291	1,1,2-Trichloro-1,2,2-trifluoroethane	76131
292	Triethanolamine	102716
293	Triethylene glycol	112276
294	3-Trifluoromethyl-4-nitrophenol	88302
295	Trifluralin	1582098
296	2,2,4-Trimethyl pentane	540841
297	2,4,4-Trimethyl-2-pentene	107404
298	1,2,3-Trimethylbenzene	526738
299	1,2,4-Trimethylbenzene	95636

	CHEMICAL NAME	CAS NUMBER
300	1,3,5-Trimethylbenzene	108678
301	Triphenyl phosphate	115866
302	tris(2,3-Dibromopropyl)phosphate	126727
303	Urea	57136
304	Vanadium	7440622
305	Vinyl acetate	108054
306	Vinyl chloride	75014
307	Xylenes	1330207
308	Zinc	7440666

ATTACHMENT F

MDEQ TOXICS STEERING GROUP (TSG)

DEVELOPMENTAL-REPRODUCTIVE CRITERIA DEVELOPMENT PROCESS REPORT

Remediation and Redevelopment Division

Michigan Department of Environmental Quality

Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria

Recommendations from the Toxics Steering Group, Children's Environmental Health Subcommittee

December 2015

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List of Abbreviations

AT	Averaging time
ATSDR	The Agency for Toxic Substances and Disease Registry
BMC	Benchmark concentration
BMD	Benchmark dose
BMDL	Lower-bound confidence limit on the benchmark dose
CEHS	Children's Environmental Health Subcommittee of the Michigan TSG
CSA	Criteria Stakeholder Advisory Group (MDEQ)
CSEFH	Child-Specific Exposure Factors Handbook (EPA, 2008)
DDEF	Data-derived extrapolation factor
DR	Developmental and/or early-life reproductive adverse endpoint
DR RfV	Reference Value based on at least one critical DR toxicity endpoint
ED	Exposure duration
EF	Exposure frequency
EFH	Exposure Factors Handbook (EPA, 2011)
EHC	Environmental Health Criteria (WHO)
EPA	United States Environmental Protection Agency
FDA	United States Food and Drug Administration
IRIS	Integrated Risk Information System (EPA)
IURF	Inhalation unit risk factor
LOAEL	Lowest Observed Adverse Effect Level
MDEQ	Michigan Department of Environmental Quality
MDHHS	Michigan Department of Health and Human Services
MDARD	Michigan Department of Agriculture and Rural Development
MRL	Minimal Risk Level (ATSDR)
NAS/NRC	National Academy of Science, National Research Council
NOAEL	No Observed Adverse Effect Level
nonDR	Noncancer adverse endpoint other than DR
OECD	Organization for Economic Cooperation and Development
PBPK	Physiologically-based pharmacokinetic model
PCBs	Polychlorinated biphenyls
PDA	Pregnancy Discrimination Act of 1978
POD	Point of departure
RfC	Reference Concentration
RfD	Reference Dose
RfV	Reference Value for noncancer adverse effects (e.g., RfC, RfD, MRL)
RRD	Remediation and Redevelopment Division (MDEQ)
RSL	Regional Screening Level
SRC	Syracuse Research Corporation
TAG2	Technical Advisory Group for Exposure Assumptions
TCE	Trichloroethylene
TSD	Technical Support Document (Appendix A)
TSG	Toxics Steering Group (MDEQ, MDHHS, MDARD)
UF	Uncertainty factor
WHO	World Health Organization

Executive Summary

Background

The Michigan Department of Environmental Quality (MDEQ) Remediation and Redevelopment Division (RRD) develops generic cleanup criteria (generic criteria) under Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, for approximately 300 hazardous substances. The generic criteria have not undergone a comprehensive update since they were originally promulgated in 2002. In anticipation of the next comprehensive update, the MDEQ convened an external Criteria Stakeholder Advisory group (CSA) in 2014 to make recommendations regarding the generic criteria update process. The CSA final report (CSA, 2014) recognized the need to protect public health and for generic criteria to be protective of sensitive toxic effects as stated in one of its guiding principles:

> *"The generic cleanup criteria need to be protective of public health and natural resources such that there are no unacceptable exposures to hazardous substances. Generic criteria are to be protective of the most sensitive toxic effect in a given exposure pathway for the hazardous substance in question."*

To protect for developmental and/or reproductive (DR) toxicity when it is the most sensitive toxic effect, the CSA made the following recommendations:

> ***2.1:*** *Receptor: Use an age-adjusted child plus adult receptor that, at present, assumes exposure across two age bins, except in the case of developmental toxicants.*
>
> ***2.2:*** *Guidance: Use EPA information to develop a process to account for those chemicals, or classes of chemicals, that have documented developmental or reproductive effects.*
>
> ***2.3:*** *Descriptive Language: Use current Part 201 rules (R299.49 (DD)) that allows the agency to regulate developmental and reproductive toxicants to protect sensitive subpopulations from these substances on a chemical-specific basis. For developmental and reproductive toxicants, the MDEQ should evaluate if the age-adjusted child plus adult receptor is protective of childhood and early-life-stage exposures on a chemical-specific basis*.

In line with these recommendations, RRD requested the assistance of the Toxics Steering Group (TSG) Children's Environmental Health Subcommittee (CEHS) to develop a process to generate criteria that address noncancer DR toxicity. This process will assist the MDEQ in establishing a consistent approach to addressing chemicals with DR toxicity and includes identifying available DR toxicity values and deriving DR toxicity values. This process will assure that cleanup criteria for various exposure pathways are adequately protective of the most sensitive endpoint based on the information available for a hazardous substance.

The CEHS evaluated the current MDEQ approach, as well as available guidance documents from the U.S. Environmental Protection Agency (EPA) and other national, international, and state agencies, to develop the following process. A review of the concepts and brief description of available guidance is included in Appendix A.

This process also considers the Part 201 statute and rules requirements. The specific regulatory language that requires consideration includes:

- **MCL 324.20120a(4)** *If a hazardous substance poses a risk of both cancer and 1 or more adverse health effects other than cancer, cleanup criteria shall be derived under this section for the most sensitive effect.*

- **MCL 324.20120b(2)** *Site-specific criteria approved under subsection (1) may, as appropriate:*
  (b) Alter any value, parameter, or assumption used to calculate generic criteria, with the exception of the risk targets specified in section 20120a(4).

- **R 299.34(3)** *The department may calculate generic cleanup criteria for certain hazardous substances using exposure assumptions other than those shown in the algorithms in these rules if either of the following conditions is satisfied:*
  (a) A hazardous substance causes an adverse effect in a sensitive subpopulation that is not adequately protected or represented by the generic exposure assumptions.
  (b) The toxicokinetics of a hazardous substance are not best represented by the average daily dose, when accounting for the most sensitive effect.

Identifying and Calculating Criteria for a Hazardous Substance with Noncancer DR Toxicity

Developmental toxicity means adverse outcomes induced during exposure at any early-life stage from preconception through adolescence (EPA, 2006; WHO, 2011). This toxicity can occur at any point in the life span and may include: (1) death; (2) structural abnormality; (3) altered growth; and/or (4) functional deficiency (EPA, 1991; EPA, 2006; WHO, 2011).

Reproductive toxicity manifests as harmful effects on sexual function and fertility. This can include changes to the female or male reproductive organs, the related endocrine system, and/or pregnancy outcomes. *For reproductive effects, the process described below is intended to address those that occur as a result of early-life exposures (i.e., from preconception through adolescence).*

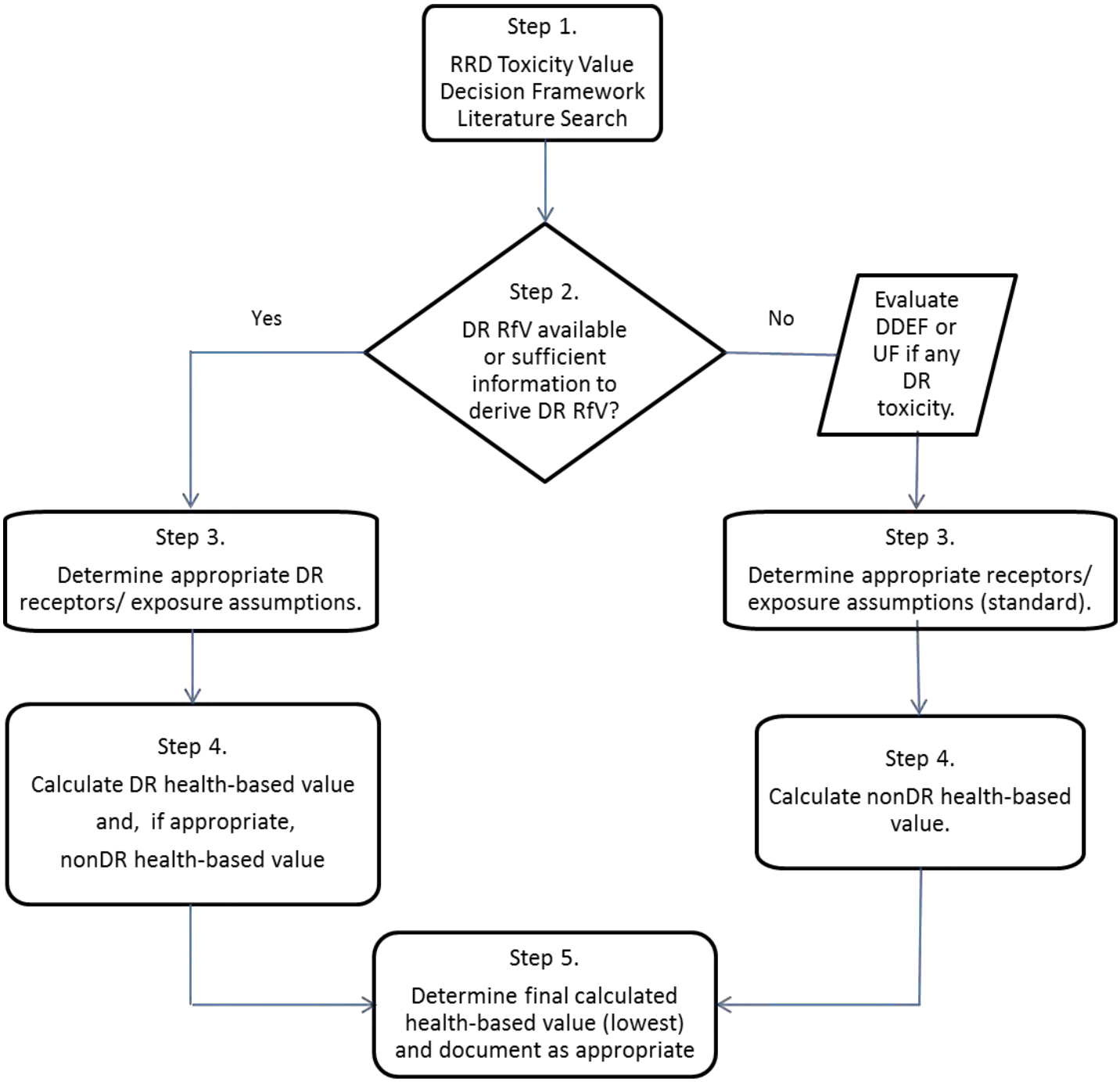
The process to evaluate a hazardous substance for DR toxicity is similar to evaluating other toxicity endpoints. A literature search is conducted to determine if there are existing toxicity values, or if other information or data are available to develop a toxicity value for various DR toxicological endpoints (e.g., organ or tissue damage, functional changes). DR toxicity values can include existing noncancer reference values (RfV) (e.g., Reference Dose [RfD], Reference

Concentration [RfC], Minimum Risk Level [MRL]). Evaluation of information from the literature search must determine if there are noncancer toxicity endpoints that occur after early-life exposure (DR toxicity).

The appropriate receptor and exposure assumptions are determined for each combination of hazardous substance, toxicity endpoint, exposure pathway, and land use. If there is a DR RfV or sufficient data to develop a DR RfV, then use that DR RfV to calculate health-based exposure pathway cleanup values with appropriate DR receptors. Compare the calculated DR health-based value to other cancer and/or nonDR noncancer health-based values to determine the final health-based cleanup values. The final cleanup value is the lowest value calculated using the appropriate algorithm for the critical cancer, mutagenic cancer, and noncancer (DR and/or NonDR) endpoints for the hazardous substance, exposure pathway, and land use. The final criterion is derived from either the final calculated health-based value or other value as required by statute or rule (e.g., state drinking water standard). Any limitations or considerations for the appropriate use of criteria for a hazardous substance are documented (e.g., footnotes) including those for DR toxicity.

Figure 1 presents the general steps in the process for establishing DR toxicity endpoints and development of DR health-based cleanup values. Detailed DR toxicity evaluation steps are outlined in the next section and a more detailed process flow chart that describes the substeps for each step follows in Figure 2.

Figure 1. General Process Description



RRD – Remediation and Redevelopment Division of the Michigan Department of Environmental Quality
DR RfV – Reference value for a developmental or developmental reproductive toxicity endpoint
DDEF – Data derived extrapolation factor
UF – Uncertainty Factor
DR – based on noncancer developmental and/or early-life reproductive toxicity
nonDR – based on noncancer toxicity that is not developmental or early-life reproductive

Detailed DR Toxicity Evaluation Process Steps

Step 1. RRD Toxicity Value Decision Framework Literature Search.

A literature search is conducted following the RRD Toxicity Value Decision Framework (Framework) (MDEQ, 2015) to identify the best available toxicity value(s) for a hazardous substance. **A literature search strategy specific to DR toxicity may need to be developed to ensure that relevant toxicity values and/or studies are located and evaluated.** [The current literature search strategy should be evaluated and refined, if appropriate, for DR toxicity in conjunction with the CEHS and RRD librarian.] The current literature search includes identification of information to determine the best available toxicity value(s) from all of the following Framework sources:

Tier 1. EPA Integrated Risk Information System (IRIS) (Note that for pesticides IRIS refers users to EPA Office of Pesticide Program documents for toxicity updates– these are an important best available toxicity value source, that includes DR toxicity values);

Tier 2. EPA Superfund Provisional Peer Reviewed Toxicity Value (PPRTV); or Agency for Toxic Substances and Disease Registry, Minimal Risk Levels for Hazardous Substances (ATSDR MRL);

Tier 3. Health Effects Assessment Summary Table (EPA); MDEQ existing value; Other state value; World Health Organization, Canadian or European Union value; *Potential future values from databases such as EPA's ToxCast, Read-across, Quantitative Structure Activity Relationships, or International Toxicity Estimates for Risk;* and

Tier 4. Search of published, with preference for peer reviewed, literature for a MDEQ toxicity assessment and RfV development.

Evaluation of the information from the literature search will result in one of the following outcomes:

Yes, information is found that allows evaluation of DR toxicity, proceed to Step 2a.
No, information is not found that allows for evaluation of DR toxicity, proceed to Step 2b.

Step 2. Determine Best Available RfV(s) and Document.

Once the available information regarding DR toxicity is evaluated, the DR and/or nonDR RfV(s) that are critical to protect for the most sensitive noncancer endpoint for a given exposure pathway are determined. **It is recommended that risk assessors refer to EPA risk assessment resources, including those listed in Appendix A, when identifying Tier 1-3 and setting Tier 4 values for DR toxicity. If a previously identified toxicity value is not based on a DR endpoint or critical effect, evidence is assessed to determine if the hazardous substance has DR effects.**

2a – An RfV protective of DR toxicity is available or can be determined with available information.

2a1 – The best available RfV (following the Framework) is based on DR toxicity (DR RfV). Determine appropriate DR receptor in Step 3 then proceed to step 4a1.

2a2 – The best available RfV (following the Framework) is a nonDR RfV. However, a DR RfV that meets the best available considerations is either available or can be determined.

- If Tier 1-3 DR RfV is available, determine appropriate DR receptors in Step 3 then proceed to step 4a2.
- If Tier 1-3 DR RfV is unavailable and information is sufficient to determine a DR RfV, derive the value and note it as Tier 4. Determine appropriate DR receptor in Step 3, then proceed to step 4a2. In this case, the MDEQ will provide an opportunity for stakeholders to give feedback on the data and methodology used to develop the toxicity value, per CSA Recommendation 1.3.

2a3 – Best available science indicates hazardous substance has DR toxicity, but an RfV specific for DR toxicity cannot be determined at this time. Evaluate if the best available nonDR RfV includes extrapolation (data-derived extrapolation factors [DDEF] or uncertainty factors [UF]) that adequately addresses DR toxicity.

- If so, use nonDR RfV and proceed to step 4b
- If not, apply an appropriate DDEF or UF to the nonDR RfV (EPA, 2014) and proceed to step 4b. Note that other preferred approaches may be available to adequately protect for DR toxicity for some hazardous substances (e.g., use of a surrogate chemical with similar structure or other toxicological characteristics).

2b - There is insufficient information to evaluate if hazardous substance has DR toxicity. Use best available nonDR RfV and proceed to step 4b.

Documentation related to DR toxicity is an important addition to the RRD chemical file. Information should be included in the chemical worksheet and file to document the DR information and the basis for the DR RfV.

Step 3. Determine DR Receptor Based on DR RfV.

As identified in Step 2, some hazardous substances will have sufficient information to determine a DR RfV. **Based on currently available information for both toxicity and exposure, the pregnant woman (to protect her fetus) and the young child are the key receptors for DR toxicants, unless there is chemical-specific information that a different critical window of exposure is appropriate.** The receptors appropriate for the DR RfV for each land use are determined to calculate exposure pathway health-based values. For most hazardous substances this will be a young child for residential land use and a pregnant woman for nonresidential land use.

The appropriate DR receptors for a DR RfV are as follows:

Residential land use:

1. A child (0-6 years);
2. A pregnant woman (single event for mortality, structural or functional abnormalities from fetal exposure; or full-term pregnancy (280 days) average for only altered growth from fetal exposure without mortality, structural or functional abnormalities or bioaccumulative chemicals); or
3. Other early-life exposure window based on chemical-specific information where there is a narrower or different critical window of exposure to be considered (e.g., adolescent receptor, prenatal only).

Nonresidential land use:

1. A pregnant woman (single event for mortality, structural or functional abnormalities from fetal exposure; full-term pregnancy (280 days) average for only altered growth from fetal exposure without mortality, structural or functional abnormalities or bioaccumulative chemicals); or
2. Other early-life exposure window based on chemical specific information that there is a narrower or different critical window of exposure to be considered (e.g., third trimester of pregnancy, preconception, working age adolescent).
    a) For bioaccumulative DR toxicants, the appropriate receptor is a woman of child-bearing age with a chronic exposure.[209]

Site-specific criteria:

The evaluation of site-specific criteria for approval will include assessment of DR toxicity. If DR toxicity is confirmed based on this process, the appropriate receptor for the toxicity endpoint, the land use at the site, and any accompanying exposure controls will be determined.

Step 4. Calculate Noncancer Cleanup Value(s).

This step uses the appropriate exposure pathway algorithm, toxicity value(s) from Step 2, and the receptor exposure assumptions from Step 3 to calculate the noncancer value(s). Exposure pathway algorithms for developmental receptors are provided in Appendix B. The noncancer health-based value(s) will be compared to the cancer value(s) (if available) to determine the final health-based cleanup value for the most sensitive effect, as indicated by the CSA recommendations.

[209] For bioaccumulative hazardous substances, the woman's body burden prior to pregnancy contributes more of an impact to the developing fetus than her exposure during pregnancy. See Appendix A for more information.

4a1 – Best available DR RfV only. Calculate noncancer exposure pathway health-based value using the best available DR RfV (Step 2a1) and the appropriate DR receptor (Step 3). Proceed to step 5a1.

4a2 – Best available NonDR RfV and DR RfV available. Calculate noncancer exposure pathway health-based values using both:

a) Best available nonDR RfV and the applicable receptor considering hazardous substance and land use (in most cases the default age-adjusted for residential land use and the default worker for nonresidential land use); and
b) Best available DR RfV (Step 2a2) and the appropriate DR receptor (Step 3).

The lower of the calculated values is the noncancer exposure pathways health-based value that protects for the most sensitive noncancer endpoint. Proceed to step 5a2.

4b - Calculate noncancer exposure pathway value using the best available nonDR RfV and the appropriate receptor considering hazardous substance and land use (e.g., in most cases typical generic receptors and exposure assumptions). Proceed to step 5b.

Step 5. Determine Final Health-based Value and Document DR Toxicity Information and Compliance Considerations.

The final health-based value is the lowest of the calculated cancer, DR noncancer, or nonDR noncancer cleanup values. Once the final criterion for the hazardous substance and exposure pathway has been determined, documentation related to DR toxicity is an important addition to the chemical file. **Identification of appropriate compliance considerations (e.g., averaging media concentrations over time) and priority setting with future updates of cleanup criteria should be included in the chemical file or worksheet.**

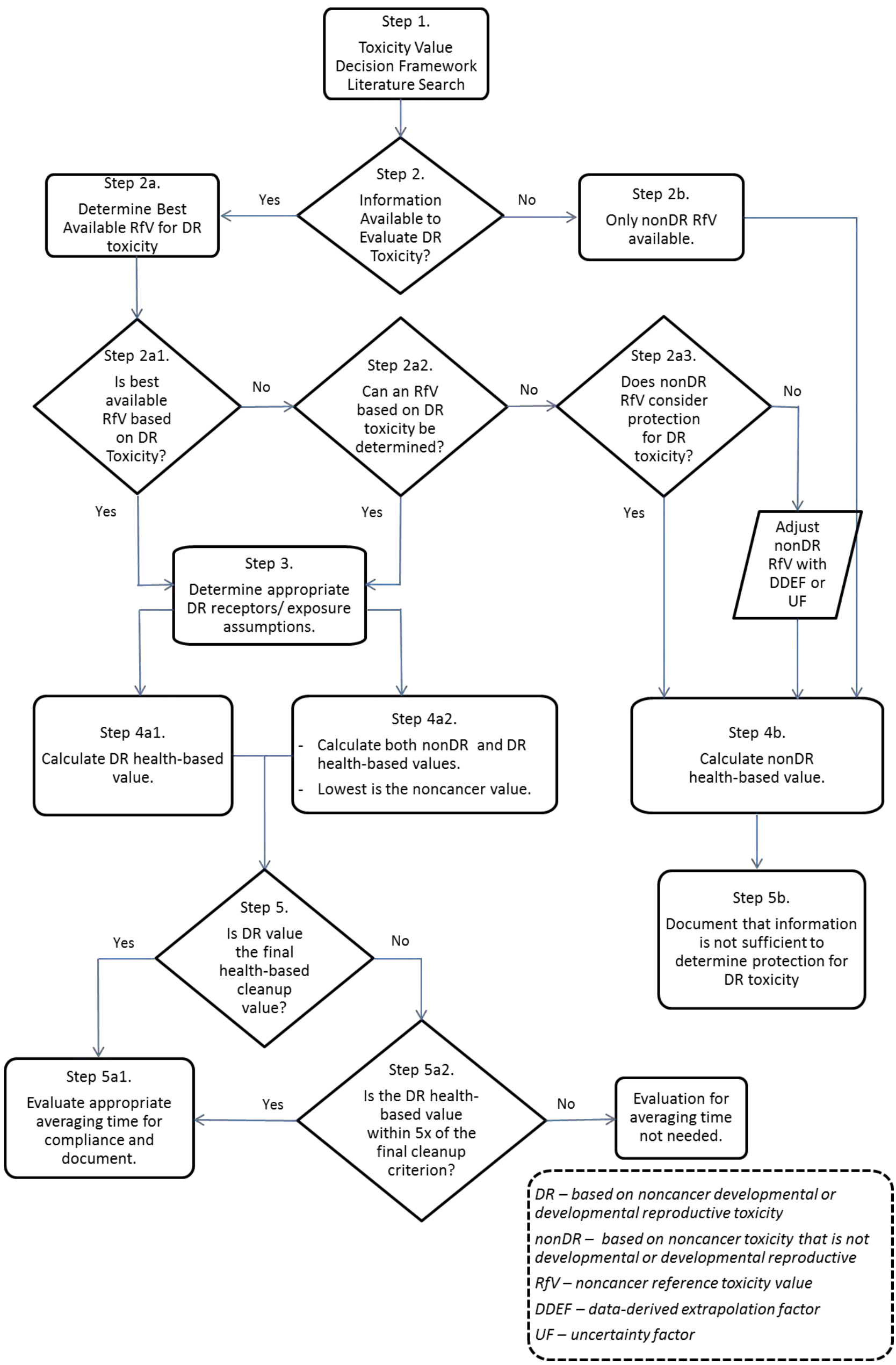
For some DR toxicity, single event prenatal exposures may result in adverse effects such as mortality and structural or functional abnormalities. As a result, it is not appropriate to average environmental media concentrations over time to compare to criteria. This applies to both residential and nonresidential land use. Although a child receptor typically has the lowest calculated value for generic residential land use, the criteria are also intended to protect for exposure to a pregnant woman in a residential setting. When chemical-specific information indicates that a different critical exposure window is appropriate, that critical exposure window should be the averaging time for environmental media concentrations.

5a1 – If a final criterion for the most sensitive effect (noncancer or cancer) is based on DR toxicity, documentation (e.g., criteria table footnote) will identify if evaluation of environmental media concentrations should be averaged over time. Hazardous substances that cause mortality, structural or functional abnormalities from fetal exposure are identified as single event DR toxicants. Hazardous substances that are bioaccumulative chemicals or are chemicals that cause altered growth from fetal exposure without mortality, structural or functional abnormalities are identified as full-term DR toxicants.

5a2 – If a final criterion for the most sensitive effect is based on an endpoint (noncancer or cancer) other than DR toxicity, but the calculated value using the DR RfV (if available) is based on mortality or structural or functional abnormalities and is less than five times higher than the final criterion, consider if it is appropriate to average environmental media concentrations over time as described above and document as appropriate. The five times value is based on consideration of exposure assumptions for average as compared to high end (to represent a single day or shorter term exposure) reported in Exposure Factors Handbook (EFH) (EPA, 2011).

5b – Document that the hazardous substance has insufficient information to determine if the criteria are adequately protective for DR toxicity. Identify the hazardous substance for a priority literature search for future criteria updates.

Figure 2. Process Flowchart to Address DR Toxicity in the Derivation of Generic Cleanup Criteria



References

CSA (Criteria Stakeholder Advisory Group), 2014. Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria. Prepared by Public Sector Consultants for Michigan Department of Environmental Quality. Lansing, Michigan. http://www.michigan.gov/documents/deq/deq-rrdCSAFinalReport-11-26-14_475701_7.pdf.

EPA (U.S. Environmental Protection Agency), 1991. Guidelines for Developmental Toxicity Risk Assessment. Federal Register 56(234):63798-63826. https://www.epa.gov/risk/guidelines-developmental-toxicity-risk-assessment.

EPA, 2006. A Framework for Assessing Health Risk of Environmental Exposures to Children. National Center for Environmental Assessment, Office of Research and Development, Washington, DC; EPA/600/R-05/093F http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=22521.

EPA, 2011. Exposure Factors Handbook – 2011 Edition. Office of Research and Development, Washington, D.C. EPA/600/R-090/052F. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

EPA, 2014. Guidance for Applying Quantitative Data to Develop Data-Derived Extrapolation Factors for Interspecies and Intraspecies Extrapolation. Risk Assessment Forum, Office of the Science Advisor, Washington, DC; EPA/100/R-14/002. http://www2.epa.gov/sites/production/files/2015-01/documents/ddef-final.pdf.

MDEQ, 2015. Michigan Department of Environmental Quality, Response to Recommendations, Criteria Stakeholders Advisory Group Final Report. MDEQ, Lansing, Michigan. http://www.michigan.gov/documents/deq/deq-rrd-CSA-DEQRRDResponseToCSAReport_495689_7.pdf.

WHO (World Health Organization), 2011. Summary of Principles for Evaluating Health Risks in Children Associated with Exposure to Chemicals. World Health Organization, Geneva, Switzerland. http://www.who.int/ceh/health_risk_children.pdf?ua=1.

APPENDIX A

SUBJECT: <u>TECHNICAL SUPPORT DOCUMENT:</u> CRITERIA TO ADDRESS DEVELOPMENTAL-REPRODUCTIVE TOXICITY

Developed under:
MCL 324.20120a(4) *…If a hazardous substance poses a risk of both cancer and 1 or more adverse health effects other than cancer, cleanup criteria shall be derived under this section for the most sensitive effect.*

MCL 324.20120b(2) *Site-specific criteria approved under subsection (1) may, as appropriate:*
- *(b) Alter any value, parameter, or assumption used to calculate generic criteria, with the exception of the risk targets specified in section 20120a(4).*

R 299.34(3) *The department may calculate generic cleanup criteria for certain hazardous substances using exposure assumptions other than those shown in the algorithms in these rules if either of the following conditions is satisfied:*
- *(a) A hazardous substance causes an adverse effect in a sensitive subpopulation that is not adequately protected or represented by the generic exposure assumptions.*
- *(b) The toxicokinetics of a hazardous substance are not best represented by the average daily dose, when accounting for the most sensitive effect.*

Key definitions for terms used in this document:

Critical window of exposure: The developmental period when vulnerability to exposures is increased and can result in developmental effects (EPA, 2006a). (Also termed as critical windows of development or windows of vulnerability.)

Developmental toxicity: The occurrence of adverse effects on the developing organism that may result from exposure prior to conception (either parent), during prenatal development, or postnatally to the time of sexual maturation. These adverse effects can be manifested in various ways (death of the developing organism, abnormality, altered growth, or functional deficiency) over the lifespan of the organism (EPA, 1991a).

Lifestages: Temporal stages of life that have distinct anatomical, physiological, and behavioral or functional characteristics that contribute to potential differences in vulnerability to environmental exposures (EPA, 2006a). This term is also defined as a distinguishable time frame in an individual's life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth (http://www2.epa.gov/children).

Process Document: Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria (MDEQ, 2015b)

Reproductive toxicity: The occurrence of biologically adverse effects on the reproductive systems of females or males that might result from exposure to harmful substances in the environment. The toxicity may be expressed as alteration to the female or male reproductive organs, the related endocrine system, or pregnancy outcomes. The manifestation of such toxicity may include, but not be limited to, adverse effects on onset of puberty, gamete production and transport, reproductive cycle normality, sexual behavior, fertility, gestation, parturition, lactation, developmental toxicity, premature reproductive senescence, or modifications in other functions that are dependent on the integrity of the reproductive systems (EPA 1996a). ***This Technical Support Document and the associated Process Document is intended to address reproductive effects that occur after early-life exposures (from preconception through adolescence).***

Introduction

This Technical Support Document (TSD) presents supporting information for the following document: Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria (Process Document). Together, these documents fulfill recommendations of the Criteria Stakeholder Advisory Group (CSA) that convened in 2014 to address updates to the Part 201 Generic Cleanup Criteria (CSA, 2014).

The generic cleanup criterion is required to be protective of the most sensitive health endpoint for the hazardous substance and exposure pathway. Evaluation of potential DR toxicity is essential to make sure that the generic cleanup criteria achieve this requirement. The CSA and the MDEQ have identified a Toxicity Value Decision Framework (MDEQ, 2015a) that RRD will use in determining the best available toxicity values for calculating cleanup criteria as identified in the Process Document.

Early-life receptors (e.g, child, pregnant woman and her fetus) are not a subpopulation, but a lifestage that occurs for the entire population. Although most chemicals have very limited or no data associated with early-life exposure, more focus at the national and international levels on adverse effects from exposures during these lifestages has occurred since the 1990s (EPA, 2006a; WHO, 2011). Early-life receptors have distinct vulnerability to environmental chemicals, compared to adult receptors, due to different exposures and for some chemicals, unique sensitivity to adverse effects. Early-life exposures may result in health effects that manifest either in early-life or in adulthood. There is a growing body of research on developmental origins of adult health and disease that includes exposures to chemicals, as well as other stressors such as nutritional imbalance (Aagaard-Tillery *et al.*, 2008; Barker *et al.*, 2002; Barker, 2012; Byrne and Phillips, 2000; Calkins and Devaskar, 2011; Faulk and Dolinoy, 2011; Fox *et al.*, 2012; Gluckman *et al.*, 2006; Grandjean *et al.*, 2015; Heindel *et al.*, 2015; McMillen *et al.*, 2008; Power *et al.*, 2013; Robinson, 2001). A risk assessment for environmental health effects in children includes information on exposures at each stage of development and on a broad range of outcomes, provided data are available.

The EPA and World Health Organization (WHO) recommend integration of toxicity and exposure at various early lifestages, but have not yet provided sufficient guidance on how to use

existing data for this approach (EPA, 2006a, 2014a, 2014c; WHO, 2006; WHO 2011). EPA's *Risk Assessment Guidance for Superfund* (RAGS) and soil screening guidance documents (EPA, 1989, 1991, 1996a, 1996b, 2002c) contain specific language to account for sensitive subpopulations or children specifically.

The EPA Regional Screening Levels (RSLs) (EPA, 2015a) for noncarcinogenic hazardous substances for residential drinking water, soil, and ambient air use a child receptor (ages 0-6 years). EPA uses a child receptor for the residential RSLs for all hazardous substances to account for the child's increased exposure. Since EPA does not treat chemicals with DR toxicity differently from other chemicals, the associated guidance does not include a separate process for incorporating DR toxicity information to developing health risk-based screening levels or criteria. Although the RSL guide specifies the equations for deriving RSLs for chemicals with mutagenic effects, there are no similar equations specific to noncancer DR endpoints since a child receptor is already used for noncancer endpoints for residential land use.

In the past, risk assessment had been typically based on adult toxicity and exposure data. Most EPA guidance now includes early-life exposures either explicitly, by requiring consideration of children or early-life exposures (EPA, 1991a, 1995a, 2006a, 2006b, 2006c, 2014; FQPA, 1996; EPA R9, 2015), or implicitly, by addressing susceptible subpopulations and/or early lifestages (EPA, 1989, 2002b, 2014a, 2014c). The CSA final report (CSA, 2014) recommends consideration of EPA guidance when developing generic cleanup criteria. The CSA specifically identified the *Framework for Human Health Risk Assessment to Inform Decision Making* (EPA, 2014c) (2014 Framework) as a document to consider for Generic Criteria updates. The 2014 Framework identifies the EPA resources listed below for considering early-life toxicity and exposures. **It is recommended that risk assessors refer to the EPA resources, including those listed below, when identifying Tier 1-3 and setting Tier 4 values for DR toxicity:**

1. *Guidelines for Developmental Toxicity Risk Assessment* (EPA, 1991a) explains how "to assess the risks for developmental toxicity from exposure to environmental agents." Manifestations of developmental toxicity include altered survival, structure, growth; and functional deficits. This document provides considerations for evaluating predominantly prenatal developmental toxicity studies and, to a lesser extent, considerations for exposure assessment.
2. *Guidelines for Reproductive Toxicity Risk Assessment* (EPA, 1996a) "provides guidance for assessing the effects of environmental agents that might adversely affect human health, including the reproductive system." However, this document does not include how risk assessment should be conducted for these agents.
3. *A Framework for Assessing Health Risks of Environmental Exposures in Children* (EPA, 2006a) is a conceptual overview of considerations for evaluating early-life exposures and subsequent outcomes. Although not a step-by-step process document, it provides a list of questions to consider with each step of the risk assessment process, many of which are specific to developmental toxicants and early-life exposures. These questions may be appropriate to consider in evaluating potential DR toxicants. However, some

questions are only applicable for chemicals with robust datasets or in circumstances where additional studies will be conducted.

4. *Guide to Considering Children's Health when Developing EPA Actions: Implementing Executive Order 13045 and EPA's Policy on Evaluating Health Risks to Children* (EPA, 2006c) (2006 Rulemaking Guide) includes guidance for EPA rulemaking and other policy development that involve human health risks and how to comply with requirements for children's health considerations. The 2006 Rulemaking Guide describes a broad range of early-life, prenatal and postnatal exposures including:
    a) Parental exposure prior to conception
    b) Maternal exposures during pregnancy
    c) Exposures during infancy and childhood
5. The 2008 edition of the *Child-Specific Exposure Factors Handbook* (CSEFH) (EPA, 2008) focused on child's exposure data for many exposure pathways. Significant amounts of comprehensive data regarding exposure during early lifestages are available in the most recent *Exposure Factors Handbook* (EFH) (EPA, 2011a), including data from the CSEFH.
6. *Next Generation Risk Assessment: Incorporation of Recent Advances in Molecular, Computational, and Systems Biology* (EPA, 2014a) describes evaluation of adverse outcomes with various predictive tools including high throughput *in vitro* screening of chemicals' toxicity; determining differing susceptibilities including age, health status and genetics; and developing various computer and biological models predicting kinetic and/or dynamic toxicological processes. (In its final report, the CSA recognized that toxicity studies are evolving with these high throughput methods and other predictive tools [MDEQ, 2014].) Many of these emerging risk assessment tools are likely to aid the assessment of potential developmental toxicants.

The National Academy of Science, National Research Council (NAS/NRC) has advisory documents related to EPA risk assessments that provide advice for accounting for early-life exposures. In its final report (MDEQ, 2014), the CSA recommended consideration of the 2014 NAS/NRC Review of EPA's Integrated Risk Information System (IRIS) Process (NRC, 2014). The NAS/NRC document recommends that EPA continue developing a systematic review process for chemical toxicity evaluations with evidence integration being a key outcome. Although the document is not focused on DR toxicity, it does consider developmental and reproductive endpoints as key components of the chemical review process.

The WHO develops Environmental Health Criteria (EHC) documents that include chemical-specific evaluations and methodologies to assess chemical risks. Early DR toxicity related EHC documents focused on testing methods for early-life susceptibilities (IPCS 1984, 1986). The more recent WHO documents provide general guidance to assess health risks to children from multiple stressors (IPCS, 2006; WHO, 2011).

The Agency for Toxic Substances and Disease Registry (ATSDR) addresses health risks to children within many of their evaluations and when setting MRLs, although guidance specific to addressing chemicals with DR toxic effects is not available at this time.

Many state agencies have established special measures to address child and other early-life susceptibility by using a child receptor in calculating residential cleanup levels. Other examples of state agencies that have specifically addressed early-life exposures include:

1. Minnesota has developed short-term drinking water health reference levels for chemicals with developmental effects; [http://www.health.state.mn.us/divs/eh/risk/rules/water/index.html]
2. Massachusetts has developed immediate and urgent response action levels for trichloroethylene (TCE) based on developmental toxicity (fetal cardiac malformations). [http://www.mass.gov/eea/docs/dep/cleanup/laws/tcestat.pdf; http://www.mass.gov/eea/docs/dep/cleanup/laws/tcevalsm.pdf] Massachusetts also addresses greater exposure to air pollutants for children by using adjustment factors until a more specific approach is developed;
3. California has modified toxicity values to address exposure of school children; and [http://oehha.ca.gov/public_info/public/kids/]
4. Oregon has included breastmilk exposure as part of the risk assessment for polychlorinated biphenyls (PCBs), based on developmental endpoints. [http://www.deq.state.or.us/lq/pubs/docs/cu/HumanHealthRiskAssessmentGuidance.pdf]

The CEHS and TSG note that EPA and many other states address the increased exposure for children by using a child receptor as the default residential receptor for all chemicals, including those chemicals lacking information on developmental toxicity. For most chemicals, information on developmental toxicity is not available and using a child receptor only for identified developmental toxicants could be a disincentive for generating and synthesizing this type of information. Additionally, there is a growing body of literature on the developmental origins of adult disease that includes early-life exposures to environmental chemicals (Grandjean *et al.*, 2015; Heindel *et al.*, 2015). Increased toxicity can occur from increased exposure alone, and does not require increased sensitivity to adverse effects. It is well documented that young children have increased exposure to most environmental media. Adult exposure assumptions contribute more than 80% of the averaging time for some of the age-adjusted receptors, and as a result, do not adequately address the increased exposure during early life. As additional data, guidance, and other changes in risk assessment approaches become available, reconsideration of the child as the default receptor for residential land use should be part of any future MDEQ criteria updates.

Identifying Hazardous Substances with DR Toxicity

Hazard identification involves determining if a hazardous substance can cause adverse health effects in humans and what those effects might be (EPA, 2006c). The simplest way to identify if a hazardous substance has DR toxicity is to determine if the endpoint or critical effect for an existing toxicity value is from dosing or exposure during an early-life stage.

Per the CSA recommendations (CSA, 2014), the MDEQ-RRD generates toxicity values based on the Toxicity Value Decision Framework (MDEQ, 2015a) as outlined in the Process

Document. **If a previously identified noncancer toxicity value is not based on a DR endpoint or critical effect, evidence should be assessed to determine if the hazardous substance has DR effects.** This includes determining whether the EPA, ATSDR, WHO, European Union, Canada, or other states have a toxicity value based on DR endpoints or have listed the chemical as a DR toxicant and reviewing the published literature. **A literature search strategy specific to DR toxicity may need to be developed to ensure that relevant noncancer toxicity values and/or studies are located and evaluated.**

Hazard identification typically is based on animal toxicity testing or, in some cases, human epidemiology studies. Most animal toxicity tests do not provide information on developmental toxicity as they are conducted on adult animals. A limited number of chemicals have been evaluated with animal toxicity testing protocols that provide information on DR adverse effects. Most of these testing protocols are focused on prenatal and/or early postnatal (including lactation) exposures. Experimental animal studies of exposure during the juvenile period are rare. Only multigenerational reproductive testing protocols include exposures from prenatal through the post-weaning lifestages of the offspring. These studies are focused on reproductive success of the parental generation and offspring generation(s), with only gross findings typically reported for other organs or systems. Therefore, there is a paucity of toxicity information for exposures from post-weaning to sexual maturity, especially for non-reproductive, developmental endpoints (EPA, 2002a; EPA, 2006a). However, due in part to the Children's Health Centers established by the National Institute of Environmental Health Sciences and the EPA [http://epa.gov/ncer/childrenscenters/], there has recently been an increase in the number of developmental toxicity studies, some of which include cohorts of children. Some studies are evaluating exposures over more than one lifestage, thus it is anticipated that this new research will inform the risk assessment process for DR toxicants.

Developmental effects in animal models may demonstrate a similar or different pattern of developmental perturbation than those seen in humans for the same chemical or class of chemicals. There is usually at least one species that mimics the adverse effect observed in humans, but other species may elicit another of the four manifestations (i.e., death, structural abnormalities, growth alterations, and functional deficits) of developmental toxicity in the same organ or system. Every species may not react the same due to species-specific characteristics in critical periods, differences in timing of exposure, metabolism, developmental patterns, placentation, or mechanism of action (EPA, 1991a). There is no simple temporal comparison across species which varies by organ system and there is not any one laboratory species most similar to humans for developmental effects (Felter *et al*, 2014).

There are some hazardous substances that have sufficient epidemiological data to determine hazard and, in a subset of these chemicals, dose-response. Most of these data are related to occupational (i.e., adults only) exposures. There are some cohorts that include exposures during pregnancy and fewer that include childhood exposures. Study power is crucial to the appropriate interpretation of epidemiological data; these studies typically require thousands of participants to reveal a modest increase in risk. Confidence in findings requires careful control of bias as well as other risk factors, effect modifiers, and confounders (EPA, 1991a). Note that

women's pre-pregnancy/lactation exposure to bioaccumulative, DR toxicants (e.g., PCBs, dioxin-like chemicals, mercury) can extend to the developing fetus and child as a result of placental transfer and breast milk contamination, even after exposure to the mother has terminated (Baccarelli *et al*, 2008; EPA, 2012; Oregon DEQ, 2010).

Prenatal or lactational exposures that result in developmental adverse effects may also show minimal maternal toxicity at the same dose. Adverse developmental effects should not be automatically discounted as secondary to maternal toxicity. At doses causing excessive maternal toxicity, an evaluation of developmental effects may be more difficult. Even if developmental effects are secondary to maternal toxicity, the maternal effects may be mild and/or reversible, but the developmental effects on the offspring are likely permanent (EPA, 1991a). If there are maternal effects at a lower dose than that observed with adverse effects in the offspring, an evaluation of the dose/response for the pregnant female receptor is necessary as compared to other nondevelopmental adverse effects. A pregnant female receptor may be more sensitive than another adult receptor (EPA, 1991a).

Hazard identification can include information on a chemical that indicates that DR toxicity may be a concern, but there is not sufficient dose-response data or other information to generate a DR reference value at the time the chemical is evaluated. **This type of information should be included in the chemical's file to: 1) document criterion is protective of the most sensitive effect; 2) consider appropriate application of extrapolation factors (e.g., data-derived extrapolation factors [DDEFs] or uncertainty factors [UFs]); 3) identify appropriate compliance considerations (e.g., media concentration averaging over time); and 4) establish priority for future updates of cleanup criteria.** Newer high-throughput toxicity testing may also allow better prioritization of chemicals for evaluation of DR toxicity.

Determining the Appropriate Toxicity Value

Dose-response analysis evaluates the quantitative relationship between dose and toxicological responses (EPA, 2006c). These evaluations typically identify threshold exposure levels that are "likely to be without significant harm". In some cases (e.g., lead, arsenic) a threshold may be difficult to determine (EPA, 1991a). Mechanism of action information can help inform the assumption of a threshold. RfVs represent acceptable doses or concentrations and are intended to protect the susceptible individuals in a population from the critical toxic endpoint.

Previously developed noncancer toxicity values (Tier 1-3 sources) based on DR endpoints or effects should be evaluated. Tier 4 derivation of a DR toxicity value will only be necessary if there is not a DR toxicity value from the preferred Tier 1-3 sources and/or if newer data demonstrates that the hazardous substance exhibits DR toxicity.

The DR RfV is determined by dividing a point of departure (POD) value by appropriate DDEFs or UFs, described below. The POD is often the No Observed Adverse Effect Level (NOAEL) or Lowest Observed Adverse Effect Level (LOAEL) found in an animal study, but, in certain circumstances, the Benchmark Dose (BMD) or Benchmark Concentration (BMC) approach may

be applied. Regardless of the source, the POD represents the dose below which no or negligible DR effects are expected to be observed.

Once a NOAEL/LOAEL or BMD/BMC is identified, risk assessors determine appropriate extrapolation factors (e.g., DDEFs, UFs) (EPA, 2014d) for applying the study derived dose for human health risk. Considerations for appropriate DDEFs include:

1. Variability in the human receptor population and the study subject population;
2. Information related to toxicokinetic or toxicodynamic differences between the study subjects and the human receptor population including age-specific differences (e.g., physiologically-based pharmacokinetic model [PBPK] or other biological models); and
3. Uncertainties associated with the key study and/or available studies or information.

When there is insufficient information for a hazardous substance to use DDEFs, UFs are used, to derive the RfD, RfC, or MRL. UFs are generally 1, 3, or 10-fold. The UFs account for:

1. Intraspecies (human interindividual) variability (UF_H);
2. Interspecies (animal-to-human) variability (UF_A);
3. Extrapolation of subchronic experimental exposure to chronic "real-life" exposure (UF_S) – this UF may not be necessary for DR toxicants when the adverse effect is related to less-than-chronic exposure;
4. Extrapolation of a LOAEL to a NOAEL(UF_L); and
5. Inadequate or insufficient database – to protect against the probability of certain sensitive adverse effects (UF_D).

Note that UFs do not address differences in *exposure* between an adult and a child. The derivation of criteria considers both toxicity and exposure. **Therefore, a nonDR RfV that is lower than a DR RfV for the same chemical may not necessarily result in the most protective criteria if the DR receptor has greater exposure.**

Toxicity assessment will continue to evolve with more in-vitro, high throughput studies that can evaluate chemicals rapidly and provide a better understanding of mechanisms and species differences that affect extrapolation. As more of this information is generated, it will result in less uncertainty and better computer modeling to aid risk assessment. Recognizing these potential evolving alternatives and alternative approaches already in use, risk assessors may determine that another approach is appropriate for establishing whether a hazardous substance has or is likely to have DR effects even when there is not sufficient hazardous substance-specific data to develop a DR RfV. Other approaches to consider include:

1. Combining *in vitro* or *in vivo* screening studies or mechanistic data with dose extrapolation (e.g., PBPK model or other biologically-based model);
2. Using hazardous substance(s) with similar structure and toxicity characteristics as a surrogate. Use the surrogate chemical's dose-response data with molar adjustment or another between-chemical extrapolation approach to predict a POD (e.g., read across, relative potency factors);

3. Other approaches as determined appropriate by the MDEQ; or
4. Applying a DDEF or database gap uncertainty factor (UF_D) to the nonDR RfV to protect for DR toxicity until sufficient dose-response data is available. **An appropriate DDEF or UF_D should be used if the other approaches are not available or plausible.**

Ideally, dose-response evaluations consider if chemical-specific information is available regarding differential toxicokinetics or other biological influences that may impact developmental receptors. As an example, a PBPK model can account for different toxicokinetics between the animal model used in the toxicity study and the human child receptor. Toxicokinetic considerations should be appropriate for the lifestage(s) assessed for the DR endpoint and receptor. Validated PBPK models can provide a better estimate of the intake dose required to yield the tissue dose associated with the critical endpoint, thereby decreasing uncertainty in the assessment (i.e., may use a DDEF).

For some chemicals, it is appropriate to use other acceptable health protective chemical standards or concentrations in lieu of a DR RfV (e.g., Centers for Disease Control and Prevention Blood Lead Level goal, National Ambient Air Quality Standards). In addition, there may be models that are used as part of the dose-response assessment (e.g., biologically-based dose-response models) or for both the dose-response and exposure assessment (e.g., the EPA lead models).

Dose-response assessment for the inhalation pathway requires special consideration. The EPA (2009) recommends that risk assessors use the concentration of the chemical in air (e.g., milligram per cubic meter or mg/m^3) rather than a dose based on inhalation rate and body weight (e.g., milligram per kilogram per day or mg/kg-day) as the exposure metric in equations for calculating risk-based concentrations, in order to be more consistent with the EPA dosimetry guidance (1994). The EPA (2009) clarifies that IURFs and RfCs used in the risk-based concentration equations are for continuous (24 hours per day [hr/d]) exposure. If the exposure scenario of interest is less than 24 hr/d, the exposure time in hr/d should be used in the equations and the averaging time should be in units of hours. POD concentrations from animal studies (e.g., 6 hr/d, 5 days per week) are typically adjusted for continual exposures (i.e., 24 hr/d, 7 days per week) as a default procedure for repeated-dose exposure studies. For most DR toxicants with a shorter critical window of exposure, however, this continual exposure adjustment may not be appropriate. Both the inhalation unit risk factor (IURF) and reference concentration (RfC) derivations rely on the extrapolation of experimental concentrations to human equivalent concentrations via the dosimetry guidance. Human equivalent concentrations are determined by applying a dosimetric adjustment factor to the POD concentration from an animal study. The dosimetric adjustment factor is typically based on ratios of animal and adult human physiologic parameters, for particles and gases.

The accounting for potential DR effects in dose-response assessment for the inhalation exposure pathway may be best demonstrated by way of example. TCE has an RfC of 2 micrograms per cubic meter ($\mu g/m^3$) (EPA, 2011b). The EPA does not assign ATs to RfCs, and they do not typically explicitly address concerns for short-term excursions above the RfC.

However, in this particular case, one of the two key studies supporting the RfC is a developmental study (Johnson *et al*., 2003) in which drinking water exposures to pregnant rats during gestation days 1-22 resulted in an increase in cardiac malformations in the offspring. EPA (2011b) derived the RfC from this developmental study using a $BMDL_{01}$ for the POD and a composite UF = 10, consisting of an UF_A= 3 for toxicodynamic uncertainty and UF_H= 3 for possible toxicodynamic differences in sensitive humans. Note that a UF_S= 1 was assigned. A higher UF_S was not utilized in deriving the RfC for protection for lifetime exposures, even though the exposure period was only on gestation days 1-22, because, "…the exposure is considered to adequately cover the window of exposure that is relevant for eliciting the effect" (EPA, 2011b). EPA (2011c) further explains that, "For some reproductive and developmental effects, chronic exposure is that which covers a specific window of exposure that is relevant for eliciting the effect, and subchronic exposure would correspond to an exposure that is notably less than the full window of exposure." EPA (2014b) provides further guidance and information on TCE, including, "In most cases, it is assumed that a single exposure at any of several developmental stages may be sufficient to produce an adverse developmental effect, but the RfC for a single exposure hasn't been determined yet by EPA."

The MDEQ Air Quality Division has established an initial threshold screening level for TCE that is consistent with the EPA RfC, and has applied a 24-hour averaging time (AT), as it is prudent to ensure protection from potential developmental effects as demonstrated in the study by Johnson *et al*. (2003). It is recommended that MDEQ cleanup criteria for the TCE inhalation pathway likewise focus on the acute dose-response and exposure potential by ensuring that airborne exposures do not exceed 2 $\mu g/m^3$ with a 24-hour AT. **This can be accomplished by adjustments to the AT, exposure duration (ED), and exposure frequency (EF) in the Part 201 algorithms that reflect a 24-hour period, and by ensuring that measurements and modeling of potential exposure levels have accounted for peak 24-hour concentrations rather than just long-term average concentrations.**

<u>Evaluating Exposures for Early-life Receptors</u>

Exposure assessment estimates the levels of the hazardous substances that come in contact with children and other populations of concern (EPA, 2006c). Most DR toxicity studies evaluate effects on the developing fetus. The pregnant woman is the receptor of interest to protect for adverse effects on the developing fetus. Current guidance and information indicates that the young child is also susceptible to DR toxicity, although the database for toxicity studies during this lifestage is not robust. **Based on currently available information for both toxicity and exposure, the pregnant woman and the young child are the key receptors for DR toxicants, unless there is chemical-specific information that a different critical window of exposure is appropriate.** As an example, hazardous substances that are bioaccumulative will build up over time in the receptor. For these bioaccumulative hazardous substances, the woman's body burden prior to pregnancy contributes more of an impact to the developing fetus than her exposure during pregnancy (EPA, 2012). Exposure assumptions should be consistent with the dose-response assessment that accounts for this bioaccumulation. **In most cases, although the child will still be the appropriate receptor for residential land use, the pregnant woman should also be evaluated for any land use and woman of child-bearing**

age for bioaccumulative DR toxicants. Evaluation of lactational exposure may also be important for many bioaccumulative DR toxicants (Oregon DEQ, 2010).

The available guidance (EPA, 1991a, 2006a; WHO, 2006) and published literature identify multiple lifestages that need to be addressed. The timing of chemical exposure may have different consequences to children's health. There are differing windows of sensitivity for the same chemical and dose during different periods of development. Windows of early-life susceptibility may be broad and can extend from preconception through the end of adolescence (EPA, 2006a; WHO, 2011). There may be shorter critical windows for certain organs or organ systems given a specific chemical and/or adverse outcome. **When the "critical window of exposure" is established or identified for a chemical, the exposure assumptions should be modified accordingly.**

It is known that a developing fetus is more susceptible to certain chemicals. There are sufficient data for many hazardous substances demonstrating that adverse endpoints can result after a single day or shorter exposure during prenatal development (EPA, 1991a; EPA,1992; EPA, 1996a; EPA,1998). Mortality, structural or functional abnormalities (terata) are adverse effects that are most likely to occur from an acute or single event fetal exposure (EPA, 2002a; EPA, 2015c; Barone, 2016). Structural or functional abnormalities that require consideration of a single event include developmental neurotoxicity (EPA, 1998). **Following EPA guidance (EPA, 1991a; EPA, 1992; EPA, 1996a; EPA, 2006a), if the specific time frame of exposure for effects is unknown, then a single day or event should be assumed as the critical window for prenatal exposures with adverse effects including mortality, structural or functional abnormalities (EPA, 2015c; Barone, 2016). An average exposure during the full-term of the pregnancy (280 days) can be considered for prenatal exposures with adverse effects that result in only altered growth (e.g., reduced birth weight, delayed ossification) without structural or functional abnormalities (EPA, 2015c; Barone, 2016).**

Although there are clear examples of infant or childhood susceptibility (e.g., nitrate/nitrite, lead), the database of hazardous substances assessed for adverse effects during infancy or childhood is not robust. As a result, there is not sufficient information to inform whether a narrow or broad critical window is appropriate for early childhood exposures. There is no clear guidance from EPA except that the RSLs are based on a young child exposure duration (0-6 years), although this approach is used without consideration of DR toxicity. **Until additional information or guidance becomes available, the EPA approach of averaging child exposure over 0-6 years of age is appropriate for residential exposures and hazardous substances with DR toxicity, unless there is chemical-specific information for a different critical window.**

If the critical effect of a hazardous substance has sufficient data to determine that the specific critical window of exposure in humans is different than averaging over 0-6 years for the young child or a single day for the pregnant female, then that information may be used to develop age-specific exposure assumptions for the specific critical window of exposure sensitivity. In most cases, there will not be sufficient information to eliminate concerns for potential susceptibility of other early-life stages for the chemical. For single day, acute, or other short-term exposures,

assumptions for average exposure should be evaluated for adequate health protection. In some instances, a higher end assumption may be appropriate, while still balancing the exposure assumptions to assure the overall assessment is relevant and reasonable for the acute or short-term exposure under consideration. **If exposure assumptions appropriate to a shorter-term critical window documented for a chemical will result in more protective criteria, then those assumptions should be used with the corresponding dose/response assessment.**

The EPA RSLs (EPA, 2015a) for residential land use are derived based on a child receptor since children are more susceptible to toxic effects due to greater exposure per unit body mass. As such, EPA has not developed a special process for RSLs specific to DR hazardous substances using a child receptor. In the case of pregnant female workers, the EPA does not have general guidance for addressing the risk of exposure of this sensitive subpopulation to DR toxicants. However, the EPA has made recommendations to consider the first trimester of pregnancy for TCE inhalation exposure to protect for fetal cardiac malformations (EPA R9, 2014) and the recently released EPA guidance (2015b) for vapor intrusion also supports the evaluation of short-term and acute effects with trichloroethylene as an example. Other EPA programs (e.g., Federal Insecticide, Fungicide, and Rodenticide Act; Safe Drinking Water Act, Clean Air Act) are also addressing risks to early-life exposures.

The equations in Appendix B are similar to those used for deriving the generic cleanup values for other noncarcinogenic endpoints and are used for deriving the generic DR cleanup values. The exposure assumptions used in the equations need to match the appropriate DR receptor (e.g., child receptor or the pregnant female receptor), as appropriate for the hazardous substance and DR RfV.

Table 1. Exposure Assumptions for DR Cleanup Values[a]

Exposure Assumptions	Residential – Child	Residential – Pregnant or Child-bearing Age Woman Single Event DR Toxicants	Residential – Pregnant or Child-bearing Age Woman[b] Full-Term DR Toxicants	Nonresidential Pregnant or Child-bearing Age Female Worker Single Event DR Toxicants	Nonresidential Pregnant or Child-bearing Age Female Worker[b] Full-Term DR Toxicants
Averaging time	2,190 days	1 day[c]	280 days	1 day[c]	280 days
Exposure duration	6 years	1 day[c]	0.767 year	1 day[c]	0.767 year
Ingestion and inhalation exposure frequency	350 days/year	1 day/day[c]	268.5 days/year	1 day/day[c]	183 days/year
Dermal exposure frequency	275 days/year	1 day/day[c]	268.5 days/year	1 day/day[c]	
Drinking water ingestion rate	0.78 L/day	1.8 L/day	1.8 L/day	0.9 L/day	0.9 L/day
Soil ingestion rate	179 mg/day	100 mg/day	100 mg/day	100 mg/day	100 mg/day
Body weight All trimesters 1st trimester 2nd trimester 3rd trimester	15 kg	 75 kg 76 kg 73 kg 80 kg	 75 kg 76 kg 73 kg 80 kg	 75 kg 76 kg 73 kg 80 kg	 75 kg 76 kg 73 kg 80 kg
Dermal exposure events	1 event/day	1 event/day	1 event/day	1 event/day	1 event/day
Skin surface area	2,400 cm^2	3,100 cm^2	3,100 cm^2	3,100 cm^2	3,100 cm^2
Skin area-weighted soil adherence factor	0.3 mg/cm^2	0.07 mg/cm^2	0.07 mg/cm^2	0.2 mg/cm^2 [c]	0.07 mg/cm^2

[a] Values based on Syracuse Research Corporation (SRC, 2015) recommendations, unless noted with [c] footnote. See SRC technical support documents for details. These values are to be used unless chemical-specific information is available that a different critical window of exposure is appropriate for a hazardous substance.

[b] For bioaccumulative hazardous substances, in addition to the child for the residential receptor, evaluate age-adjusted residential values and nonresidential worker values appropriate for nonDR toxicity for women of child-bearing age unless chemical-specific information indicates alternate exposure assumptions are appropriate.

[c] See CEHS recommendation below for value instead of SRC recommended value.

CEHS Recommendation for Pregnant or Child-bearing Age Woman Receptor
RRD requested that the Children's Environmental Health Subcommittee (CEHS) of the Toxics Steering Group evaluate the following exposure assumption recommendations for pregnant or child-bearing age workers for hazardous substances with reference values for developmental toxicity.

AT and ED are typically expressed with the following units:

- AT - days (days/year * years)
- ED - years

These parameters are set equivalent to a single day/event to account for short critical windows for developmental toxicity related to prenatal exposures with adverse effects including mortality or structural or functional abnormalities. Since this single day exposure is very different from the typical chronic exposure scenario expressed in years, the pregnant worker equations requires a change in the values and units for these parameters to a single day.

EF is typically expressed in days/year. Since the exposure is a single day, the exposure frequency is not necessary for the calculation for the pregnant worker and, optimally, could be omitted from the equation. If EF is included in the equation for the pregnant worker to be consistent with the generic equations, the value and unit should be 1 day/day. This will be consistent with the value and unit of 1 day for ED.

For the skin adherence factor (AF) for soil direct contact and the pregnant nonresidential receptor (i.e., a worker), SRC recommended the AF for residential adult soil contact activities AF (e.g., adult gardeners, farmers) rather than the nonresidential worker AF (e.g., construction workers, utility workers, equipment operators). The CEHS recommends using the same AF that is used for the generic worker be used for the pregnant nonresidential worker receptor. It is reasonable to assume a pregnant worker will have the same exposure potential for soil adherence as the generic worker, especially based on the requirements of the Pregnancy Discrimination Act of 1978 (PDA). The PDA forbids discrimination based on pregnancy including changing job assignments even if "based on fears of danger to the employee or her fetus, fears of potential tort liability, assumptions and stereotypes about the employment characteristics of pregnant women such as their turnover rate, or customer preference."[210]

<u>Calculating Generic DR Health-based Values</u>
This step uses the appropriate exposure pathway algorithm to combine the DR toxicity value(s) with the DR receptor exposure assumptions to calculate DR noncancer health-based value(s). The algorithms for calculating the noncancer health-based values for DR toxicants are shown in Appendix B.

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[210] US Equal Employment Opportunity Commission Notice 915.003, 2015. Enforcement Guidance: Pregnancy Discrimination and Related Issues.
http://www.eeoc.gov/laws/guidance/pregnancy_guidance.cfm#

Since the criteria are required to be protective of the most sensitive effect, calculated values for DR noncancer endpoints are compared to values for cancer and other noncancer endpoints. The lowest calculated value is the final health-based value for the most sensitive effect. In some cases, noncancer values will need to be calculated for both nonDR toxicity and DR toxicity.

Document DR Toxicity Information and Compliance Considerations

Consistent with the CSA recommendation for transparency regarding the basis for generic cleanup criteria, documentation of the DR toxicity evaluation is necessary. Information regarding DR toxicity will be included in the chemical's file to document that the final criterion is protective of the most sensitive effect, to identify appropriate compliance considerations (e.g., averaging media concentrations over time), or to identify that a hazardous substance does not have sufficient information to determine DR RfV and will need to be a priority for future updates of the cleanup criteria.

For DR toxicity, single event prenatal exposures may result in adverse effects including mortality or structural or functional abnormalities. As a result, it is not appropriate to average environmental media concentrations over time to compare to criteria based on these adverse effects. This applies for both residential and nonresidential land use. Although a child receptor is used for generic residential land use, these criteria are also intended to protect for exposure for a pregnant woman. When chemical-specific information indicates that a different critical exposure window is appropriate, that critical exposure window should be the averaging time for environmental media concentrations.

Since peak single event exposures will be the appropriate averaging time for many hazardous substances with DR toxicity, the CEHS evaluated the difference between long-term average and high-end (e.g., 90-95 percentile) intake rates from EFH (EPA, 2011). For most critical intake rates such as drinking water intake, the high-end intake was typically within five times the average intake rate.

The final criterion for the hazardous substance and exposure pathway may be either a cancer or noncancer value. If the final criterion is based on DR toxicity or the calculated DR health-based value is within five times the final criterion, it is important to document the appropriate averaging time or other considerations for the evaluation of environmental media data to compare to the final criterion. This information needs to be clearly identified with the published criterion, such as a footnote to the hazardous substance or criterion, as appropriate.

Documentation should identify the following:

1. If there is insufficient information to determine if the hazardous substance has DR toxicity;
2. If the hazardous substance has been evaluated for DR toxicity, but the final criterion is less than five times a calculated DR health-based value; or

3. If a final criterion is based on DR toxicity or the calculated DR cleanup value is within five times the final criterion, document if averaging environmental media concentrations is appropriate for comparison to the criterion. This may be best accomplished with a footnote for the hazardous substance or the exposure pathway criterion.

Appendix A References

Aagaard-Tillery, K.M., Grove, K., Bishop, J., Ke, X., Fu, Q., McKnight, R., and Lane, R.H. 2008. Developmental origins of disease and determinants of chromatin structure: maternal diet modifies the primate fetal epigenome. *Journal of Molecular Endocrinology* 41:91-102. Available from http://jme.endocrinology-journals.org/content/41/2/91.full.pdf+html (accessed August 2015).

Amler, S.N., DeRosa, C.T., Williams-Johnson, M.M., Jones, D.E., Amler, R.W., and Wilbur, S. 2003. Risk analysis, uncertainty factors, and the susceptibilities of children. *Human and Ecological Risk Assessment* 9(7):1701-1711.

Baccarelli, A., Giacomini, S.M., Corbetta, C., Landi, M.T., Bonzini, M., Consonni, D., Grillo, P., Patterson, D.G., Pesatori, A.C., Bertazzi, P.A. 2008. Neonatal thyroid function in Seveso 25 years after maternal exposure to dioxin. *PLoS Medicine*, 5:e161. 197059. Available from http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.0050161 (accessed November 2015).

Barker, D.J.P., Eriksson, J.G., Forsen, T., and Osmond, C. 2002. Fetal origins of adult disease: strength of effects and biological basis. *International Journal of Epidemiology* 31:1235-1239. Available from http://ije.oxfordjournals.org/content/31/6/1235.full.pdf+html (accessed August 2015).

Barker, D.J.P. 2012. Developmental origins of chronic disease. *Public Health* 126:185-189. Available from https://www.rsph.org.uk/filemanager/root/site_assets/membership/publications/xix_world_epidemiology_congress/sir_richard_doll_lecture.pdf (accessed August 2015).

Barone S. 2016. Overview of temporal considerations for risk assessment of acute scenarios. Office of Pollution Prevention and Toxics. Presented at Temporal Exposure Issues for Environmental Pollutants: Health Effects and Methodologies for Estimating Risk. January 27, 2016.

Byrne, C.D., and Phillips, D.I. 2000. Fetal origins of adult disease: epidemiology and mechanisms. *Journal of Clinical Pathology* 53:822-828. Available from http://jcp.bmj.com/content/53/11/822.full.pdf+html (accessed August 2015).

Calkins, K., and Devaskar, S.U. 2011. Fetal origins of adult disease. *Current Problems in Pediatric and Adolescent Health Care* 41(6). Available from http://ac.els-cdn.com/S1538544211000964/1-s2.0-S1538544211000964-main.pdf?_tid=65569f0c-2591-11e5-abfe-00000aacb360&acdnat=1436374390_e74c7d49f622657f30df07488d6d6a22. (accessed August 2015).

Chou, C-H.S., Holler, J., and DeRosa, C.T. 1998. Minimal risk levels (MRLs) for hazardous substances. *Journal of Clean Technology, Environmental Toxicology and Occupational Medicine* 7(1):1-24.

Cohen Hubal, E.A., de Wet, T., Du Toit, L., Firestone, M.P., Ruchirawat, Ms., van Engelen, J., and Vickers, C. 2014. Identifying important life stages for monitoring and assessing risks from exposures to environmental contaminants: results of a World Health Organization

review. *Regulatory Toxicology and Pharmacology* 69(1):113-24. Available from http://www.sciencedirect.com/science/article/pii/S0273230013001530 (accessed August 2015).

CSA (Criteria Stakeholder Advisory Workgroup). 2014. *Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria*. Lansing, Michigan: Public Sector Consultants for the Michigan Department of Environmental Quality. Available from http://www.michigan.gov/documents/deq/deq-rrdCSAFinalReport-11-26-14_475701_7.pdf (accessed August 2015).

EPA (U.S. Environmental Protection Agency), 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. Available from https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part (accessed April 2016).

EPA, 1991a. *Guidelines for developmental toxicity risk assessment*. Federal Register 56(234):63798-63826. Available from https://www.epa.gov/risk/guidelines-developmental-toxicity-risk-assessment (accessed April 2016).

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 Response. EPA/540/R-92/003. Available from https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-b (accessed April 2016).

EPA, 1994. *Methods for derivation of inhalation reference concentrations (RfCs) and application of inhalation dosimetry*. U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Washington, DC, EPA/600/8-90/066F. Available from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=71993 (accessed August 2015).

EPA, 1995a. *Policy on evaluating health risks to children*. Office of the Administrator, Washington, DC. Available from https://www.epa.gov/children/epas-policy-evaluating-risk-children (accessed April 2016).

EPA,1995b. *Application of benchmark dose methodology to data from prenatal developmental toxicity studies*. Washington, DC; EPA/600/A-95/135. Available from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=40957 (accessed August 2015).

EPA, 1996a. *Guidelines for reproductive toxicity risk assessment*. Risk Assessment Forum, Washington, DC; EPA/630/R-96/009. Available from http://cfpub.epa.gov/ncea/raf/pdfs/repro51.pdf (accessed August 2015).

EPA, 1996b. *Soil screening guidance: User's guide*. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-23. Available from https://www.epa.gov/superfund/superfund-soil-screening-guidance (accessed April 2016).

EPA, 1996c. *Soil screening guidance: Technical background document*. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-17A. Available from http://www.epa.gov/superfund/health/conmedia/soil/introtbd.htm (accessed August 2015).

EPA, 1997. *Summary report of a peer involvement workshop on the development of an exposure factors handbook for the aging*. February 14-15, 2007. Arlington, VA. Available from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=171923 (accessed August 2015).

EPA, 1998. Guidelines for neurotoxicity risk assessment. Federal Register 63(93):26926-26954. EPA/630/R-95/001F. Available from https://www.epa.gov/risk/guidelines-neurotoxicity-risk-assessment (accessed April 2016).

EPA, 2001. *Risk assessment guidance for superfund (RAGS): Volume I - Human health evaluation manual (Part D, standardized planning, reporting and review of superfund risk assessments)*. Office of Emergency and Remedial Response, Washington, DC; 9285.7-01D. Available from https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-d (accessed April 2016).

EPA, 2002a. *A review of the reference dose and reference concentration Processes*. Risk Assessment Forum, Washington, DC; EPA/630/P-02/002F. Available from https://www.epa.gov/osa/review-reference-dose-and-reference-concentration-processes (accessed April 2016).

EPA. 2002b. *Determination of the appropriate FQPA safety factor(s) in tolerance assessment*. Office of Pesticide Programs, Office of Pesticide Programs, Washington, DC. Available from https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/consideration-fqpa-safety-factor-and-other (accessed April 2016).

EPA, 2002c. *Supplemental guidance for developing soil screening levels for superfund sites*. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-24. Available from https://www.epa.gov/superfund/superfund-soil-screening-guidance (accessed April 2016).

EPA, 2006a. *A framework for assessing health risk of environmental exposures to children*. National Center for Environmental Assessment, Office of Research and Development, Washington, DC; EPA/600/R-05/093F Available from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=22521 (accessed August 2015).

EPA, 2006b. *Guidance on selecting age groups for monitoring and assessing childhood exposures to environmental contaminants*. National Center for Environmental Assessment, Washington, DC; EPA/630/P-30/003F. Available from http://www2.epa.gov/sites/production/files/2013-09/documents/agegroups.pdf (accessed August 2015).

EPA, 2006c. *EPA's action development process: Guide to considering children's health when developing EPA actions: Implementing Executive Order 13045 and EPA's policy on evaluating health risks to children*. OPEI Regulatory Development Series, Washington, DC. Available from http://www2.epa.gov/sites/production/files/2014-05/documents/epa_adp_guide_childrenhealth.pdf (accessed August 2015).

EPA, 2008. *Child-specific exposure factors handbook (final report)*. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-06/096F. Available from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=199243 (accessed August 2015).

EPA, 2009. *Risk assessment guidance for superfund. Volume 1: Human health evaluation manual (Part F, Supplemental guidance for inhalation risk assessment)*. Office of Superfund Remediation and Technology Innovation. OSWER 9285.7-82. EPA-540-R-070-002. Available from https://www.epa.gov/sites/production/files/2015-09/documents/partf_200901_final.pdf (accessed April 2016).

EPA, 2011a. *Exposure factors handbook – 2011 edition.* Office of Research and Development, Washington, D.C. EPA/600/R-090/052F. Available from https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252 (accessed April 2016).

EPA. 2011b. IRIS database. *Chemical file for trichloroethylene.* Chronic inhalation RfC assessment, last revised 9/28/2011. Available from https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=199 (accessed May 2016).

EPA. 2011c.*Toxicological Review of Trichloroethylene (CAS No. 79-01-6). In support of summary information on the Integrated Risk Information System (IRIS)*. EPA/635/R-09/011F. Available from https://www.epa.gov/iris/supporting-documents-trichloroethylene (accessed April 2016).

EPA, 2012. EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to National Academy of Sciences (NAS) Comments, Volume 1. EPA/600/R-10/038F. Available from https://www.epa.gov/iris/supporting-documents-2378-tetrachlorodibenzo-p-dioxin-tcdd (accessed April 2016).

EPA, 2014a. *Next generation risk assessment: Incorporation of recent advances in molecular, computational, and systems biology*. National Center for Environmental Assessment, Office of Research and Development, Washington, D.C. EPA/600/R-14/004. Available from http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=286690 (accessed August 2015).

EPA, 2014b. *Compilation of information relating to early/interim actions at Superfund sites and the TCE IRIS assessment*. Memorandum from Robin Richardson. Office of Superfund Remediation and Technology Innovation, Washington, D.C. Available from https://semspub.epa.gov/work/11/174044.pdf (accessed April 2016).

EPA, 2014c. *Framework for Human Health Risk Assessment to Inform Decision Making.* Risk Assessment Forum, Office of the Science Advisor, Washington, D.C. EPA/100/R-14/001. Available from http://www2.epa.gov/sites/production/files/2014-12/documents/hhra-framework-final-2014.pdf (accessed August 2015).

EPA, 2014d. *Guidance for applying quantitative data to develop data-derived extrapolation factors for interspecies and intraspecies extrapolation*. Risk Assessment Forum, Office of the Science Advisor, Washington, DC; EPA/100/R-14/002. Available from http://www2.epa.gov/sites/production/files/2015-01/documents/ddef-final.pdf (accessed August 2015).

EPA, 2015a. *Regional screening table*. Available from http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm (accessed August 2015).

EPA, 2015b. *OSWER technical guide for assessing and mitigating the vapor intrusion pathway from subsurface vapor sources to indoor air*. Office of Superfund Remediation and Technology Innovation. OSWER 9200.2-154 Available from https://www.epa.gov/vaporintrusion/technical-guide-assessing-and-mitigating-vapor-intrusion-pathway-subsurface-vapor (accessed April 2016).

EPA, 2015c. *TSCA work plan chemical risk assessment. N-methylpyrrolidone: paint stripper use.* Office of Chemical Safety and Pollution Prevention. EPA Document 740-R1-5002.

EPA R9, 2014b. *EPA Region 9 response action levels and recommendations to address near-term inhalation exposures to TCE in air from subsurface vapor intrusion*. July 9, 2014. Available from http://www.epa.gov/region9/superfund/prg/files/r9-tce-interim-action-levels-response-recs-memo-2014.pdf (accessed August 2015).

Faulk, C., and Dolinoy, D.C. 2011. Timing is everything: the when and how of environmentally induced changes in the epigenome of animals. *Epigenetics* 6(7):791-797. Available from http://www.tandfonline.com/doi/pdf/10.4161/epi.6.7.16209 (accessed August 2015).

Felter S.P., Daston, G.P., Euling, S.Y., Piersma, A.H., and Tassinari, M.S. 2015. Assessment of health risks resulting from early-life exposures: Are current chemical toxicity testing protocols and risk assessment methods adequate? *Critical Reviews in Toxicology* 45: 219-244

Fox, D.A., Grandjean, P., de Groot, D., and Paule, M. 2012. Developmental origins of adult diseases and neurotoxicity: epidemiological and experimental studies. *Neurotoxicology* 33(4):810-816. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3657611/pdf/nihms363112.pdf (accessed August 2015).

Gluckman, P.D., Hanson, M.A., Cooper, C., and Thornburg, K.L. 2008. Effect of in utero and early-life conditions on adult health and disease. *New England Journal of Medicine* 359(1):61-73. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3923653/pdf/nihms-116666.pdf (accessed August 2015).

Grandjean, P., Barouki, R., Bellinger, D., Casteleyn, L., Chadwich, L.H., Cordier, S., Etzel, R., Gray, K.A., Ha, E., and Junien, C., et al. 2015. Life-long implications of developmental exposure to environmental stressors: new perspectives. *Endocrinology*: in press. Available from http://press.endocrine.org/doi/pdf/10.1210/EN.2015-1350 (accessed August 2015).

Heindel, J.J., Balbu, J., Birnbaum, L., Brune-Drisse, M.N., Grandjean, P., Gray, K., Landrigan, P.J., Sly, P.D., Suk, W. Cory, Slechta, D., Thompson, C., and Hanson, M. Forthcoming 2015. Developmental origins of health and disease: integrating environmental influences. *Endocrinology*: in press. Available from http://press.endocrine.org/doi/pdf/10.1210/EN.2015-1350 (accessed August 2015).

IPCS (International Programme on Chemical Safety), 1984. *Principles for evaluating health risks to progeny associated with exposure to chemicals during pregnancy*. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 30). Available from http://www.inchem.org/documents/ehc/ehc/ehc30.htm (accessed August 2015).

IPCS, 1986. *Principles for evaluating health risks from chemicals during infancy and early childhood: the need for a special approach*. Geneva, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria 59). Available from http://www.inchem.org/documents/ehc/ehc/ehc59.htm (accessed August 2015).

Johnson, P., Goldberg, S., Mays, M., and Dawson, B. 2003. Threshold of trichloroethylene contamination in maternal drinking waters affecting fetal heart development in the rat. *Environmental Health Perspectives* 111: 289-292. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241384/ (accessed August 2015).

MA DEP (Massachusetts Department of Environmental Protection), 2014a. *Fact sheet TCE toxicity information: implications for chronic and shorter-term exposure*. August 15, 2014. Available from http://www.mass.gov/eea/docs/dep/cleanup/laws/tcestat.pdf. (accessed August 2015).

MA DEP, 2014b. *US EPA Trichloroethylene Toxicity Values and Office of Research and Standads Recommendations Regarding Remediaiton Targets and Timeframes to Address Potential Developmental Risks*. August 15, 2014. Available from http://www.mass.gov/eea/docs/dep/cleanup/laws/tcevalsm.pdf. (accessed August 2015).

McMillen, I.C., MacLaughlin, S.M., Muhlhausler, B.S., Gentili, S., Duffield, J.L., and Morrison, J.L. 2008. Developmental origins of adult health and disease: the role of periconceptional and fetal nutrition. *Basic and Clinical Pharmacology and Toxicology* 102:82-89. Available from http://onlinelibrary.wiley.com/doi/10.1111/j.1742-7843.2007.00188.x/epdf. (accessed August 2015).

MDEQ (Michigan Department of Environmental Quality), 2015a. *Michigan Department of Environmental Quality response to recommendations criteria stakeholders advisory group final report*. MDEQ, Lansing, Michigan. Available from http://www.michigan.gov/documents/deq/deq-rrd-CSA-DEQRRDResponseToCSAReport_495689_7.pdf.

MDEQ, 2015b. *Process to address developmental and/or reproductive toxicity in the derivation of generic cleanup criteria*. Toxics Steering Group, Children's Environmental Health Subcommittee, Lansing, Michigan. (unpublished)

NRC (National Research Council), 2009. *Science and decisions: advancing risk assessment*. Washington, DC: National Academies Press. Available from http://www.nap.edu/catalog/12209/science-and-decisions-advancing-risk-assessment (accessed November 2015)

NRC, 2014. *Review of EPA's integrated risk information system (IRIS) process*. Washington, DC: National Academies Press. Available from http://www.nap.edu/catalog/18764/review-of-epas-integrated-risk-information-system-iris-process (accessed November 2015)

OR DEQ (Oregon Department of Environmental Quality), 2010. *Human Health Risk Assessment.* Portland, OR: Environmental Cleanup Program. 10-LQ-023. Available from http://www.deq.state.or.us/lq/pubs/docs/cu/HumanHealthRiskAssessmentGuidance.pdf (accessed November 2015).

Pohl, H.R., and Abadin, H.G. 1995. Utilizing uncertainty factors in minimal risk levels derivation. *Regulatory Toxicology and Pharmacology* 22:180-188.

Pohl, H.R., Smith-Simon, C., and Hicks, H. 1998. Health effects classification and its role in the derivation of minimal risk levels: developmental effects. *Regulatory Toxicology and Pharmacology* 28:55-60.

Pohl, H.R., Luukinen, B., and Holler, J.S. 2005. Health effects classification and its role in the derivation of minimal risk levels: reproductive and endocrine effects. *Regulatory Toxicology and Pharmacology* 42:209-217.

Power, C., Kuh, D., and Morton, S., 2013. From developmental origins of adult disease to life course research on adult disease and aging: insights from birth cohort studies. *Annual Review of Public Health* 34:7-28. Available from http://www.closer.ac.uk/wp-content/uploads/annurev-publhealth-031912-114423.pdf (accessed August 2015).

Protecting Children's Environmental Health. Washington, DC: Environmental Protection Agency; Updated June 29, 2015. Available from http://www2.epa.gov/children/early-life-stages (accessed August 2015).

Robinson, R. 2001. The fetal origins of adult disease: no longer just a hypothesis and may be critically important in south Asia. BMJ 322:375-376. Available from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1119617/pdf/375.pdf (accessed August 2015).

WHO (World Health Organization), 2006. *Environmental health criteria 237: principles for evaluating health risks in children associated with exposure to chemicals*. World Health Organization, Geneva, Switzerland. Available from http://www.who.int/ipcs/publications/ehc/ehc237.pdf?ua=1 (accessed August 2015).

WHO, 2011. *Summary of principles for evaluating health risks in children associated with exposure to chemicals*. World Health Organization, Geneva, Switzerland. Available from http://www.who.int/ceh/health_risk_children.pdf?ua=1 (accessed August 2015).

APPENDIX B: Equations for Calculating Cleanup Values for DR Toxicants

Developmental Drinking Water Value

Residential (child):

$$DWV_{dev} = \frac{THQ \times AT_{child} \times RfD_{dev} \times BW_{child} \times RSC_w \times CF}{ED_{child} \times EF_{res} \times IR_{dw,child}}$$

where,

DWV_{dev}	(Drinking water value)	=	chemical-specific, µg/L or ppb
THQ	(Target hazard quotient)	=	1
AT_{child}	(Averaging time)	=	2,190 days
RfD_{dev}	(Oral reference dose)	=	chemical-specific, mg/kg-day
BW_{child}	(Body weight)	=	15 kg
RSC_w	(Relative source contribution)	=	0.2 or chemical-specific
CF	(Conversion factor)	=	1000 µg/mg
ED_{child}	(Exposure duration)	=	6 years
EF_{child}	(Exposure frequency)	=	350 days/year
$IR_{dw,\ child}$	(Drinking water ingestion rate)	=	0.78 L/day

Residential (pregnant woman):

$$DWV_{dev} = \frac{THQ \times AT_{preg} \times RfD_{dev} \times BW_{preg} \times RSC_w \times CF}{ED_{preg} \times EF_{dev} \times IR_{dw,preg}}$$

where,

DWV_{dev}	(Drinking water value)	=	chemical-specific, µg/L or ppb
THQ	(Target hazard quotient)	=	1
$AT_{preg,FT}$	(Averaging time, full-term pregnancy)	=	280 days or chemical-specific
$AT_{preg,SE}$	(Averaging time, single event exposure during pregnancy)	=	1 day or chemical-specific
RfD_{dev}	(Oral reference dose)	=	chemical-specific, mg/kg-day
BW_{preg}	(Body weight, pregnant resident)	=	75 kg
RSC_w	(Relative source contribution)	=	0.2 or chemical-specific
CF	(Conversion factor)	=	1,000 µg/mg
$ED_{preg,FT}$	(Exposure duration, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{preg,SE}$	(Exposure duration, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{preg,FT}$	(Exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{preg,SE}$	(Exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific
$IR_{dw,\ preg}$	(Drinking water ingestion rate, pregnant resident)	=	1.8 L/day

Nonresidential (pregnant worker):

$$DWV_{dev} = \frac{THQ \times AT_{dev} \times RfD_{dev} \times BW_{dev} \times RSC_w \times CF}{ED_{dev} \times EF_{dev} \times IR_{dw,dev}}$$

where,

DWV_{dev}	(Drinking water value)	=	chemical-specific, µg/L or ppb
THQ	(Target hazard quotient)	=	1
$AT_{dev,FT}$	(Averaging time, pregnant worker, full-term pregnancy)	=	280 days or chemical-specific
$AT_{dev,SE}$	(Averaging time, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
RfD_{dev}	(Oral reference dose, developmental)	=	chemical-specific, mg/kg-day
BW_{dev}	(Body weight, pregnant worker)	=	75 kg
RSC_w	(Relative source contribution)	=	0.2 or chemical-specific
CF	(Conversion factor)	=	1,000 µg/mg
$ED_{dev,FT}$	(Exposure duration, pregnant worker, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{dev,SE}$	(Exposure duration, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical specific
$EF_{dev,FT}$	(Exposure frequency, pregnant worker, full-term pregnancy)	=	183 days/year or chemical specific
$EF_{dev,SE}$	(Exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical specific
$IR_{dw,\ dev}$	(Drinking water ingestion rate)	=	0.9 L/day

Developmental Direct Contact Value

Residential (child):

$$DCV_{dev} = \frac{THQ \times AT_{child} \times BW_{child} \times RSC_s \times CF}{ED_{child} \times [(\frac{1}{RfD_{o,dev}} \times EF_{i,res} \times IR_{s,child} \times AE_i) + (\frac{1}{RfD_{d,dev}} \times EF_{d,res} \times SA_{child} \times EV \times AF_{child} \times AE_d)]}$$

where,

DCV_{dev}	(Direct contact value)	=	chemical-specific, µg/kg or ppb)
THQ	(Target hazard quotient)	=	1
AT_{child}	(Averaging time)	=	2,190 days
BW_{child}	(Body weight)	=	15 kg
RSC_s	(Relative source contribution for soil)	=	1 or chemical-specific
CF	(Conversion factor)	=	1E+9 µg/kg
ED_{child}	(Exposure duration)	=	6 years
$RfD_{o,dev}$	(Oral reference dose, developmental)	=	chemical-specific mg/kg-day
$EF_{i,res}$	(Ingestion exposure frequency)	=	350 days/year
$IR_{s,child}$	(Soil ingestion rate)	=	179 mg/day
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or as specified by chemical category

$RfD_{d,dev}$	(Dermal reference dose)	=	chemical-specific mg/kg-day
$EF_{d,res}$	(Dermal exposure frequency)	=	275 days/year
SA_{child}	(Skin surface area)	=	2,400 cm^2
EV	(Event frequency)	=	1 event/day
AF_{child}	(Soil adherence factor)	=	0.3 mg/cm^2-event
AE_d	(Dermal absorption efficiency)	=	chemical-specific or as specified by chemical category

Residential (pregnant woman):

$$DCV_{dev} = \frac{THQ \times AT_{preg} \times BW_{preg} \times RSC_s \times CF}{ED_{preg} \times [(\frac{1}{RfD_{o,dev}} \times EF_{i,preg} \times IR_{s,preg} \times AE_i) + (\frac{1}{RfD_{d,dev}} \times EF_{d,preg} \times SA_{preg} \times EV \times AF_{preg} \times AE_d)]}$$

where,

DCV_{dev}	(Direct contact value)	=	chemical-specific, µg/kg or ppb)
THQ	(Target hazard quotient)	=	1
$AT_{preg,FT}$	(Averaging time, full-term pregnancy)	=	280 days or chemical-specific
$AT_{preg,SE}$	(Averaging time, single event exposure during pregnancy)	=	1 day or chemical-specific
BW_{preg}	(Body weight, pregnant resident)	=	75 kg
RSC_s	(Relative source contribution for soil)	=	1 or chemical-specific
CF	(Conversion factor)	=	1E+9 µg/kg
$ED_{preg,FT}$	(Exposure duration, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{preg,SE}$	(Exposure duration, single event exposure during pregnancy)	=	1 day or chemical-specific
$RfD_{o,dev}$	(Oral reference dose)	=	chemical-specific, mg/kg-day
$EF_{i,preg,FT}$	(Ingestion exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{i,preg,SE}$	(Ingestion exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific
$IR_{s,preg,FT}$	(Soil ingestion rate)	=	89 mg/day
$IR_{s,preg,SE}$	(Soil ingestion rate)	=	100 mg/day
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or as specified by chemical category
$RfD_{d,dev}$	(Dermal reference dose)	=	chemical-specific, mg/kg-day
$EF_{d,preg,FT}$	(Dermal exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{d,preg,SE}$	(Dermal exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific
SA_{preg}	(Skin surface area, pregnant resident)	=	5,500 cm^2
EV	(Event frequency)	=	1 event/day

AF_{preg}	(Soil adherence factor)	=	0.07 mg/cm^2-event
AE_d	(Dermal absorption efficiency)	=	chemical-specific or as specified by chemical category

<u>Nonresidential (pregnant worker):</u>

$$DCV_{nc} = \frac{THQ \times AT_{dev} \times BW_{dev} \times RSC_s \times CF}{ED_{dev} \times \left[\left(\frac{1}{RfD_{o,dev}} \times EF_{i,dev} \times IR_{s,dev} \times AE_i\right) + \left(\frac{1}{RfD_{d,dev}} \times EF_{d,dev} \times SA_{dev} \times EV \times AF_{dev} \times AE_d\right)\right]}$$

where,

DCV_{dev}	(Direct contact value)	=	chemical-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
$AT_{dev,\ FT}$	(Averaging time, pregnant worker, full-term pregnancy)	=	280 days or chemical-specific
$AT_{dev,\ SE}$	(Averaging time, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
BW_{dev}	(Body weight, pregnant worker)	=	75 kg
RSC_s	(Relative source contribution)	=	1 or chemical-specific
CF	(Conversion factor)	=	1E+9 µg/kg
$ED_{dev,FT}$	(Exposure duration, pregnant worker, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{dev,SE}$	(Exposure duration, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
$RfD_{o,dev}$	(Oral reference dose, developmental)	=	chemical-specific, mg/kg-day
$EF_{i,dev,FT}$	(Ingestion exposure frequency, pregnant worker, full-term pregnancy)	=	183 days/year or chemical-specific
$EF_{i,dev,SE}$	(Ingestion exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical-specific
$IR_{s,dev,FT}$	(Soil ingestion rate, pregnant worker, full-term pregnancy)	=	89 mg/day
$IR_{s,dev,SE}$	(Soil ingestion rate, pregnant worker, single event exposure during pregnancy)	=	100 mg/day
AE_i	(Ingestion absorption efficiency)	=	chemical-specific or as specified by chemical category
$RfD_{d,dev}$	(Dermal reference dose, developmental)	=	chemical-specific, mg/kg-day
$EF_{d,dev,FT}$	(Dermal exposure frequency, pregnant worker)	=	183 days/year or chemical-specific
$EF_{d,dev,SE}$	(Dermal exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical specific
SA_{dev}	(Skin surface area, pregnant worker)	=	3,100 cm^2/day

EV	(Event frequency)	=	1 event/day
AF_{dev}	(Soil adherence factor, pregnant worker)	=	0.2 mg/cm^2-event
AE_d	(Dermal absorption efficiency)	=	chemical-specific or as specified by chemical category

Developmental Acceptable Air Value

Residential (child):

$$AAV_{dev} = \frac{THQ \times AT_{child} \times RfC_{dev} \times RSC}{ED_{child} \times EF_{child}}$$

where,

AAV_{dev}	(Acceptable air value)	=	chemical-specific, µg/m^3
THQ	(Target hazard quotient)	=	1
AT_{child}	(Averaging time)	=	2,190 days
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
ED_{child}	(Exposure duration)	=	6 years
EF_{child}	(Exposure frequency)	=	350 days/year

Residential (pregnant woman):

$$AAV_{dev} = \frac{THQ \times AT_{preg} \times RfC_{dev} \times RSC}{ED_{preg} \times EF_{preg}}$$

where,

AAV_{dev}	(Acceptable air value)	=	chemical-specific, µg/m^3
THQ	(Target hazard quotient)	=	1
$AT_{preg,FT}$	(Averaging time, full-term pregnancy)	=	280 days or chemical-specific
$AT_{preg,SE}$	(Averaging time, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
$ED_{preg,FT}$	(Exposure duration, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{preg,SE}$	(Exposure duration, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{preg,FT}$	(Exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{preg,SE}$	(Exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific

Nonresidential (pregnant worker):

$$AAV_{dev} = \frac{THQ \times AT_{dev} \times RfC_{dev} \times RSC}{ED_{dev} \times EF_{dev}}$$

where,

AAV_{dev}	(Acceptable air value)	=	chemical-specific, μg/m^3
THQ	(Target hazard quotient)	=	1
$AT_{dev,FT}$	(Averaging time, pregnant worker, full-term pregnancy)	=	280 days or chemical-specific
$AT_{dev,SE}$	(Averaging time, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, μg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
$ED_{dev,FT}$	(Exposure duration, pregnant worker, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{dev,SE}$	(Exposure duration, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{dev,FT}$	(Exposure frequency, pregnant worker, full-term pregnancy)	=	183 days/year or chemical-specific
$EF_{dev,SE}$	(Exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical-specific

Developmental Volatile Soil Inhalation Value

Residential (child):

$$VSIV_{dev} = \frac{THQ \times AT_{child} \times RfC_{dev} \times RSC}{ED_{child} \times EF_{res} \times \left(\frac{1}{VF_{res}}\right)}$$

where,

$VSIV_{dev}$	(Volatile soil inhalation value for infinite or finite source)	=	chemical- and source size-specific, μg/kg or ppb
THQ	(Target hazard quotient)	=	1
AT_{child}	(Averaging time)	=	2,190 days
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, μg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
ED_{child}	(Exposure duration)	=	6 years
EF_{res}	(Exposure frequency)	=	350 days/year
VF_{res}	(Volatilization factor for infinite or finite source)	=	chemical- and source size-specific, m^3/kg

Residential (pregnant woman):

$$VSIV_{dev} = \frac{THQ \times AT_{preg} \times RfC_{dev} \times RSC}{ED_{preg} \times EF_{preg} \times \left(\frac{1}{VF_{res}}\right)}$$

where,

$VSIV_{dev}$	(Volatile soil inhalation value for infinite or finite source)	=	chemical and source size-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
$AT_{preg,FT}$	(Averaging time, full-term pregnancy)	=	280 days or chemical-specific
$AT_{preg,SE}$	(Averaging time, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
$ED_{preg,FT}$	(Exposure duration, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{preg,SE}$	(Exposure duration, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{preg,FT}$	(Exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{preg,SE}$	(Exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific
VF_{res}	(Volatilization factor for infinite or finite source)	=	chemical and source size-specific, m^3/kg

Nonresidential (pregnant worker):

$$VSIV_{dev} = \frac{THQ \times AT_{dev} \times RfC_{dev} \times RSC}{ED_{dev} \times EF_{dev} \times (1/VF_{dev})}$$

where,

$VSIV_{dev}$	(Volatile soil inhalation value for infinite or finite source)	=	chemical- and source size-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
$AT_{dev,FT}$	(Averaging time, pregnant worker, full-term pregnancy)	=	280 days or chemical-specific
$AT_{dev,SE}$	(Averaging time, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
$ED_{dev,FT}$	(Exposure duration, pregnant worker, full-term pregnancy)	=	0.767 year or chemical-specific

$ED_{dev,SE}$	(Exposure duration, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{dev,FT}$	(Exposure frequency, pregnant worker, full-term pregnancy)	=	183 days/year or chemical-specific
$EF_{dev,SE}$	(Exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical-specific
VF	(Volatilization factor for infinite or finite source)	=	chemical- and source size-specific, m^3/kg

<u>Developmental Particulate Soil Inhalation Value</u>

<u>Residential (child):</u>

$$PSIV_{dev} = \frac{THQ \times AT_{child} \times RfC_{dev} \times RSC}{ED_{child} \times EF_{res} \times \left(\frac{1}{PEF_{dev}}\right)}$$

where,

$PSIV_{dev}$	(Particulate soil inhalation value)	=	chemical- and source size-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
AT_{child}	(Averaging time)	=	2,190 days
RfC_{dev}	(Reference concentration, developmental)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
ED_{child}	(Exposure duration)	=	6 years
EF_{res}	(Exposure frequency)	=	350 days/year
PEF_{dev}	(Particulate emission factor)	=	source size-specific, m^3/kg

<u>Residential (pregnant woman):</u>

$$PSIV_{dev} = \frac{THQ \times AT_{preg} \times RfC_{dev} \times RSC}{ED_{preg} \times EF_{preg} \times \left(\frac{1}{PEF_{dev}}\right)}$$

where,

$PSIV_{dev}$	(Particulate soil inhalation value)	=	chemical- and source size-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
$AT_{preg,FT}$	(Averaging time, full-term pregnancy)	=	280 days or chemical-specific
$AT_{preg,SE}$	(Averaging time, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific

$ED_{preg,FT}$	(Exposure duration, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{preg,SE}$	(Exposure duration, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{preg,FT}$	(Exposure frequency, full-term pregnancy)	=	268.5 days/year or chemical-specific
$EF_{preg,SE}$	(Exposure frequency, single event exposure during pregnancy)	=	1 day/day or chemical-specific
PEF_{dev}	(Particulate emission factor)	=	source size-specific, m^3/kg

<u>Nonresidential (pregnant worker):</u>

$$PSIV_{dev} = \frac{THQ \times AT_{dev} \times RfC_{dev} \times RSC}{ED_{dev} \times EF_{dev} \times \left(\frac{1}{PEF_{dev}}\right)}$$

where,

$PSIV_{dev}$	(Particulate soil inhalation value)	=	chemical- and source size-specific, µg/kg or ppb
THQ	(Target hazard quotient)	=	1
$AT_{dev,FT}$	(Averaging time, pregnant worker, full-term pregnancy)	=	280 days or chemical-specific
$AT_{dev,SE}$	(Averaging time, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
RfC_{dev}	(Reference concentration)	=	chemical-specific, µg/m^3
RSC	(Relative source contribution)	=	1 or chemical-specific
$ED_{dev,FT}$	(Exposure duration, pregnant worker, full-term pregnancy)	=	0.767 year or chemical-specific
$ED_{dev,SE}$	(Exposure duration, pregnant worker, single event exposure during pregnancy)	=	1 day or chemical-specific
$EF_{dev,FT}$	(Exposure frequency, full-term pregnancy)	=	183 days/year or chemical-specific
$EF_{dev,SE}$	(Exposure frequency, pregnant worker, single event exposure during pregnancy)	=	1 day/day or chemical-specific
PEF_{dev}	(Particulate emission factor, pregnant worker)	=	source size-specific, m^3/kg

ATTACHMENT G

BACKGROUND DOCUMENT

SUBJECT: IDENTIFICATION OF GENERIC ASSUMPTIONS AND VALUES FOR SOIL TYPE, COUNTY BASED SOIL TEMPERATURE, AND DEPTH TO GROUNDWATER

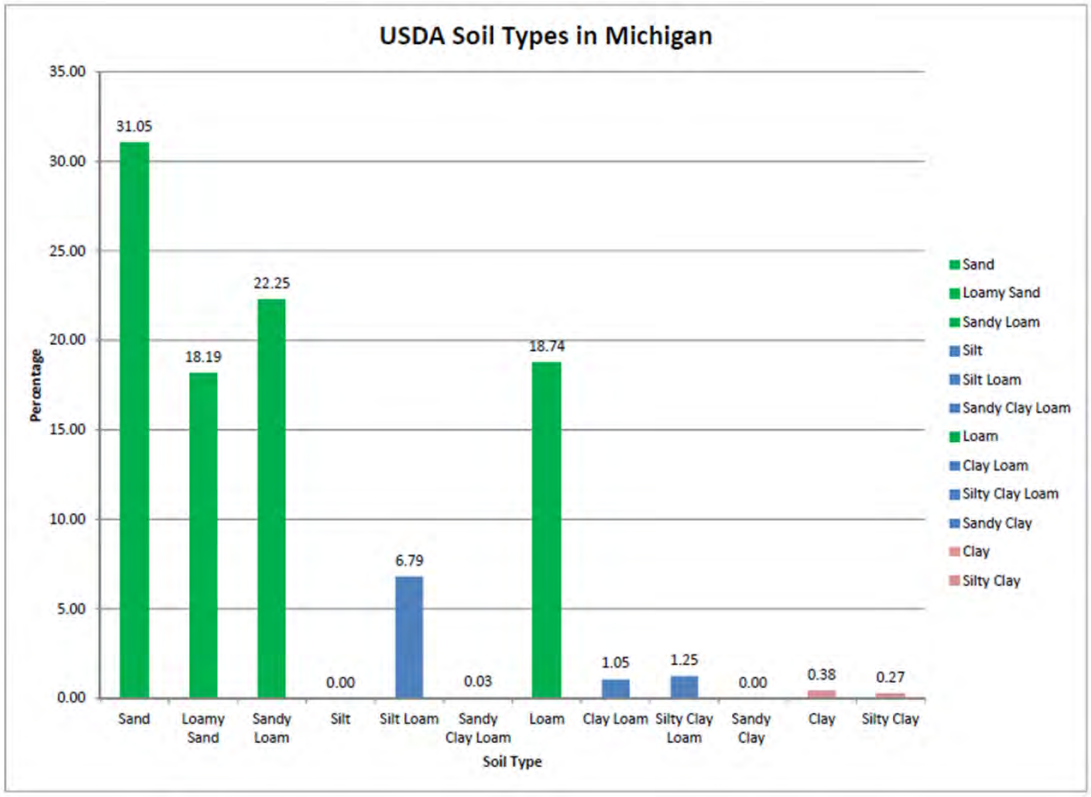
This Background Document describes the identification and use of the generic soil type, the derivation of the soil temperatures for each county, and an evaluation of the depth to the first encountered groundwater in Michigan. Each section below provides the basis for the information and the conclusion drawn.

Establishing a Generic Soil Type for Michigan

Soil surveys contain information that affects land use planning in survey areas. These surveys identify soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas that are used in making various decisions. Significant differences in soil properties can occur within short distances. The National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture (USDA), other federal agencies, and state agencies including the Agricultural Experiment Stations, and local agencies, provides information about soils in a specific area. The information on soil profiles for all of the areas in Michigan that are mapped is available through the Natural Resources Conservation Service (NRCS) Web Soil Survey portal (NRCS, 2015).

A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. When an area is mapped there is a specific parent material associated with it. The parent material is classified into one of the 12 USDA NRCS soil-types. The USDA classifications are based upon the relative percentages of sand, silt, and clay a given soil profile. A map of the location of the 12 basic USDA soil types in Michigan is depicted on Figure 1.

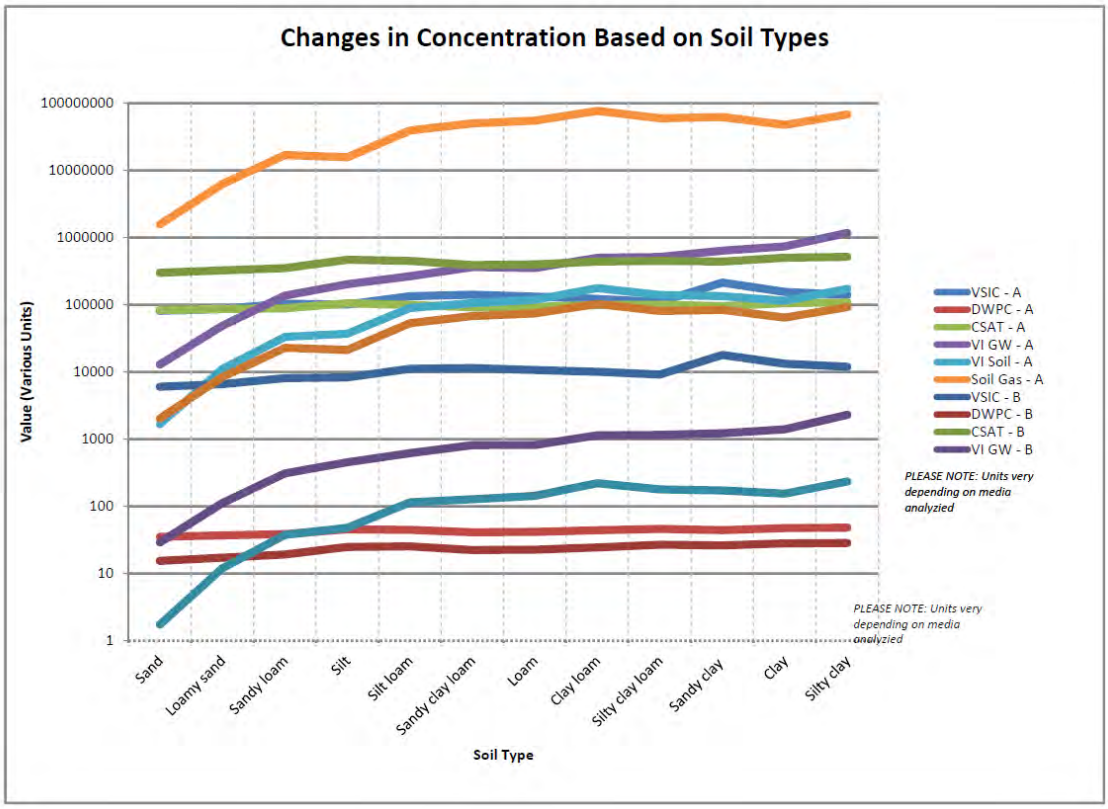
The data from Figure 1 was used to assist in determining the percentage of different soil types that are present in Michigan. Chart 1 shows a representation of the soil types in Michigan. Figures 2 through 5 are maps depicting the location of USDA Classifications for Sand (Figure 2), Loamy Sand (Figure 3); Sandy Loam (Figure 4); and Loam (Figure 5) in Michigan. Based on Graph 1 below, it is clear that sand is the most prevalent soil-type throughout Michigan. Though sand appears to be generally located in northern part of the Lower Peninsula (refer to Figure 2), sand is present at locations in every county throughout Michigan. The Kalkaska soil series was adopted as Michigan's official state soil by enactment of the State Soil, 1990 PA 302. The Kalkaska series, which formed in sandy deposits left by glaciers, occurs in both the Upper and Lower Peninsula and is present in 29 of the state's 83 counties. While the Kalkaska series is present throughout Michigan, it is not the only series that contains sand. More information on the Kalkaska series by the NRCS is provided in Appendix A.



Graph 1 – Percent of USDA Soil Types in Michigan based on NRCS

The MDEQ also performed a limited parameter sensitivity analysis to evaluate the impact of the multiple inputs associated with the different soil types on the development of generic criteria values. The parameters used for the soil types were based on those identified in Table 2 of R 299.7(7) (MDEQ, 2015l). Those parameters were established provided in the User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings (USEPA, 2004) as being appropriate values for specific USDA soil types. An example of this sensitivity for two chemicals is depicted on Graph 2. The names of the individual chemicals are not reported, as the graph is intended to demonstrate that the relationship between the different soil types, and all chemicals for which the analysis was completed demonstrated similar trends.

The analysis has identified that sand is consistently the soil type that provides the most conservative values. This analysis, combined in combination with the information fact that sand is has been identified as being the principal soil matrix in over 30 percent of the state, justifies that sand and sand associated soil inputs in the development generic soil criteria.



Graph 2 – Contaminant trends using soil type specific inputs

County-Specific System Temperature

Information on the identification and the derivation of the soil temperatures for each county provides to develop the facility-specific temperature values that may be used in the deriving generic criteria. Refer to Table 1 below for the soil temperatures. As outlined in the Decision Framework established for updating the criteria exposure assumptions (CSA, 2014), the update process includes use of Michigan-specific data when available. Soil temperatures for Michigan counties can be obtained from Michigan State University (MSU) Extension. MSU Extension collects daily minimum and maximum soil temperatures from more than 80 weather stations across Michigan. Enviro-weather, formerly known as Michigan Automated Weather Network , is a web based program that is the warehouse for the data and is a collaborative project between the Michigan Climatological Resources Program and the MSU Integrated Pest Management Program (Enviro-weather, 2015).

This program, managed by Dr. Jeff Andresen, of the MSU Department of Geography and who also serves as the State Climatologist, identified twenty weather stations that would best provide representative annual soil temperature statewide. The MDEQ used 19 of these stations; however, the MDEQ did modify the list to include used the McMillan/Newberry station in place of the Chatham station to provide a better spatial representation of the surficial soil temperatures. McMillan/Newberry is the only station located towards the eastern end of the Upper Peninsula and still provides a far northern location. Data from the selected stations was obtained downloaded from the Enviro-weather database and analyzed to develop obtain estimates of an annual average soil temperatures. The resulting data set contained 10 years of data for most of the stations. Figure 6 displays the locations of each of the stations and Appendix B provides a data summary for each station. Full data sets can be obtained from the Enviro-weather (2015) Web site.

The average soil temperatures across Michigan are based on a contour dataset, the contours are shown on Figure 7. The contours on the map connect locations of equal temperature based on the values established at the each of the 20 stations. Further analysis was completed by ArcGIS Spatial Analyst to establish a centroid temperature value for each county. Each centroid's temperature value was rounded to the nearest 0.5 C^o based on an evaluation of the distances between the known data points and the variability expected across an entire county. The resulting values are shown on Figure 8 and in Table 1[1].

TABLE 1.
Facility-specific Soil Temperatures by County (degrees Celsius)

COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP
Alcona	9	Dickinson	9	Lake	11.5	Oceana	12
Alger	8.5	Eaton	12	Lapeer	11	Ogemaw	9.5
Allegan	11.5	Emmet	9.5	Leelanau	11	Ontonagon	8
Alpena	9	Genesee	10.5	Lenawee	11.5	Osceola	11
Antrim	10	Gladwin	10	Livingston	11	Oscoda	9.5
Arenac	9.5	Gogebic	8	Luce	8.5	Otsego	9.5
Baraga	8.5	Grand Traverse	11	Mackinac	8.5	Ottawa	11
Barry	12	Gratiot	11	Macomb	11	Presque Isle	9
Bay	10	Hillsdale	12.5	Manistee	11.5	Roscommon	10
Benzie	11	Houghton	8	Marquette	8.5	Saginaw	10.5
Berrien	13	Huron	11	Mason	12	Sanilac	11
Branch	12.5	Ingham	11.5	Mecosta	11	Schoolcraft	8.5
Calhoun	13	Ionia	11	Menominee	9.5	Shiawassee	11
Cass	12.5	Iosco	9.5	Midland	10.5	St. Clair	11
Charlevoix	9.5	Iron	8.5	Missaukee	10	St. Joseph	12
Cheboygan	9	Isabella	10.5	Monroe	11	Tuscola	10
Chippewa	8.5	Jackson	12.5	Montcalm	11	Van Buren	12
Clare	10.5	Kalamazoo	12	Montmorency	9	Washtenaw	11.5
Clinton	11	Kalkaska	10	Muskegon	12	Wayne	11
Crawford	9.5	Kent	11	Newaygo	12	Wexford	11
Delta	9	Keweenaw	8	Oakland	11		

Depth to Groundwater

Information on the identification for the depth to groundwater used to establish volatilization to indoor air criteria is provided below. As outlined in the Decision Framework (CSA, 2014), MDEQ searched for Michigan-specific data. A groundwater inventory and mapping project was developed by the MDEQ as required by Part 324, Aquifer Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 452, as amended (Part 328), to collect and compile groundwater data into a statewide groundwater inventory and map. Part 328 required the MDEQ to include eight specific data sets in the "groundwater inventory and map", and the map be available to the public. The MDEQ created a cooperative research

[1] R 299.7(7) – Table 3

team involving groundwater and mapping experts from the U.S. Geological Survey (USGS) and MSU. The final maps assembled to comply with Part 328 are provided in a technical report (Lush et al., 2006) and are available at: http://www.egr.msu.edu/igw/GWIM%20Figure%20Webpage/. In addition, inventory items, data sets, as well as the maps are available at: http://gwmap.rsgis.msu.edu/.

The MDEQ evaluated the presence of water in Michigan at three discrete depths: 1) 0-5 feet below ground surface (ft. bgs) [Figure 9]; 2) 0-10 ft. bgs [Figure 10]; and 3) 0-15ft. bgs [Figure 11]. Each water contour dataset was created using the contour function in ArcGIS Spatial Analyst. Analysis of the data set was performed by Michigan's Department of Technology, Management and Budget, Center for Shared Solutions based on a request from the MDEQ. The information used to generate the statewide groundwater inventory and map contained over 70 million discrete sets and required the use of a dedicated server. The analysis identified that even at five feet below the surface, groundwater was likely to be encountered at over 50 percent of the state. Though this water may not be potable, it is a key issue in assessing many of the exposure pathways including the volatilization to indoor air and it is a fundamental principle that must be accounted for in any deviation from applicable generic cleanup criteria. Table 2 identifies the findings of the analysis, which includes the total area meeting the analysis requirements as well as the percentage of Michigan where the condition is likely to occur.

Table2

Depth Range of First Encountered Water* (ft. bgs)	Total Area (m^2)	Percent of State (%)
0 and 5	83,438,011,124	55
0 and 10	98,457,020,787	65
0 and 15	107,671,248,576	71

**Note that the data set is inclusive of the first and last number of the range.*

References

CSA (Criteria Stakeholder Advisory Workgroup), 2014. Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria. Lansing, Michigan: Public Sector Consultants for the Michigan Department of Environmental Quality. Available online at: http://www.michigan.gov/documents/deq/deq-rrdCSAFinalReport-11-26-14_475701_7.pdf (accessed August 2015).

Technical Advisory Group 2 (TAG). (2014). Final Report: Part 201: Updating Exposure Pathway Assumptions and Data Sources. Prepared by The Criteria Stakeholder Advisory Group (CSA). October.

Lush, Reeves, and Miller. 2006. Michigan Groundwater Maps, Groundwater Inventory and Mapping Project web site, Michigan State University. Available at: http://www.egr.msu.edu/igw/GWIM%20Figure%20Webpage/.

Enviro-weather. 2015. Michigan Automated Weather Network (MAWN) and Enviro-weather Program. Accesible at: http://www.agweather.geo.msu.edu/mawn/station.asp?id=alb and http://enviroweather.msu.edu/homeMap.php

Michigan Department of Environmental Quality (MDEQ). (2015). Part 201 Generic Cleanup Criteria Exposure Assumptions Update. Technical Support Document. Subject: Soil-to-Ambient Air Volatilization Related Parameters. October, 2015.

Natural Resources Conservation Service (NRCS), 2015. Web Soil Survey portal. Accessible at: ???

USEPA, 2004. User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings. United States Environmental Protection Agency, Office of Emergency and Remedial Response. February 22, 2004.

Figures

Figure 1. Map of the USDA Soil Classification Types in Michigan (All Soils)

Figure 2. Map of the USDA Soil Classification Type Sand in Michigan

Figure 3. Map of the USDA Soil Classification Type Loamy Sand in Michigan

Figure 4. Map of the USDA Soil Classification Type Sandy Loam in Michigan

Figure 5. Map of the USDA Soil Classification Type Loam in Michigan

Figure 6. Map of Enviro-Weather Stations Utilized

Figure 7. Gradational System Temperature Map

Figure 8. County Centroid System Temperature Map

Figure 9. Depth to First Encountered Groundwater 5 Feet Below the Ground Surface

Figure 10. Depth to First Encountered Groundwater 10 Feet Below the Ground Surface

Figure 11. Depth to First Encountered Groundwater 15 Feet Below the Ground Surface

Appendices

Appendix A. Kalkaska – Michigan State Soil

Appendix B. Weather Data from Michigan Stations

ATTACHMENT H

MDEQ GENERIC ASSUMPTION VALUES
TECHINICAL SUPPORT DOCUMENTS (TSDs)

Document Name

Body Weight

Drinking Water Intake Rate

Exposure Duration and Averaging Time

Parameters Related to Particulate Emission from Wind Erosion and Vehicular Traffic

Skin Surface Area

Soil and Dust Ingestion Rate

Soil Dermal Adherence Factor

Soil Direct Contact Exposure Frequency

Soil-To-Ambient Air Volatilization Related Parameters

ATTACHMENT I

BACKGROUND DOCUMENT

SUBJECT: TEMPERATURE ADJUSTMENT FACTOR (TAF)

The Michigan Department of Environmental Quality (MDEQ) applies a temperature adjustment factor (TAF) to Henry's law constants (HLC) when developing the generic Part 201 cleanup criteria and screening levels. Chemical-specific HLCs are generally measured and reported at standard ambient laboratory temperatures. The purpose of the TAF is to adjust the reported HLCs to values that better represent the reduced HLCs expected at Michigan's lower average annual soil and groundwater temperatures. This document provides the technical basis for the development of the annual average Michigan soil temperature and the TAF, and provides information on developing facility- and site-specific temperature adjustments to the HLCs.

Dimensionless Henry's Law Constant

Chemical-specific HLCs are used in predicting chemical partitioning between different environmental media as well as estimating the emission or flux rates of volatile hazardous substances from groundwater, soil, and vapor into indoor or ambient air. The laboratory reported HLCs are generally expressed in units of atmosphere-meter^3/mole (atm-m^3/mole). Reported HLCs are typically converted to dimensionless HLCs (H' or HLC') when used in algorithms or models that estimate environmental partitioning and emission rates (see Equation 1 below). For example, reported HLCs are first converted to their respective H' in the Part 201 equations for soil saturation concentration (Csat) screening levels, soil-water partitioning values (SWPVs), and volatile soil inhalation values (VSIV).

Equation 1. Calculation of the dimensionless Henry's law constant (refer to R 299.22(3), Equation 2).

$$H' = \frac{(HLC \times CF)}{(R \times T)}$$

where,

H'	Dimensionless Henry's law constant	chemical-specific, dimensionless
HLC	Henry's law constant	chemical-specific, atm-m^3/mol
CF	Conversion factor	1,000 L/m^3
R	Ideal gas constant	8.206E-2 atm-L/mol-K
T	Temperature at 25° C	298.15 K

Michigan Average Annual Soil Temperature

An average annual Michigan soil temperature of 10° C was developed based on Michigan-specific soil data (MDEQ, 2015l). Daily minimum and maximum soil temperatures, measured at two inches and four inches below surface, are collected from more than 80 weather stations across the state by Michigan State University (MSU) Extension. This program is managed by Dr. Jeff Andresen, Associate Professor of Meteorology/Climatology in the Department of Geography and State Climatologist for Michigan.

Dr. Andresen selected twenty of the 80+ weather stations as those that would best provide a reliable representation of annual state-wide soil temperature and recommended that at least 10 years of data be used in order to capture information regarding the temperature variability with year and location. Daily minimum and maximum soil temperatures at two inches below grade were downloaded from the Enviro-weather database for each of the selected twenty weather stations. The inclusive dates were from January 1, 2005 through December 31, 2014. Less than two percent of the total datapoints were not available.

For each daily measurement, an average value across the minimum and maximum reported values was calculated. An average soil temperature of 10.8° C (51.5° F) was then calculated by averaging across all stations and years. The average annual state-wide soil temperature of 10.8° C is consistent with the estimated average annual soil temperature historically used to derive the TAF. Therefore, the MDEQ has retained 10° C as the generic average annual Michigan soil temperature for calculating the updated groundwater and soil cleanup criteria and screening levels.

Temperature Adjustment of Henry's Law Constants

Chemical-specific HLCs are typically measured and reported at a standard ambient laboratory temperature of approximately 25° C. A lower soil temperature correlates with reduced volatility of a hazardous substance. It has been shown for a subset of hazardous substances that the estimated HLC values at 10° C decrease by a factor of approximately two as compared to their respective HLC values at 25° C (Environ, 1997). Available literature shows that this factor may actually be in the range of 2 to 3.3; that is, a chemical's HLC value at 10° C may be 2- to 3.3-fold lower than at 25° C (Environ, 1997). Based on this information, the MDEQ adjusts the HLC values by applying a TAF of 0.5 (or ½) to estimate environmental partitioning and chemical emission rates at Michigan's average annual soil and groundwater temperature of 10° C for some exposure pathways. It is important to note that vapor intrusion screening levels are derived at 10° C using the methodology presented in Equation 2 rather than application of the TAF.

To estimate a chemical-specific H' at 10° C, the reported HLC at 25° C is multiplied by a TAF of 0.5. The MDEQ's TAF-based approach does not limit a party from deriving a chemical-specific

HLC or H' at soil or groundwater temperatures (i.e., system temperature) other than 10° C or from using other experimental data, methods, or models.

Facility-specific generic H' at environmental temperatures other than 10° C can be derived using MDEQ's facility-specific soil temperatures by Michigan county (see Table 1 below) in the H' formula presented in Equation 2. Similarly, site-specific system temperatures can also be used in Equation 2, but will require appropriate site characterization in addition to department review and approval.

Equation 2. Calculation of the dimensionless Henry's law constant at alternative facility- or site-specific system temperatures.

$$H'_{TS} = \frac{\exp\left[-\frac{\Delta H_{V,TS}}{R_C}\left(\frac{1}{T_S}-\frac{1}{T_R}\right)\right] \times HLC}{R \times T_S}$$

where,

H'_{TS}	Henry's law constant at the system temperature	Chemical-specific, dimensionless
$\Delta H_{V,TS}$	Enthalpy of vaporization at the system temperature	Chemical-specific, cal/mol
T_S	System temperature	283.15 K, facility- or site-specific
T_R	Henry's law constant reference temperature	298.15 K
HLC	Henry's law constant at the reference temperature	Chemical-specific atm-m^3/mol
R_C	Gas constant	1.9872 cal/mol-K
R	Gas constant	8.206E-5 atm-m^3/mol-K

Table 1. Facility-specific soil temperatures by Michigan county (in degrees Celsius; MDEQ, 2016).

COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP
Alcona	9	Dickinson	9	Lake	11.5	Oceana	12
Alger	8.5	Eaton	12	Lapeer	11	Ogemaw	9.5
Allegan	11.5	Emmet	9.5	Leelanau	11	Ontonagon	8
Alpena	9	Genesee	10.5	Lenawee	11.5	Osceola	11
Antrim	10	Gladwin	10	Livingston	11	Oscoda	9.5
Arenac	9.5	Gogebic	8	Luce	8.5	Otsego	9.5
Baraga	8.5	Grand	11	Mackinac	8.5	Ottawa	11
Barry	12	Gratiot	11	Macomb	11	Presque Isle	9
Bay	10	Hillsdale	12.5	Manistee	11.5	Roscommon	10
Benzie	11	Houghton	8	Marquette	8.5	Saginaw	10.5
Berrien	13	Huron	11	Mason	12	Sanilac	11
Branch	12.5	Ingham	11.5	Mecosta	11	Schoolcraft	8.5
Calhoun	13	Ionia	11	Menominee	9.5	Shiawassee	11
Cass	12.5	Iosco	9.5	Midland	10.5	St. Clair	11
Charlevoix	9.5	Iron	8.5	Missaukee	10	St. Joseph	12

COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP	COUNTY	TEMP
Cheboygan	9	Isabella	10.5	Monroe	11	Tuscola	10
Chippewa	8.5	Jackson	12.5	Montcalm	11	Van Buren	12
Clare	10.5	Kalamazoo	12	Montmorency	9	Washtenaw	11.5
Clinton	11	Kalkaska	10	Muskegon	12	Wayne	11
Crawford	9.5	Kent	11	Newaygo	12	Wexford	11
Delta	9	Keweenaw	8	Oakland	11		

The MDEQ's application of the TAF is presented in the following soil-based generic equations. Where facility- or site-specific H'_{TS} values have been calculated using Equation 2 above, the temperature-specific H'_{TS} would substitute for the combined "H' × TAF" term of each equation as shown below.

Soil saturation concentration (Csat) screening levels (refer to R 299.18(2) for variable definitions)

Generic: $$Csat = \frac{S}{\rho_b} \times \left[\left(K_d \times \rho_b\right) + \theta_w + \left(H' \times TAF \times \theta_a\right)\right]$$

Substituted: $$Csat = \frac{S}{\rho_b} \times \left[\left(K_d \times \rho_b\right) + \theta_w + \left(H'_{TS} \times \theta_a\right)\right]$$

Soil-water partition value (SWPV)(refer to R 299.22(3), Equation 1 for variable definitions)

Generic: $$SWPV = Cw \left[K_d + \left(\frac{\theta_w + \left(H' \times TAF \times \theta_a\right)}{\rho_b} \right) \right]$$

Substituted: $$SWPV = Cw \left[K_d + \left(\frac{\theta_w + \left(H'_{TS} \times \theta_a\right)}{\rho_b} \right) \right]$$

Volatile soil inhalation value (VSIV) apparent diffusivity (D_A) parameter (refer to R 299.26(10), Equation 9(c) for variable definitions)

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

Substituted: $$D_A = \frac{\left[\left(\theta_a^{3.33} D_a \left(H'_{TS}\right) + \theta_w^{3.33} D_w\right) / n^2\right]}{\rho_b K_d + \theta_w + \theta_a \left(H'_{TS}\right)}$$

References

Environ Corp. Memo to Michigan Department of Environmental Quality. 1997. Estimation of Henry's Law Constant at 10° C. June, 1997.

Howe, G.B., Mullins, M.E., and Rogers, T.N. 1987. Evaluation and Prediction of Henry's Law Constants and Aqueous Solubilities for Solvents and Hydrocarbon Fuel Components, Volume I: Technical Discussion – Final Report. Research Triangle Institute.

Michigan Department of Environmental Quality (MDEQ), 2016. Identification of Generic Assumptions and Values for Soil Type, County Based Soil Temperature, and Depth to Groundwater. Background Doument. Remediation and Redevelopment Division.

Nurnberger, F.V. 1997. Personal Communication with Dr. Nurnberger Michigan State University.

MDEQ, 2015I. Generic Exposure Assumptions Values Update Technical Support Document on Soil-to-Air Volatilization Related Parameters. October, 2015. (unpublished).

Remediation and Redevelopment Division
Michigan Department of Environmental Quality

ATTACHMENT J

MDEQ STATEWIDE DEFAULT SOIL BACKGROUND LEVELS BACKGROUND DOCUMENT

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

TO: Robert Wagner, Chief
Remediation and Redevelopment Division

FROM: David Slayton, Geology Specialist
Dale Bridgford, Senior Geologist
Hazardous Waste Section
Office of Waste Management and Radiological Protection

DATE: March 17, 2016

SUBJECT: Proposed Revision of Part 201 Statewide Default Background Levels

Introduction

Based on a request from the Remediation and Redevelopment Division, a review has been conducted for a proposed update to the Part 201 Statewide Default Background Levels for metals. The review is based on data from the new 2015 Michigan Background Soil Survey (MBSS) versus the original 1993 Default Background data. This was done by deriving the mean and standard deviation for the various metals, calculated as appropriate for the statistical distribution (normal, lognormal, nonparametric). As was done for the 1993 Default Background Levels, the mean value of all samples for each distinct site was calculated, and then those site values were used to calculate a statewide mean with all general soil types combined (topsoil, sand, clay). Using site averages was done to compensate for potential weighting of the data toward those sites that had a large number of samples. The following are the specific steps taken for the data:

Statistical Methods

Site metals concentrations were queried from the 2015 MBSS database (Database). For each site's data, perform the following steps:

1. Site is defined as a specific geographic location where one or more samples were collected, such as a manufacturer, cleanup site, regulated facility, etc.
2. Accumulate the site's data counting the number of detects, non-detects (censored observations), and the number of samples for the site.
3. Calculate the average for the site for each available metal as follows:
   a. Determine the level of censoring for each site/metal.
   b. If there are between 0 and 15 percent non-detects, substitute half the detection limit of each censored observation. Then multiply all observations together and take the nth root to get the geometric mean of the site observations for each metal (identified in the Database as e.g., CuCenLevel = 1).
   c. If there are between 15 and 50 percent non-detects, perform Cohen's approximation. Cohen's assumes a single censoring, so any detected values are raised to the highest detection limit in the sample population and flagged censored (removed from the

detected dataset). Following this step, the censoring level for that site/metal is recalculated so that the site average for the metal is correctly determined. (Identified in the Database as e.g., Cu CenLevel = 2).

d. If the censoring level is 50% to less than 100%, the highest detected value is the site average, as an analog to the 97 percentile. (Identified in the Database as e.g., Cu CenLevel = 3).
e. If all values are censored, take the largest detection limit as the site average. (Identified in the Database as e.g., Cu CenLevel = 4).

4. Using each site's average from all sites across the state, determine the statewide distribution (normal, lognormal, non-parametric) of each metal.
5. For each metal, calculate a statewide mean and one standard deviation using all of the site averages.
6. One standard deviation has been used for a statewide value because of the broad geographic coverage and multiple soil types that were sampled.

Selection of Metals for a Statewide Default Background Level

The attached table (Review of draft 2015 Default Background Values) summarizes the number of samples and locations, the percent of non-detects, the distribution, mean, standard deviation, a calculation of the mean and one standard deviation, and a summary of the percent change of the proposed new values compared to the 1993 default values.

- Four of the original 17 metals have increased proposed default values.
- Ten of the original 17 metals have lower proposed default values.
- Three of the original metals are not included based on a high percentage of non-detect values (mercury, silver) or lack of sufficient data with high percent non-detect (cyanide).
- Three new metals are proposed that were not included in the 1993 defaults (beryllium, strontium, vanadium).

For the proposed values, the method for selecting a specific metal was as follows:

1. All 25 metals from the 2015 MBSS were reviewed, which includes all original 1993 default metals except cyanide.
2. Metals not considered:
   a. Magnesium and Sodium: These metals were not included in the original 1993 defaults since site-specific background sampling did not include them. Data available for the 2005 MBSS was small, and rarely a parameter of concern. Although more data became available for the 2015 MBSS, given the reasons noted above and the very high cleanup criteria for these two metals, they were not included in the updated defaults.
3. Metals Removed:
   a. Cyanide: Originally in the 1993 defaults because claims were made it could be naturally occurring. The data was 91% non-detect and cyanide was rarely a parameter of concern. Therefore cyanide was not included in the updated defaults.
   b. Mercury: Data from the 2015 MBSS is 89% non-detect. Metals with 84% or greater non-detects were not included, based on the concept that a non-parametric estimate of one standard deviation of the mean (the 84th percentile) cannot be determined.
   c. Silver: Data from the 2015 MBSS is 92% non-detect. Metals with 84% or greater non-detects were not included, based on the concept that a non-parametric estimate of one standard deviation of the mean (the 84th percentile) cannot be determined.
4. Metals Added:

a. Beryllium: With 71% non-detects, the number of samples and spatial coverage were deemed adequate.
b. Strontium: All data was detected above laboratory detection limits, and although the number of samples was not very great, the spatial coverage was deemed adequate.
c. Vanadium: Only 2% of the data was non-detect, and spatial coverage and number of samples was deemed adequate.

Summary of Proposed 2015 Statewide Default Background

The attached table contains the proposed revised default levels. The original 1993 default background included 17 metals. The 2015 proposal includes 3 new metals and 14 of the original 1993 metals for a total of 17. Please contact us with any questions, and we will be available to meet if needed.

Attachment
cc: Patty Brandt, RRD
Christine Flaga, RRD
Sara Pearson, RRD
Abby Hendershott, RRD
Steve Sliver, OWMRP
DeLores Montgomery, OWMRP
Dale Bridgford, OWMRP

Michigan Department of Environmental Quality
Based on 2015 Michigan Background Soil Survey Data

Review of Proposed 2015 Statewide Default Background Levels

March 17, 2016

METAL	Number of Samples	Number of Sites	% Non-detect	Distribution of 2015 Site Mean Data	2015 Mean (mg/kg) {a}	2015 Standard Deviation {b}	2015 Mean and 1SD, or 84th quantile {c}	**Proposed 2015 Default Value (mg/kg)**	Comment	1993 Default Background (mg/kg)	% Change from 1993 values	
Aluminum (Al)	508	171	0%	Lognormal	2619	2.170	5683	**5700**		6900	-17.40	(Al)
Antimony (Sb)	259	82	83.8%	Non-parametric	--	--	1.1	***NI***	high % non-detects , poor geographic coverage	not done		(Sb)
Arsenic (As)	1795	490	6.3%	Lognormal	2.1	2.599	5.5	**5.5**		5.8	-5.17	(As)
Barium (Ba)	1241	401	2.0%	Lognormal	17.1	2.63	45.0	**45**		75	-40	(Ba)
Beryllium (Be)	390	155	71.3%	Non-parametric	--	--	1.0	**1**		not done	New	(Be)
Cadmium (Cd)	1347	413	69.9%	Non-parametric	--	--	2.0	**2**		1.2	66.7	(Cd)
Chromium (Cr)	861	247	12.5%	Lognormal	5.5	2.793	15.4	**15**		18	-16.7	(Cr)
Cobalt (Co)	1161	426	18.4%	Lognormal	5.2	2.006	10.4	**10**		6.8	47.1	(Co)
Copper (Cu)	1393	437	7.4%	Lognormal	5.4	2.543	13.7	**14**		32	-56.3	(Cu)
Iron (Fe)	568	197	0%	Lognormal	4775	2.356	11250	**11250**		12000	-6.25	(Fe)
Lead (Pb)	1619	482	18.0%	Lognormal	4.7	2.399	11.3	**11**		21	-47.6	(Pb)
Lithium (Li)	312	124	28.5%	Lognormal	4.6	2.359	10.9	**11**		9.8	12.2	(Li)
Manganese (Mn)	574	209	0%	Lognormal	113	3.184	359.8	**360**		440	-18.2	(Mn)
Mercury (Hg)	1168	414	89.1%	Non-parametric	--	--	0.1	***NI***	high % non-detects	0.13		(Hg)
Molybdenum (Mo)	275	116	89.1%	Non-parametric	--	--	1.351	***NI***	high % non-detects	not done		(Mo)
Nickel (Ni)	850	255	18.8%	Lognormal	6.9	2.095	14.5	**15**		20	-25	(Ni)
Selenium (Se)	1209	420	77.3%	Non-parametric	--	--	0.61	**0.61**		0.41	48.8	(Se)
Silver (Ag)	973	320	92.2%	Non-parametric	--	--	0.5	***NI***	high % non-detects	1		(Ag)
Strontium (Sr)	81	51	0%	Normal	78.3	50.3	128.6	**129**	Insufficient data for review? Has semi-decent coverage	not done	*New*	(Sr)
Thallium (Tl)	369	124	90.2%	Non-parametric	--	--	1.0	***NI***	high % non-detects	not done		(Tl)
Titanium	97	41	0%	Non-parametric	--	--	161.6	***NI***	poor geographic coverage	not done		(Ti)
Vanadium (V)	406	167	1.7%	Lognormal	11.2	2.403	26.9	**27**		not done	*New*	(V)
Zinc (Zn)	1392	433	2.2%	Lognormal	16.1	2.424	39.0	**39**		47	-17	(Zn)

Potential new metals to include

All data is from the 2015 Michigan Background Soil Survey. The means and standard deviations are based on the average values from all samples at a site. For example, the aluminum mean is calculated from 171 site averages, and not on the individual 508 samples. Some sites had more than one sample, and to avoid weighting the average for each site is used.

{a} For normal distributions this represents the arithmetic mean. For lognormal distributions, this represents the geometric mean. The mean was not estimated for data with non-parametric distributions (greater than 50% non-detect).

{b} For lognormal distributions, this represents the geometric standard deviation. The standard deviation is not estimated for nonparametric data.

{c} Value given is the mean and one standard deviation, calculated using the appropriate normal or lognormal formulas. The nonparametric value is based on the 84th quantile of the data set.

NI : *Not Included. Percent non-detect is close to or greater than the 1 standard deviation (84th quantile), any estimated value would be a non-detected one* ***and/or*** *locations of sites sampled does not have good geographic coverage of the entire state.*

ATTACHMENT K

BACKGROUND DOCUMENT

SUBJECT: UPDATED DISPERSION FACTOR (Q/C) AND WIND SPEED

Background and Introduction

This document describes the process used to update the dispersion factor (Q/C) and wind speed values used in calculating the volatilization factor (VF) and particulate emission factors (PEF). The VF and PEF parameters are used by the Michigan Department of Environmental Quality (MDEQ) to derive the health-based values for ambient air: volatile soil inhalation values (VSIV) and particulate soil inhalation values (PSIV). The VSIV and PSIV address inhalation exposures to soil contaminants in ambient air. The MDEQ had used Michigan meteorological data in deriving Q/C and wind speed values in the past. The Decision Framework for updating exposure assumptions (CSA, 2014) was used in establishing the default values for Q/C and wind speed.

This document consists of four sections: 1) Description of dispersion model used to generate the Q/C values; 2) Selection of representative meteorological monitoring station (data source); 3) Updated wind speed value; 4) Comparison with the United States Environmental Protection Agency (USEPA) and other states; and 5) Evaluation of data and conclusion.
The Q/C (ratio of emission rate to predicted concentration) represents dispersion of airborne contaminants from a square area source (e.g. ½ acre) expressed as grams per square meter per second (g/m^2-sec) per kilograms per cubic meter (kg/m^3) and derived using a dispersion model. The USEPA Soil Screening Guidance (SSG) (USEPA, 1996a,b) presents default Q/C values that represent the 90th percentile of the distribution of nationally modeled Q/C values from 29 selected locations (e.g., Minneapolis, MN; Cleveland, OH; and Chicago, IL), but did not include a Michigan location. Although estimates of state-specific Q/C values are available, no Michigan-specific data were included in the USEPA modeled values.

The wind speed is a parameter used to calculate the emissions due to wind erosion (Ew). Ew is a component of the PEF that represents particulate emissions generated by wind erosion of contaminated soil. The Ew is derived using the equation for the “unlimited reservoir” model from Cowherd et al. (1985) and expressed in mass (g) of uncontrolled soil particle emissions per square meter (m^2) of surface area of source per second. It is necessary to derive the default value for wind speed using the same meteorological dataset used to derive the Q/C (MDEQ, 2007).

Table 1 below provides a comparison of the previous and 2016 updated values.

Table 1. Existing and Updated Q/C and Wind Speed

Parameter	Previous Value	Updated Value
Q/C		
Q/C values (e.g. ½ acre) in g/m^2-s per kg/m^3	82.33 (for ½ acre)	42.45 (for ½ acre)
Number and range of Q/C values	14 values; 400 ft^2 to 1,000 acres	21 values; 100 ft^2 to 1,500 acres
Statistical estimate	90th percentile	90th percentile
Meteorological 5-year data evaluated	1987-1991	2010-2014
Number of meteorological stations evaluated	15 of 15 stations	15 of 72 stations
Representative meteorological stations with median Q/C values based on latest year data	South Bend, Detroit, and Gross Ile; 1991 data	Midland-Bay-Saginaw, Flint, and Muskegon; 2014 data
Selected source of 5-year meteorological data	South Bend, Indiana	Flint
Dispersion model used for modeling Q/C	Industrial Source Complex Short-term Dispersion Model (ISCST3)	AERMIC Dispersion Model (AERMOD)
Wind Speed		
Um = Wind speed (m/sec)	4.56	6.92
Statistical estimate	Mean annual	90th percentile annual
Measurement height (m); diffusion height	6.4	10
Data source (5 years)	1987-1991	2010-2014
Representative meteorological data source	South Bend, IN	Flint, MI
PEF adjustment to address short-term-peak particulate levels to account for non-annual averaging time	½ of PEF (50%)	none

Section 1. Selection of Dispersion Model

A dispersion model is used to estimate the Q/C values for different contamination source area sizes. The original model used to generate the present default Q/C values was the USEPA ISCST3. This type of dispersion model was used primarily to support the USEPA regulatory modeling programs (e.g., National Ambient Air Quality Standards, Prevention of Significant Deterioration) at that time. Due to various limitations and inadequacies of the ISCST3 model, USEPA has adopted a refined AERMIC model, AERMOD, to model stationary sources of air pollution and is useful for modeling point, area, and volume sources. The MDEQ's Air Quality Division currently use and requires the AERMOD for dispersion modeling.

The ISCST3 model
The Industrial Source Complex Model for area source (ISCST3) was used with rural dispersion coefficients and several default assumptions (see below) to estimate the generic dispersion of airborne contaminants. This model assumed a zero (0) receptor height and uniform emission rate from a one half acre source of 1.0 g/m^2-sec.

The AERMOD model
The USEPA recommended that AERMIC Model (AERMOD) replace ISCST3 for dispersion modeling evaluations of criteria air pollutant and toxic air pollutant emissions from typical industrial facilities. The MDEQ-Air Quality Division (AQD) adopted the use of the AERMOD model pursuant to Part 55, Air Pollution Control of Act 451, and its administrative rules, R 336.1240 et seq. Compared to ISCST3, AERMOD has new or improved algorithms for dispersion and provide reasonable concentration estimates under a wide variety of conditions (USEPA, 2015a).

In an evaluation of the PSIC, the MDEQ Toxics Steering Group (TSG) (MDEQ, 2009) recommended the use of the AERMOD model, together with the most current meteorological data sets, to generate Q/C values as this represents the most up-to-date science available and is the model required by the USEPA and the AQD for dispersion modeling. AERMOD details are discussed on USEPA's website (USEPA, 2015a).

Section 2. Selection of Representative Meteorological Station and Data Source

The Q/C and wind speed values were updated using more current meteorological data (2010-2014) from 15 Michigan meteorological monitoring stations (hereafter referred to as "station"). The MDEQ Meteorological Data Support Document (MDEQ, 2015c) shows the locations of 72 available stations. Hourly meteorological data is collected at all these stations; 29 stations also collect one-minute meteorological data. For dispersion modeling, USEPA recommends the use of one-minute meteorological data as the hourly average winds calculated using the one-minute meteorological data better reflects actual conditions compared to the single 2-minute observation used with the hourly meteorological data (MDEQ, 2015c).

2.1 Data Source Selection Approach

The procedure outlined below for selecting the representative data source for the updated Q/C is essentially the same as previous Q/C derivation with minor modifications. Refer to RRD Operational Memorandum No. 1. Technical Support Document Attachment 7 (MDEQ, 2007) for more details. Table 2 below shows the basis for the previous and updated data source.

Table 2. Meteorological Data Sources for Q/C and Wind Speed Values

Parameter	Previous	Updated
Available stations	15	72
Selected three stations based on latest year data	Midland-Bay-Saginaw, Grand Rapids, and South Bend (Indiana); 1991	Midland-Bay-Saginaw, Flint, and Muskegon; 2014
5-year data used	1987-1991	2010-2014
Selected five-year data source	South Bend (Indiana)	Flint

Procedure for Selecting Data Source:

Step 1. A ½ acre source area size was used for modeling the Q/C values for the 15 stations. The most recent year of available data for each station was chosen. The previous approach used 1991 datasets from 15 regional stations as the starting point for selecting the data. These 15 sets of data were routinely used in Michigan air dispersion modeling at that time. For the updated approach, 2014 data from selected 15 stations were used. Michigan has a total of 72 meteorological stations in the state. The AQD considers data from these selected stations to be representative of different regions across the state. For consistency and ease of comparison, the number of stations included in the selection method remained the same as the previous approach.

Step 2. The AQD modeled the "maximum annual average concentrations" (concentrations) for each dataset. The concentrations represent the annual average of modeled maximum concentrations. The annual averaging period is the AQD default approach. The 90th percentile of the distribution of the modeled average air concentrations for all receptors represented the 2014 Q/C for each station. See Table 1 of Appendix A for the modeled Q/C values.

Step 3. From the results in Step 2, datasets from three (3) stations were selected from which 5-year data were evaluated. These 3 stations are ones that generated the median value or values above and below the median when the concentrations values were ranked. The three stations represent the "average" meteorological conditions for the state. The previous approach identified Midland-Bay City-Saginaw (MBS), Grand Rapids (GR), and South Bend (SBN) as the representative stations. While SBN does not lie within the geographical boundaries of Michigan, the SBN dataset was considered representative of southwest Michigan at that time and was routinely used in air modeling by MDEQ. The updated approach identified Midland-Bay City-Saginaw (MBS), Flint (FNT), and Muskegon (MKG) stations. Refer to Table 2 of Appendix A.

Step 4. Available data for the most recent five years for the selected 3 stations were modeled to generate the concentrations for ½ acre source size only. The five-year analysis is necessary to ensure that the data source chosen to calculate the default Q/C values is representative of general weather conditions for that area (i.e., the year did not represent unusual weather events). The Q/C value for ½ acre source size established

from the 5-year data of each location was used to determine the data source that will be used to model the default Q/C values. For the previous approach, the five-year data consisted of 1987 to 1991 data. The updated approach was based on 2010 to 2014 data (MDEQ, 2015a and b). The modeled concentrations and updated Q/C values for ½ acre were based on the Flint (FNT) data. Refer to Table 3 of Appendix A.

Step 5. The results in Step 4 identified the 5-year dataset that will be used to produce the median ½ acre-based Q/C value. This dataset was then used in this step to model the Q/C values for all source area sizes in addition to ½ acre. This 5-year dataset represented the location with roughly the 50th percentile of dispersion characteristics for all Michigan meteorological monitoring locations. For the previous approach, the default Q/C values were based on the South Bend 5-year dataset. The updated Q/C values were based on the Flint 5-year dataset.

Step 6. The Q divided by C or Q/C factor for developing the PEF or VF is based on the 90th percentile of the distribution of modeled annual average air concentrations (C) for all on-property receptor locations. The emission rate, Q, is based on an assumed uniform emission rate of 0.001 g/m^2-sec from the source area. To derive Q/C, Q is divided by the modeled concentration, C, represented by the 90th percentile concentration for a particular source area size. A 10^9 conversion factor is applied to convert µg/m^3 to kg/m^3.

2.2 Updated Q/C Values

The updated Q/C values that must be used for calculating the VSIV and PSIV for different source area sizes of contamination are shown below. The generic VSIC and PSIC presented in the Criteria Tables (R 299.46) are based on VF or PEF for a ½ acre source size. For source sizes other than ½ acre, the VSIV and PSIV must be determined using the appropriate Q/C value. The modifiers presented in the following table facilitate such determination.

Concentrations, Q/C, and Modifier Values

Contamination Source Area Size (ft^2 or acres)	90th Percentile Concentration (C) (µg/m^3)	Dispersion Factor (Q/C) (g/m^2-s per kg/m^3)	Source Size Modifier
100 ft^2	3,380	295.82	6.97
400 ft^2	7,732	129.34	3.05
1000 ft^2	10,983	91.05	2.14
2000 ft^2	13,565	73.72	1.74
½ acre	23,558	**42.45**	**1.00**
1 acre	26,852	37.24	0.88
2 acres	30,476	32.81	0.77
5 acres	35,689	28.02	0.66
10 acres	39,966	25.02	0.59
20 acres	44,911	22.27	0.52
30 acres	47,859	20.89	0.49
50 acres	51,988	19.24	0.45
75 acres	55,371	18.06	0.43

Contamination Source Area Size (ft^2 or acres)	90th Percentile Concentration (C) ($\mu g/m^3$)	Dispersion Factor (Q/C) (g/m^2-s per kg/m^3)	Source Size Modifier
100 acres	58,098	17.21	0.41
150 acres	61,824	16.17	0.38
200 acres	64,806	15.43	0.36
300 acres	68,989	14.50	0.34
400 acres	72,057	13.88	0.33
500 acres	74,714	13.38	0.32
1000 acres	83,213	12.02	0.28
1500 acres	88,904	11.25	0.26

Section 3. Updated Wind Speed

The updated wind speed value must be based on the same data used to generate the Q/C. Therefore, the Flint 5-year meteorological dataset was used to develop the updated wind speed value. See Table 1 for the differences between the previous and updated approach.

3.1 Wind Speed Adjustment Factor

The wind speed value used in calculating the previous emissions due to wind erosion was an average annual value. In conjunction with this annual average wind speed, a 50 percent adjustment factor was applied to the PEF to account for short-term peak particulate levels for noncarcinogenic hazardous substances with MDEQ inhalation toxicity endpoints or initial threshold screening levels (ITSL) based on a non-annual (quarterly, 24-hour, 8-hour, or 1-hour) *averaging time*. This adjustment reduces the noncarcinogenic PSIC value by one-half. The basis for the adjustment factor is explained in a report to the MDEQ Toxics Steering Group (TSG) from the TSG Subcommittee for the Application of the Manganese Particulate Soil Inhalation Criteria (PSIC) in the Detroit Area (MDEQ, 2009). The 1998 MDEQ stakeholder workgroup that developed the PSIC methodology recognized the inconsistency in applying averaging time for some substances. The wind erosion and other parameters of the PEF methodology are designed to address long term emissions and impacts (annual averages). However, some ITSLs have short term averaging times (1-hour, 8-hours, or 24-hours) rather than annual averaging times. The MDEQ-AQD uses the averaging times in relation to ITSL values when evaluating the acceptability of emission impacts, establishing permitted emission limits, and interpreting air monitoring data. The ITSLs (and their associated averaging times) serve as basis for developing generic health-based inhalation values for noncarcinogenic effects and therefore, the use of long term (annual average) emissions and impacts does not account for the potential for short term peak impacts. Available empirical data demonstrated that monitored ambient air peak (90th percentile) particulate (PM10) levels measured over 24-hour periods were roughly two fold greater than annual average PM10 levels. Therefore, the 1998 MDEQ stakeholder workgroup incorporated into the noncarcinogenic PSIC methodology a PEF adjustment factor of 50 percent (MDEQ, 2009). Based on current empirical data, the AQD indicates that this 2-fold difference between short-term ambient air peak PM10 levels measured over 24-hour periods and annual average PM10 levels continues to be identified (MDEQ, 2011).

The PEF adjustment is applied only to hazardous substances with ITSLs having 1-hour, 8-hour, or 24-hour averaging times. This adjustment lowers the noncarcinogenic PSIC values by one half (50 percent) (MDEQ, 2007). To address the impacts to ambient air concentrations of peak particulate emissions and prevent exceedance of hazardous substances which have been assigned short term *averaging times* in air, the 90th percentile of the distribution of wind speed measurements is selected as the default wind speed value to ensure that potential exposure levels account for peak 24-hour concentrations rather than just long-term average concentrations. The use of the 90th percentile wind speed value would eliminate the need to apply an adjustment factor.

3.2 Consideration for Hazardous Substances with Developmental Effects

For developmental and reproductive (DR) toxicants, the *averaging time* remains an important consideration. The MDEQ Toxics Steering Group Report (MDEQ TSG, 2015) details a process to address developmental and/or reproductive toxicity in the derivation of generic cleanup criteria. This process includes chemical-specific evaluation to identify appropriate compliance considerations (e.g., averaging media concentrations over time). The report indicates that "For DR toxicity, single day prenatal exposures may result in adverse effects, so it is not appropriate to average environmental media concentrations over time to compare to criteria (EPA, 1991). When chemical-specific information indicates that a different critical exposure window is appropriate, that critical exposure window should be the averaging time for environmental media concentrations."

Section 4. Comparison with USEPA and Other States:

Q/C Values

The USEPA Q/C values presented in the Soil Screening Guidance (SSG) (USEPA, 1996a and b) represent the 90th percentile of the distribution of nationally modeled Q/C values from 29 meteorological locations including Minneapolis, Cleveland, and Chicago. These values were based on a 1-year dataset. USEPA recommends the use of Q/C values presented in Table 3 of the SSG depending on the site's location (nearest modeled location), meteorological conditions (climatic zone) and source area size. The Q/C of 90.80 g/m^2-sec per kg/m^3 for a ½ acre source size based on Minneapolis data is used to generate the generic PEF for the USEPA Regional Screening Levels (RSL) (USEPA, 2015b). This Q/C is considered the best approximation of the 90th percentile of normalized concentrations from the 29 datasets (EPA, 1996a and b; USEPA, 2015b). Other states including Region 5 states use the USEPA (1996a) Table 3 Q/C values that correspond to their region's Climatic Zones (Refer to Table 5). Appendix D of the Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002) also presents tables of coefficients and a map depicting climatic zones that may be used for determining the site-specific dispersion factor that corresponds to a climatic zone and city. The table below summarizes the MDEQ and USEPA approaches:

Table 4. MDEQ Updated and USEPA Q/C and Wind Speed Determination Approaches

Parameter	MDEQ updated (2016)	USEPA (1996a,b;2002)
Best available data set	5-year data source (2010-2014)	One year data source (1993)
Meteorological data sources	15 Michigan-specific stations	29 US locations (does not include Michigan)
Representative Data source	Michigan-specific data (Flint)	Minneapolis-based QC or site-specific (dependent on appropriate climatic zone and/or city)
Selected representative five-year data source	Flint, MI	none
Dispersion model	AERMOD	ISCST3

Wind speed Value
The USEPA generic PEF is calculated using a mean annual wind speed value of 4.69 meter/second. The basis for this value is not presented or discussed in the USEPA soil guidance documents (EPA, 1996). Since the dispersion factor for wind erosion is a function of wind speed, then the wind speed value must be based on the same meteorological data used to model the dispersion factor.

Section 5. Evaluation of Information and Conclusion
Using the Decision Framework (CSA, 2014), MDEQ evaluated available information and values for updating the generic dispersion factor and wind speed.

Evaluation of Information:
Michigan-Specific Updated Values
Michigan-specific meteorological data (2010-2014) were used for modeling the updated Q/C values and deriving the wind speed value (MDEQ, 2015b). The latest dispersion model, AERMOD, recommended and currently used by both the USEPA and MDEQ-AQD was used to generate the Q/C values.
USEPA Recommended Values
The USEPA Q/C and wind speed values are based on older datasets from 29 different locations across the United States that did not include a Michigan-specific data. In addition, the USEPA Q/C values were modeled using an outdated dispersion model.

Evaluation of Data Quality Objectives (DQO)

1) *Relevance and applicability to Michigan (geographic, temporal, and demographic representativeness).* The MDEQ updated values are based on Michigan-specific data. Rating (See Appendix B for explanation of DQO ratings): High.
2) *Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search).* The MDEQ updated values are based on 5-year empirical data from 15 locations representative of regions in the state. The data is comprehensive and the approach provides a thorough description of the steps considered in deriving the recommended values. Rating: High.
3) *Soundness and credibility* (*adequacy of approach; intrinsic sources of bias; sample size*). The consideration of 15 data sets for the most current year (2014) in selecting 3 representative data sets and the selection of most representative data using 5-year data sets from 3 monitoring stations indicate that the data and approach considered in the development of the updated values were free of bias, rigorous criterion, and represent the state's 50th percentile dataset. The approach is clear and consistent with previous approach with modifications to accommodate the use of best available information (most current data and best model). Rating: High.
4) *Transparency and objectivity (availability of supporting data; funding source; peer-review)*. The approach have been previously described (MDEQ, 2007) and the meteorological data used are available to the public (MDEQ, 2015b). Rating: High.
5) *Certainty (number and agreement of studies)*. The datasets considered for derivation of the MDEQ updated values were large, one year data of 15 stations and 5-year data of 3 stations, resulting in high confidence on the dataset used to generate the Q/C values. Rating: Medium.

Other State Values

The state values were either based on the USEPA default values used for calculating the RSL or values presented in the SSG (USEPA, 1996a and b). Therefore, evaluation of DQOs for these values is not necessary.

Table 5. Comparison of State Values Pertaining to Q/C and Wind Speed

Parameter	USEPA-RSL	IL[1]	IN[1]	MN[1]	OH[1]	WI[1]
Q/C for ½ acre, g/m^2 per kg/m^3	93.77	90.80 (residential); 85.81 (industrial /commercial)	68.81	93.77	85.63	98.43
Wind speed, m/sec	4.69	4.69	4.69	4.69	4.83	4.69
Data are based on USEPA (1996a,b, 2002)	Minneapolis data	Chicago data	(Regional data)	Minneapolis data	Cleveland data	Chicago data
Model used	ISC	ISC	ISC	ISC	ISC	ISC

[1]Data sources: Illinois EPA, Indiana Department of Environmental Management (IDEM, 2012), Minnesota Pollution Control Agency (MPCA, 2015), Ohio EPA, and Wisconsin Department of Natural Resources (WI-DNR)

Conclusion:
The updated MDEQ values for dispersion factor and wind speed are based on best available, robust, and Michigan-specific meteorological data. In addition, the dispersion factor values are modeled using the most current USEPA and MDEQ-approved dispersion model (AERMOD). Therefore, the MDEQ updated values are rated high quality as they are based on recent Michigan-specific data and best available science (modeling method) compared to USEPA or other states values.

References

Cowherd, C., G.E. Muleski, P.J. Englehard, and D.A. Gillette. 1985. Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites. EPA/600/8-85/002. U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Washington, DC. February, 1985.

CSA (Criteria Stakeholder Advisory Group), 2014. Final Report: Part 201: Stakeholder Recommendations for Updating Michigan's Generic Cleanup Criteria. Prepared by Public Sector Consultants for Michigan Department of Environmental Quality. Lansing, Michigan. http://www.michigan.gov/documents/deq/deq-rrdCSAFinalReport-11-26-14_475701_7.pdf

MDEQ (Michigan Department of Environmental Quality). 2007. Technical Support Document – Attachment 7. Part 201 Generic Soil Inhalation Criteria for Ambient Air/Part 213 Tier I Soil Inhalation Risk-based Screening Levels for Ambient Air. July 2007. Available at: http://michigan.gov/documents/deq/deq-rrd-OpMemo_1-Attachment6_285488_7.pdf

MDEQ Toxics Steering Group (TSG). 2009. Report of Subcommittee for the Application of the Manganese Particulate Soil Inhalation Criteria (PSIC) in the Detroit Area.

MDEQ TSG Children's Environmental Health Subcommittee. 2015. Process to Address Developmental and/or Reproductive Toxicity in the Derivation of Generic Cleanup Criteria. Toxics Steering Group, Children's Environmental Health Subcommittee, Lansing, Michigan. (Unpublished)

MDEQ Air Quality Division. 2011. Communication from Robert Sills: Use of PEF Adjustment for the Updated Soil Criteria. Lansing, Michigan. March, 2011.

MDEQ Air Quality Division. 2015a. McDonald, Tracey (Air Quality Division) Communication to RRD. 2015. Modeled Dispersion Factors from 15 Michigan Monitoring Stations. Lansing, Michigan.

MDEQ Air Quality Division. 2015b. Meteorological Data from Michigan Monitoring Stations. Lansing, Michigan. (Data is available upon request from RRD or AQD)

MDEQ Air Quality Division. 2015c. Meteorological Data Support Document. Available at: http://www.michigan.gov/documents/deq/deq-aqd-mm-met_support_256121_7.pdf or http://www.michigan.gov/deq/0,4561,7-135-3310_70487-66831--,00.html

USEPA (U.S. Environmental Protection Agency). 1991. Guidelines for Developmental Toxicity Risk Assessment. Fed Reg 56(234):63798-63826. Available at: http://www.epa.gov/ncea/raf/pdfs/devtox.pdf

USEPA. 1996a. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-23. Available at: https://www.epa.gov/superfund/superfund-soil-screening-guidance

USEPA. 1996b. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-17A. Available at: https://www.epa.gov/superfund/superfund-soil-screening-guidance

USEPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-24. Available at: https://semspub.epa.gov/work/HQ/175237.pdf

USEPA. 2015a. Preferred/Recommended Models/AERMOD Modeling System. Available at: https://www3.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_3August2015.pdf; http://www3.epa.gov/scram001/dispersion_prefrec.htm

USEPA. 2015b. Regional Screening Table. Available from http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

APPENDIX A

Table 1. Modeled Maximum Air Concentrations using 2014 Data* and AERMOD

Station Location	Modeled Air Concentration ($\mu g/m^3$)	Station Name
Sault Ste. Marie	10679	ANJ
Alpena	25776	APN
Detroit Metro	24063	DTW
Flint	21854	FNT
Grand Rapids	15902	GRR
Houghton Lake	12270	HTL
Iron Mountain	24805	IMT
Lansing	26268	LAN
Manistee	11576	MBL
MBS	18398	MBS
Muskegon	22978	MKG
Mount Pleasant	16014	MOP
South Bend	17319	SBN
Toledo	31395	TOL
Traverse City	26065	TVC

* Based on 1-minute meteorological data, except for MBL and MOP

Table 2. Rank of Modeled Maximum Air Concentrations Using 2014 Data and Selected Three Representative Locations

Ranking	Concentration ($\mu g/m^3$)	Station
1	10679	ANJ
2	11576	MBL
3	12270	HTL
4	15902	GRR
5	16014	MOP
6	17319	SBN
7	**18398**	**MBS**
8 (Median)	**21854**	**FNT**
9	**22978**	**MKG**
10	24063	DTW
11	24805	IMT
12	25776	APN
13	26065	TVC
14	26268	LAN
15	31395	TOL

Table 3. Rank of Modeled Maximum Air Concentrations ($\mu g/m^3$) for ½ Acre Source Size

Data Year	MBS	FNT	MKG
2010	20234	**24127**	28390
2011	20320	**24027**	26736
2012	22035	**25457**	27654
2013	19526	**23581**	24932
2014	18398	**21854**	22978
Average	20102	**23809**	26318

APPENDIX B

EXPLANATION OF RELATIVE DATA QUALITY OBJECTIVE (DQO) RATINGS

This Appendix provides an outline of how the Decision Framework DQOs (CSA, 2014) were applied. The DQO ratings used by SRC in evaluating the data and data sources used for developing the updated exposure assumptions was adopted in the evaluation of the Q/C and wind speed data against the DQOs. Refer to the CSA Report (2014) and Cleanup Criteria and Screening Levels Development and Application Technical Support Document. Note that the ratings are relative and not absolute.

Relevance and applicability to Michigan (*geographic, temporal, and demographic representativeness*).

High: Based on recent data obtained in Michigan, in members of its population, or developed based on data specific to Michigan (e.g., exposure frequency based on climate conditions in Michigan).

Medium: Based on recent data obtained outside Michigan or its population, but in an area or population with comparable geographic, temporal, and demographic conditions.

Low: Based on data obtained outside Michigan or its population, in an area or population with different geographic, temporal, and demographic conditions, or with unknown geographic, temporal, and demographic conditions.

Clarity and comprehensiveness (completeness of method and data reporting, completeness of literature search).

High: Derived value with complete documentation of the selection process, and based on known or apparently thorough literature search, OR, single study with thorough description of methods and results.

Medium: Derived value with incomplete documentation of the selection process, and/or based on limited literature search, OR, single study with some noncritical information missing from methods and results.

Low: Derived value with little or no documentation of the selection process, and/or without accompanying literature search, OR, single study lacking critical information from method or results.

Soundness and credibility (*adequacy of approach; intrinsic sources of bias; sample size*).

High: Using an established method to estimate the parameter, without intrinsic sources of bias, and with adequate sample size(s).

Medium: Using an established method to estimate the parameter, with some known or expected intrinsic sources of bias, and with adequate sample size(s).

Low: Using a novel or uncertain method to estimate the parameter, with or without intrinsic sources of bias, and with inadequate sample size(s).

Transparency and objectivity (availability of supporting data; funding source; peer-review).

High: Based on peer-reviewed study(s) performed by researcher(s) without demonstrable conflict of interest and supported by other studies.

Medium: Based on peer-reviewed study(s) performed by researcher(s) without demonstrable conflict of interest, but without support from other studies.

Low: Based on unpublished study(s) and/or performed by researcher(s) with potential conflict of interest and/or based on professional judgment, without support from other studies.

Certainty (number and agreement of studies).

High: Based on > 3 studies with values ranging up to ±50% from the selected value.

Medium: Based on at least 2 or 3 studies with values ranging up to ±100% from the selected value.

Low: Based on a single study or more than one study with variability ranging >±100% from the selected value, or based on professional judgment.

ATTACHMENT L

BACKGROUND DOCUMENT

SUBJECT: SOURCE AREA SIZE AND GENERIC VSIC AND PSIC DETERMINATION

Source area size may be determined by the property boundaries when property lines are well defined and off-site migration of contaminants is not likely. For unknown and/or large contamination areas, the source area size and modified health-based criteria (VSIC and PSIC) for contaminated areas may be determined through the following method:

1) Establish source area size and modified VSIV and PSIV

- First, establish the screening level (SL) by adjusting the one-half acre residential health-based value (infinite source VSIV or PSIV) presented in the Criteria Table using the modifier for 1,000 acres, which is 0.28. The 1,000-acre based-adjusted VSIC will serve as the SL. Other SLs may be proposed and considered depending on the appropriate site information.
- Next, the soil concentrations are compared to the SL to identify the source areas. The source area is the contaminated area with soil concentration(s) exceeding the SL.
- Third, sum up the identified source areas to determine the source area size.
- Fourth, utilizing the modifier that corresponds to the source area size [Source Size Modifier Table in 299.26(9) or R 299.49(1) Footnote (Y)], modify the one-half acre infinite or finite source VSIV or PSIV.

Where the source area size falls between the sizes presented in the Source Size Modifier Table, use the modifier for the next larger source area size (R 299.26(9)). For example, if the source area size is determined to be 50 acres, the one-half acre PSIC is multiplied by the modifier for 50 acres, 0.45, to generate the generic modified PSIC.

Table of Dispersion Factor (Q/C) Values and Modifiers

Contamination Source Area Size (ft^2 or acres)	Dispersion Factor (Q/C) (g/m^2-s per kg/m^3)	Modifier for deriving final VSIV/PSIV
100 ft^2	295.82	6.97
400 ft^2	129.34	3.05
1000 ft^2	91.05	2.14
2000 ft^2	73.72	1.74
½ acre	**42.45**	**1.00**
1 acre	37.24	0.88
2 acres	32.81	0.77

Contamination Source Area Size (ft^2 or acres)	Dispersion Factor (Q/C) (g/m^2-s per kg/m^3)	Modifier for deriving final VSIV/PSIV
5 acres	28.02	0.66
10 acres	25.02	0.59
20 acres	22.27	0.52
30 acres	20.89	0.49
50 acres	19.24	0.45
75 acres	18.06	0.43
100 acres	17.21	0.41
150 acres	16.17	0.38
200 acres	15.43	0.36
300 acres	14.50	0.34
400 acres	13.88	0.33
500 acres	13.38	0.32
1000 acres	12.02	0.28
1500 acres	11.25	0.26

2) Determine the Generic Criterion (VSIC or PSIC)

Compare the modified VSIV or PSIV to the chemical's target detection limit (TDL) and the maximum ceiling concentration. If the modified value is lower than the TDL, the TDL becomes the criterion [Footnote (Y)]. If the resulting value exceeds the maximum ceiling concentration (of 1.0E+8 µg/kg), that concentration becomes the criterion [Footnote (D)].

The criterion may exceed the chemical-specific Csat. If C_{sat} is exceeded, the person proposing or implementing response activity must document whether additional response activity is required to control NAPL to protect against risks associated with NAPL by using methods appropriate for the NAPL present [Footnote (C) and R 299.4(9)].

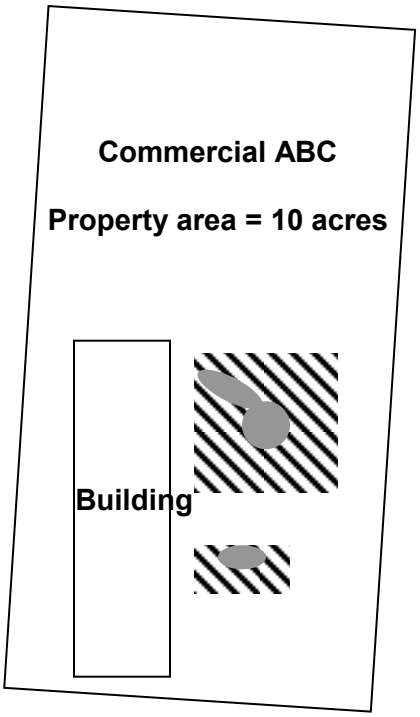
3) Noncontiguous source areas

For non-contiguous source areas, the contamination emitted from each of the source areas is assumed to commingle in ambient air at the "Property" to produce an air concentration greater than that from a single source area. The modified VSIV using a source size based on the sum of all the non-contiguous source areas, will provide a conservative screen since the airborne contaminants emitted from the non-contiguous source areas would likely be more greatly dispersed over the entire source and non-source areas than would be the case if all source areas were contiguous. Professional judgment and information concerning the entire study area or site should be used to determine the extent of sampling required to characterize the areas between source areas.

4) VSIC Application Example

Consider the following example of a nonresidential 10-acre site with trichloroethylene (TCE) contamination that has been adequately characterized.

VSIC Modification Example



Legend:

- Area exceeding SL
- Area exceeding VSIC

Assumptions:

- The total nonresidential "property" area is 10 acres.
- Adequate vertical characterization indicates a 5 meter finite VSIC is appropriate.
- Property boundaries are defined.
- Potential off-site migration is not likely to occur.

Screening Level Method:

Example: Trichloroethylene (TCE).

1) Determine the Screening Level for the contaminant.

a) The nonresidential **one-half acre infinite VSIC for TCE** is **1,400 µg/kg or ppb (DD) based on developmental effect**.
b) The modifier for 1,000-acre source area size is 0.28.
c) **TCE nonresidential Screening Level = 392 ppb.**

2) Compare soil TCE concentrations to 392 ppb. Areas with exceedances are the source areas.

3) Determine source area size. Assume source area size is 1.5 acres. **Use the modifier for a 2-acre source size**.

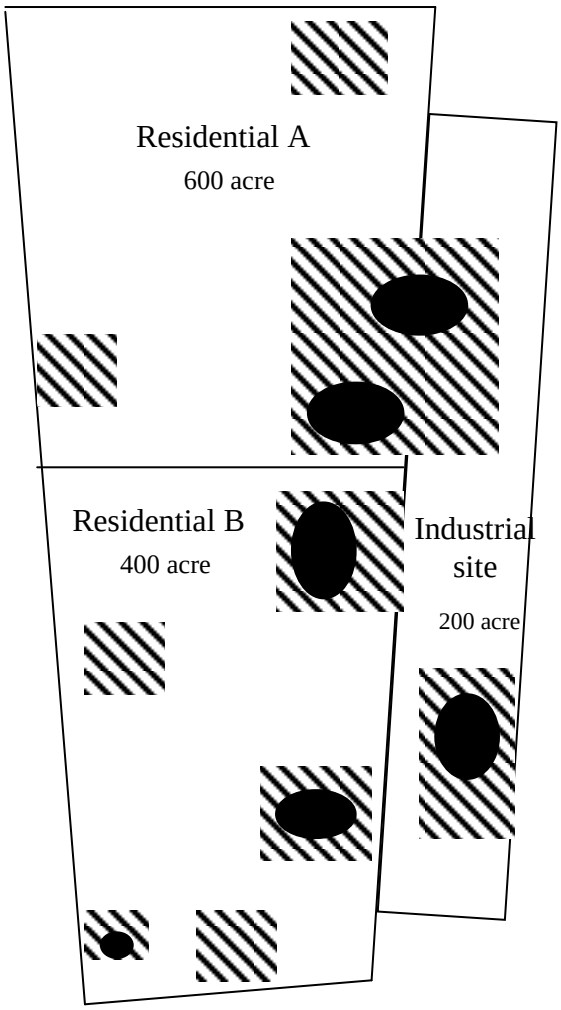
4) Modify one-half acre 5-meter finite VSIV:

a) The one-half acre **5 meter finite VSIV** for TCE is 8.0E+5 or **800,000 ppb (DD)**.
b) The **modifier for 2-acre source size** is **0.77.**
c) **TCE modified 5 meter finite VSIV = 616,000 ppb.**

5) Compare the TCE modified VSIV to the TDL (50 ppb) and maximum ceiling concentration (1.0E+8 ppb). In this case, the VSIV is the 5-meter VSIC.

6) Compare the 5-meter VSIC to C_{sat} (250,000 ppb). In this case, TCE VSIC (616,000 ppb) is higher than TCE C_{sat}; therefore, assessor must refer to Footnote (C) and R 299.4(9) for additional requirements.

Figure 2. PSIC Modification Example



Legend:

- **Area exceeding SL**
- **Area exceeding 300 acre-based PSIC**

Assumptions:

- Mixed residential and Industrial - nonresidential properties.
- Total acreage is 1,200 acres.

Screening Level Method:
Example: Manganese (Mn).

1) **Determine the Screening Level for Mn**.
   a) The **one-half acre PSIC for Mn** are:
      Residential - 15,000 mg/kg or ppm
      Nonresidential - 22,000 ppm.
   b) The **modifier for 1,000-acre source area size is 0.28**.
   c) **Mn Screening Levels:**
      Residential 4,200 ppm
      Nonresidential 6,160 ppm

2) **Identify the source areas**
Compare residential and Nonresidential soil concentration(s) to the screening levels. Areas with screening level exceedances are the source areas.

3) **Determine source area size**
Source area size is the sum of all Residential and Nonresidential source areas. Assume total of all source areas is 250 acres. Use the **modifier for 300 acres.**

4) **Modify one-half acre PSICs for Mn**
   a) **Residential - 15,000 ppm**
      Nonresidential - 22,000 ppm
   b) The **modifier for 300 acres is 0.34.**
   c) The modified **300-acre PSIV for Mn** are:
      Residential - 5,100 ppm
      Nonresidential - 7,480 ppm

5) Compare the Mn modified PSIVs to the TDL (1 ppm) and maximum ceiling concentration (1.0E+5 ppm). In this case, the PSIVs are the criteria or PSIC.

6) Compare residential and nonresidential soil concentrations to the residential (5,100 ppm) and nonresidential PSIC (7,480 ppm), respectively.

ATTACHMENT M

BACKGROUND DOCUMENT

SUBJECT: FRACTION OF ORGANIC CARBON CONTENT

The Michigan Department of Environmental Quality (MDEQ) has adopted an organic carbon content or fraction of organic carbon in soil (*foc*) of 0.002 gram/gram or 0.2% based on the soil-type sand. The fraction of organic carbon is used in estimating the emission or flux rates of hazardous substances from groundwater or soil into indoor or ambient, air as well as predicting chemical partitioning between different environmental media.

The MDEQ conducted a comprehensive evaluation of Michigan-specific data on soil types and established that sand is the appropriate generic soil type because it is the predominant soil type in Michigan. Sand is present at over 30 percent of the state. As a result, the MDEQ used sand associated soil-type inputs (e.g. fraction of organic carbon) in calculating the health-based values (HBVs) for indoor air, ambient air, and groundwater protection, in addition to soil saturation screening levels (Csat). The fraction of organic carbon of 0.002 is consistent with the value used by the USEPA (1996a and b) for subsurface soils. MDEQ has used this value to develop Csat and residential volatilization to indoor air screening values and criteria. The soil data source and quality are consistent with the Collaborative Stakeholder Advisory (CSA) recommendations for developing exposure and fate and transport values. Refer to the CSA Report (2014) and Cleanup Criteria and Screening Levels Development and Application Resource Materials Sections 4.4, 9.1 and 12.7.

Use of a site-specific fraction of organic carbon content value in calculating HBVs and Csat concentrations may allow for an unrestricted closure. If site-specific HBVs are calculated for any soil pathway using site-specific soil type and associated soil inputs such as sand-based fraction of organic carbon content, the same parameter values must be used for the site-specific Csat calculations and vice versa.

Adequate site characterization is necessary to establish appropriate soil type and uncontaminated areas. Therefore, site-specific fraction of organic carbon content must be based upon representative sampling. Given the variability of the fraction of organic carbon content for different soil conditions, a single measurement is not an acceptable representation. General guidelines for conducting representative sampling are as follows. Refer to MDEQ Sampling Strategies and Statistics Training Materials for Cleanup Criteria (S^3TM) (MDEQ, 2002) for more details on the sampling methods.

- Soil samples must be taken from uncontaminated areas; the samples need to represent native soil conditions unaffected by any release.
- Soil samples must be collected from the same soil type associated with the contamination but not from the contaminated area.

- Soil samples must include a chemical analysis to assure that the sample area is not contaminated.
- The appropriate analytical method must be used as described above.
- A minimum of 4 samples from each soil type must be analyzed.

If fewer than 9 samples are collected, the lowest value from each soil type should be used in calculating the site-specific fraction of organic carbon. If a minimum of 9 samples from each soil type is analyzed, a 95 percent lower confidence limit (LCL) for the mean may be used to determine the site-specific fraction of organic carbon. If an LCL for the mean is calculated, a random sampling strategy should be used to collect the samples from the appropriate soil type (i.e., the same soil type as that associated with the release from uncontaminated areas).

REFERENCES:

MDEQ, 2002. DEQ Sampling Strategies and Statistics Training Materials (S^3TM) for Part 201 Cleanup Criteria. August 2002.

USEPA, 1996a. Soil Screening Guidance: User's Guide. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-23. Available online at: http://www.epa.gov/superfund/health/conmedia/soil/index.htm#user (accessed August 2015).

USEPA, 1996b. Soil Screening Guidance: Technical Background Document. Office of Emergency and Remedial Response. Washington, DC. OSWER No. 9355.4-17A. Available online at: http://www.epa.gov/superfund/health/conmedia/soil/introtbd.htm (accessed August 2015).

ATTACHMENT N

BACKGROUND DOCUMENT

SUBJECT: CARCINOGENIC POLYNUCLEAR AROMATIC HYDROCARBONS

Health-based values for certain groups of hazardous substances with similar toxicity characteristics are developed with special considerations[1]: "If 2 or more hazardous substances are present and known to result in toxicological interaction, then the interactive effects, including additivity, shall be considered in establishing levels that are protective of the public health, safety, and welfare and the environment."

The cleanup criteria tables include seven carcinogenic polynuclear aromatic hydrocarbons (cPAHs). Of these seven cPAHs, only benzo(a)pyrene has available cancer toxicity data sufficient to derive a chemical-specific oral cancer slope factor (CSF) and inhalation unit risk factor (IURF), which can then be used to develop health-based values. The concentrations of the remaining six cPAHs are estimated using the Toxic Equivalence Factor (TEF) approach and the CSF or IURF for benzo(a)pyrene (Schoeny and Poirier, 1993; IRIS, 2014). The seven cPAHs and their associated TEFs relative to benzo(a)pyrene are shown below:

Compound	CAS Number	TEF
Benzo(a)pyrene	50328	1.0
Benz(a)anthracene	56553	0.1
Benzo(b)fluoranthene	205992	0.1
Benzo(k)fluoranthene	207089	0.01
Chrysene	218019	0.001
Dibenzo(a,h)anthracene	53703	1.0
Indeno(1,2,3-c,d)pyrene	193395	0.1

The cleanup criteria rules include numeric criteria only for benzo(a)pyrene. A Footnote (Q) is presented in lieu of numeric cleanup criteria values in the criteria cells of the tables for the other six cPAHs[2], pursuant to. The Footnote (Q) requires summing of concentrations of all cPAHs detected at a site as follows:

"The concentration of each carcinogenic polynuclear aromatic hydrocarbon (cPAH) detected at a facility shall be expressed as its equivalent concentration of benzo(a)pyrene by multiplying the

[1] R 299.34(1)
[2] R 299.49(1)(Q)

concentration by its respective toxicity equivalent factor (TEF). All TEF-adjusted cPAH concentrations shall then be added together and the total TEF-adjusted concentration compared to the relevant criteria for benzo(a)pyrene."

The health-based soil direct contact values (DCVs) for benzo(a)pyrene are based on a cancer endpoint. The TEF approach is applicable for the cancer evaluation of the other cPAHs for the direct contact pathway. An example calculation demonstrating the application of the TEF approach for the soil DCVs, as stated in Footnote (Q), is provided at the end of this document.

When any of the cPAHs are reported at levels below the detection level, one-half the detection level will be used when determining the total TEF-adjusted concentration. Other approaches may be proposed when addressing non-detect data for the cPAHs and submitted to the department for approval.

The TEF approach is used by the USEPA and other states to develop cleanup up values for the cPAHs. The USEPA Regional Screening Levels (RSLs) for each cPAH are based on its relative potency to benzo(a)pyrene using the TEFs. The total or cumulative cancer risk for all cPAHs present at a site is estimated by adding the risk associated with each cPAH.

The RSL User's Guide indicates two approaches to estimate cumulative risk for cPAH:

1. TEFs may be applied to the cPAH concentrations found in environmental samples, or
2. TEFs may be applied to the cPAH's toxicity values.

TEFs should not be applied using both approaches. The department has previously used the TEFs to adjust the CSF for benzo(a)pyrene and generate numeric criteria for the other cPAHs. The TEF concept is not new; however, its application has been updated.

The current USEPA guidance regarding the assessment of cPAHs is presented in the *Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons* (Schoeny and Poirier, 1993). An updated and expanded version of this guidance is currently available as an external review draft (USEPA, 2010). The department did not adopt the USEPA draft guidance at this time because it includes a significantly expanded list of cPAHs including many that are not currently listed in the Criteria Tables. The scientific information related to the cPAHs will be monitored and re-evaluated for inclusion in the next criteria update or when the USEPA document is finalized.

The TEF approach is consistent with the approach used for dioxin and dioxin-like congeners (i.e., polychlorinated and polybrominated dibenzodioxins, dibenzofurans, and polychlorinated biphenyl congeners) in which the total dioxin and the TEF-adjusted dioxin-like chemical concentrations are compared to the numeric 2,3,7,8-TCDD criteria pursuant to R 299.49(1)(O). Criteria for the dioxin-like congeners are not presented in the Criteria Tables, only the Footnote (O).

Footnote (Q) example calculation. Soil sample data and calculation of the total TEQ-adjusted soil concentration for comparison to the benzo(a)pyrene generic residential soil DCV and PSIV (1/2 acre source-size PSIV).

Hazardous Substance	Soil Sample Conc. (µg/kg)	Chemical Specific TEFs (µg/kg)	Soil Target Detection Limit (µg/kg)	TEF-adjusted Soil Conc. (µg/kg) for DCV	Residential Carcinogenic DCC (µg/kg)
Benzo(a)pyrene	720	1.0	330	720	2,800
Benz(a)anthracene	680	0.1	330	68	(Q)
Benzo(b)fluoranthene	930	0.1	330	93	(Q)
Benzo(k)fluoranthene	390	0.01	330	3.9	(Q)
Chrysene	674	0.001	330	0.674	(Q)
Dibenzo(a,h)anthracene	ND	1.0	330	165[1]	(Q)
Indeno(1,2,3-c,d)pyrene	600	0.1	330	60	(Q)
Total cPAH TEF-Adjusted Concentration				1,111[2] (<DCV)	

[1] Non-detect is assumed to be one-half of the target detection limit.

[2] The total cPAH TEF-adjusted soil concentration is compared to the benzo(a)pyrene soil DCV for the appropriate land-use. In this example, the land-use is residential. The TEF-adjusted soil concentration of 1,111 ppb is less than the DCV of 2,800 ppb for benzo(a)pyrene.

REFERENCES

Schoeny, R. and K. Poirier. 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. U.S. Environmental Protection Agency, Office of Research and Development, Office of Health and Environmental Assessment, Washington, DC, EPA/600/R-93/089, July 1993. Available at: https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=49732&CFID=60672852&CFTOKEN=25002466#Download (accessed April, 2016).

USEPA, 2010. Development of a Relative Potency Factor (RPF) Approach for Polycyclic Aromatic Hydrocarbon (PAH) Mixtures (External Review Draft). EPA/635/R-08/012A. Available at: https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=194584 (accessed April, 2016).

USEPA, 2016. Regional screening table. Available at: https://www.epa.gov/risk/regional-screening-levels-rsls (accessed March,

Remediation and Redevelopment Division
Michigan Department of Environmental Quality

ATTACHMENT O

BACKGROUND DOCUMENT

SUBJECT: CYANIDE ACUTE SOIL DIRECT CONTACT VALUE

As a part of the 2016 comprehensive update of the criteria rules, the residential acute soil direct contact criterion for cyanide was reviewed and partially updated. The updated residential acute soil direct contact value is 52,000 parts per billion. The updated nonresidential chronic-based soil direct contact criterion of 820,000 replaces the former acute-based criterion for that pathway.

The following exposure assumption updates were made to those presented in the original October 18, 1999 Cyanide Toxicological Assessment. The complete 1999 Cyanide Toxicological Assessment is included with this document for reference.

RESIDENTIAL
A six month to 2-year-old child is the receptor of concern for the residential soil direct contact exposure scenario. During the course of play activities, the child is assumed to ingest a quantity of soil over a short period of time either intentionally (pica behavior) or accidentally. The generic residential soil direct contact equation and the updated input parameters pertinent to acute exposure are presented in the calculation below.

Averaging Time, Exposure Duration, and Exposure Frequency:
The child receptor is assumed to ingest a quantity of soil over 24 hours for the acute scenario. Therefore, averaging time, exposure duration, and exposure frequency default to one.

Child Body Weight:
The body weight of a child aged six months to 2 years was updated to 9.6 kilograms, based on the SRC, Inc. body weight recommendation (MDEQ, 2015). A child bodyweight value of 11 kilograms had been previously identified in the 1999 Cyanide Toxicological Assessment.

Acute Soil Ingestion Rate:
The acute soil ingestion rate identified in the calculation of the 1999 acute soil direct contact criterion was 5 grams per day. The information in the USEPA Exposure Factors Handbook (USEPA, 2011) was evaluated to determine if data were available to support an updated acute soil ingestion rate. For children age 6 weeks to <1 year, no high-end estimate is provided. For children age 1 year to <6 years, a high-end estimate of 1,000 milligrams per day is provided. This value is presented as a soil-pica value. A value of 50,000 milligrams per day is also provided for this same age group as a value for geophagy (the practice of eating earth). The

upper end estimate of 1,000 milligrams per day to represent soil pica was selected as the most appropriate acute soil ingestion rate for a child receptor.

Skin Surface Area:

The total skin surface area of a child age six months to 2 years is 2,035 square centimeters based on USEPA Exposure Factors Handbook (USEPA, 2011) estimates for the 0 to <2 years age group (see Table 1 below).

Table 1. Average Skin Surface by Exposed Body Part (in square centimeters)

Age (years)	Head	Hands	Forearms	Lower Legs	Feet	Head, Forearms, Lower Legs, Hands, and Feet
0 to <2	798	255	279	409	294	2,035

Calculation for the Acute Residential Soil Direct Contact Value :

$$DCV_{acute} = \frac{THQ \times AT_{acute} \times BW_{child} \times RSC_s \times CF}{ED_{acute} \times [(\frac{1}{RfD_{o,acute}} \times EF_{i,acute} \times IR_{s,acute} \times AE_i) + (\frac{1}{RfD_{d,acute}} \times EF_{d,acute} \times SA_{child} \times EV \times AF_{child} \times AE_d)]}$$

Where,

DCV_{acute}	(Direct contact value)	=	51,525 or 52,000 µg/kg or ppb
THQ	(Target hazard quotient)	=	1
AT_{acute}	(Averaging time)	=	1 day
BW_{child}	(Body Weight, ages 6 months – 2 years)	=	9.6 kg
RSC_s	(Relative source contribution for soil)	=	1 or chemical-specific
CF	(Conversion factor)	=	1E+9 µg/kg
ED_{acute}	(Exposure duration)	=	1 day
$RfD_{o,acute}$	(Acute oral reference dose)	=	5.4E-3 mg/kg-day
$EF_{i,acute}$	(Ingestion exposure frequency)	=	1 day/ 1 day
$IR_{s,acute}$	(Soil ingestion rate)	=	1,000 mg/day
AE_i	(Ingestion absorption efficiency)	=	1.0
$RfD_{d,acute}$	(Acute dermal reference dose)	=	5.4E-3 mg/kg-day
$EF_{d,acute}$	(Dermal exposure frequency)	=	1 day / day
SA_{child}	(Skin surface area)	=	2,035 cm^2
EV	(Event frequency)	=	1 event/day
AF_{child}	(Soil adherence factor)	=	0.3 mg/cm^2-event
AE_d	(Dermal absorption efficiency)	=	0.01

NONRESIDENTIAL

A nonresidential acute soil direct contact criterion of 760,000 parts per billion, based on an assumed acute adult soil ingestion rate of 500 milligrams per day, was previously reported in the 2013 Part 201 Criteria Tables and 1999 Cyanide Toxicological Assessment. The

nonresidential acute soil direct contact criterion was not evaluated and updated as part of the 2016 comprehensive update of the cleanup criteria due in part to the limited availability of adult soil ingestion rate data.

The USEPA Exposure Factors Handbook (USEPA, 2011) identifies a single adult soil ingestion study (Davis and Mirick, 2006). This study is based on a small sample population of adult residents and the reported adult soil ingestion rates demonstrate substantial variability in both mean (23 to 625 milligrams per day) and median (0 to 260 milligrams per day) values. Using both the upper end of the mean and median adult soil ingestion rates from this study, a 24 hour acute exposure scenario, acute exposure assumptions (one day each for averaging time and exposure duration and one day per day for exposure frequency), and a soil adherence factor of 0.3 milligram per square centimeter per event for a high soil-activity, the estimated acute cyanide soil direct contact values range from 680,000 to 1,600,000 parts per billion.

The nonresidential chronic-based soil direct contact criterion for cyanide, developed using the generic nonresidential soil direct contact equations and assumptions including soil ingestion rate of 89 milligrams per day, is 820,000 parts per billion. This chronic-based criterion falls within the range of the estimated acute direct contact values above and is less than two-fold different than the lower estimate of 680,000 parts per billion. The chronic cyanide soil direct contact criterion is therefore considered adequate to address the risk of acute cyanide exposure in the nonresidential exposure scenario.

ANALYTICAL METHODS

Additional information regarding cyanide sampling is available in the MDEQ Application of Target Detection Limits and Designated Analytical Methods, Appendix C.

REFERENCES

Davis, S. and Mirick, DK, 2006. Soil ingestion in children and adults in the same family. J. Expo. Sci. Environ. Epidemiol. 16: 63-75.

MDEQ, 2015. Generic Exposure Assumption Values Update Technical Support Document on Body Weight (BW). October 9, 2015.

USEPA, 2011. Exposure Factors Handbook. EPA/600/R-09/052F. National Center for Environmental Assessment. September 2011.

PART 201

SOIL DIRECT CONTACT CLEANUP CRITERIA FOR CYANIDE:

Toxicological Assessment and Review of Analytical Methods

October 18, 1999

This document provides the basis for the development of Part 201 soil direct contact criteria (DCC) for cyanide (CN) presented below. A review of the available toxicological database indicates that DCC calculated using a chronic oral reference dose are not protective of acute exposures to CN-contaminated soil. Part 201 §20120a(4) states, "If a hazardous substance poses a risk of both cancer and 1 or more adverse health effects other than cancer, cleanup criteria shall be derived under this section for the most sensitive effect." The values given below are protective of the most sensitive effect for each land use category.

Land Use Category	Soil Direct Contact Criteria
Residential and Commercial I	12 mg/Kg (ppm)
Industrial and Commercial II, III, and IV	250 mg/Kg (ppm)

The DCC of 12 parts per million (ppm) for Residential and Commercial I land use is protective of acute ingestion of CN-contaminated soil by a child. The default DCC of 250 ppm for Industrial and Commercial II, III, and IV is protective of potential generation of hydrogen cyanide gas. CN concentrations of 760 ppm are acceptable for Industrial and Commercial II, III, and IV land uses if a demonstration is made that releasable CN is soil does not exceed 250 ppm. The DCC of 760 ppm for these land uses is protective of acute ingestion of CN-contaminated soil by an adult. Site-specific circumstances may warrant the application of the residential DCC to industrial or commercial properties where land-use patterns indicate that children may be present and engage in activities which pose a risk.

The soil DCC of 12 and 760 ppm are based on an acute exposure scenario. As such, random exposure across a property or exposure unit may not be assumed. Point-by-point comparison of soil concentrations to the acute DCC for CN is therefore required to determine compliance. Discrete sampling locations that exceed the acute DCC for CN must be remediated. Laboratory methods acceptable under Part 201 for analysis of CN in soil and groundwater are discussed on pages five through six of this document.

Cyanide Toxicity and Metabolism

The United States Environmental Protection Agency (EPA) Integrated Risk Information System (IRIS) gives a chronic oral reference dose (RfD) of 2.0E-2 mg/Kg-day for CN (Howard and Hanzel, 1955). In the 2-year study used to develop the CN RfD, rats (10/sex/group) were fed food fumigated with hydrogen cyanide (HCN). The average CN concentration in the food was estimated based on data for concentrations at the beginning and end of each food preparation

period and by assuming first-order rate of loss during the intervening period. Average concentration of CN in-feed was estimated to be 73 and 183 mg CN/Kg-day for low and high dose groups respectively. From the data reported on food consumption and body weight, daily estimated doses were 4.3 mg and 10.8 mg CN/Kg of body weight. No treatment related effects were noted in dosed groups, therefore, 10.8 mg/Kg-day was identified as a no observed adverse effect level (NOAEL) for CN in this study. An uncertainty factor of 100 (10 for interspecies extrapolation and 10 for protection of sensitive human receptors) and a modifying factor of 5 were used to develop of the RfD (10.8/(100 x 5)) of 2.0E-2 mg CN/Kg-day (rounded to a single significant digit). The modifying factor of 5 was used to account for the apparent tolerance to CN when ingested with food rather than when administered by gavage or ingested in drinking water.
In the study described above, it may be presumed that the CN dose was delivered in several small doses over the course of a day in a manner consistent with the feeding behavior of rats. EPA stated in the Drinking Water Criteria Document for Cyanide (1988) that "the intermittent ingestion of low doses over a day would allow for sufficient detoxification to account for sublethal effects" at total daily doses that would have lethal effects if given in a single bolus dose. Studies in which CN was administered both in-feed and as a single bolus dose indicate that rats can tolerate a total daily chronic dose 25 times the one-dose LD_{50} (lethal dose to 50% of the test group) (Hayes, 1967). In contrast to the chronic NOAEL of 10.8 mg CN/Kg from Howard and Hanzel (1955), the Agency for Toxic Substances and Disease Registry (ATSDR, 1996) reports LD_{50} values in rats at 2.7 mg CN/Kg (Ballantyne, 1988), 4 mg CN/Kg (Ferguson, 1962), and 8 and 11 mg CN/Kg (Smyth et. al., 1962). The LD_{50} values in mice and in rabbits, as reported by ATSDR (1996), are 6 mg CN/Kg (Ferguson, 1962) and 4.3 mg CN/Kg (Ferguson, 1962), respectively. Since the chronic NOAEL provides a daily dose higher than that proven to cause lethality when administered as a single large dose, it may be concluded that CN detoxification in the body is rapid and efficient *provided there is sufficient time elapsed between exposures to accomplish this task.*

The major pathway for CN detoxification *in vivo* is the conversion to thiocyanate through the enzymatic action of rhodanese. This reaction requires a sulfur donor that contains a thiosulfate or surfane sulfur (a sulfur bonded to another sulfur). Availability of the sulfur donor is the rate limiting step in the pathway, therefore, administration of sodium thiosulfate ($Na_2S_2O_3$) is the treatment of choice for CN poisoning. In the absence of treatment, the availability of the sulfur donor is rapidly depleted and the detoxification mechanism may be overwhelmed by a large single dose of CN or several smaller doses received over a short period of time.

Acute effects of CN are primarily produced through the inactivation of the mitochondria electron transport chain. Cyanide forms a stable complex with cytochrome oxidase, the terminal enzyme in the transport chain, effectively inhibiting cellular respiration. As a result, cells are no longer able to utilize oxygen: a condition referred to as histotoxic hypoxia. Anaerobic metabolism becomes predominant with a resultant accumulation of lactate, pyruvic acid, and glucose (EPA, 1988). Victims of poisoning will exhibit bright red venous blood: indicating that the hemoglobin continues to carry oxygen which would otherwise have been used for cellular functions. Organ systems particularly susceptible to hypoxia are the heart and the central nervous system. Initial

symptoms of acute exposure include rapid, deep breathing and shortness of breath, followed by convulsions and loss of consciousness. Death may ensue in minutes.

Acute Cyanide Poisoning In Humans

Estimation of the lethal dose in humans is difficult since most lethal events occur under either accidental or suicidal conditions. Gettler and Baine (1938) applied an analytical methodology first developed under experimental conditions to four human suicide cases to estimate both an average and a lowest human lethal dose. Under controlled experimental conditions, lethal doses of CN were administered to dogs through inhalation and stomach intubation and organ tissues were then analyzed to determine the CN content relative to the lethal dose. Expressed per unit of organ weight, CN content was shown to be consistent throughout several organs with slightly higher concentrations in the blood. Since tissue samples are frequently available for only a limited number of organs from human autopsies, the brain and liver were selected to be representative of the CN present in the total body. Experimental results, confirmed by whole body human autopsies, indicate that the absorbed CN dose is approximately seven times the total concentration of CN in the liver and brain combined. Based on these findings, absorbed lethal doses were calculated for four suicide victims and an average human lethal dose for CN was estimated at 1.4 mg CN per Kg of body weight. The lowest human lethal absorbed dose of 0.54 mg CN per Kg of body weight is selected as the lowest observed adverse effect level (LOAEL) for the lethal endpoint.

An uncertainty factor (UF) of 10 is applied to the LOAEL to account for human differences in sensitivity to the effects of CN. A full value of 10 is justified in part because no data are available for children, one of the subpopulations of interest in this assessment. An additional UF of 10 is applied to account for extrapolation from a LOAEL to a NOAEL. A full 10-fold UF is consistent with MDEQ policy and is justified by the significance of the lethal endpoint used for this analysis. Since the LOAEL is based on a lethal dose in a human subject, no UF is necessary to account for interspecies differences.
Application of the total UF of 100 (10 X 10) to the LOAEL of 0.54 mg CN/Kg results in an acute oral RfD of 5.4E-3 mg CN/Kg for the lethal effects of CN in human subjects. A comparison of the RfD for lethal effects in humans to that of 2.0E-2 mg/Kg-day for chronic effects derived from the Howard and Hanzel (1955) study in rats indicates that lethality is the more sensitive effect in human subjects. Therefore, the RfD of 5.4E-3 mg/Kg will be used to derive Part 201 DCC.

Exposure Scenarios

The RfD developed above represents an acute health effect (i.e., death). It is not appropriate, therefore, to combine this value with generic algorithms developed to be protective of chronic health effects to calculate Part 201 DCC. The exposure scenarios assumed for the development of Part 201 DCC for CN and the resultant criteria are described below.

Acute Residential Exposure Scenario

A 6-month to 2-year old child is the receptor of concern for the residential exposure scenario. During the course of play activities, the child is assumed to ingest a quantity of soil over a short period of time either intentionally (pica behavior) and/or accidentally.

Exposure Assumptions for Residential Scenario:

- The ingested soil is assumed to weigh 5 grams. Very little data are available to support the choice of a soil ingestion rate for an acute scenario. EPA recommends a value of 10 grams per day for a pica child. However, it is unlikely that this quantity of soil would be ingested in a single event (TSG, 1999).
- The child weighs 11 Kg. This value represents the body weight of male and female children at the following percentiles: the 95% percentile for children age 6-11 months, the 50th percentile for children age 1 year, and the 5th percentile for children age 2-years (U.S. EPA, 1997). A body weight of 11 Kg is therefore considered conservative for a 2-year old child, average for a 1-year old child, and nonconservative for a child less than one year of age.
- An absorption efficiency of 100% from ingested soil is used in this analysis. No adjustment is made for absorption efficiency from soil because the RfD is based upon an absorbed oral dose of *available* CN and this scenario is concerned with the identical route of exposure for *available* CN in soil. Available CN is defined as that portion of total CN that is biologically available for absorption in the human gastrointestinal system.

The residential soil direct contact criteria (DCC) protective of acute ingestion is calculated as

$$\text{DCC mg/Kg} = \frac{5.4\text{E-3 mg/Kg} \times 11\text{ Kg} \times 1000\text{ g/Kg}}{5\text{ g}}$$

follows:

The resulting ***acute*** residential DCC = 12 mg/Kg. This value is more restrictive than the calculated ***chronic*** age-adjusted residential DCC of 9,300 ppm indicating that the acute effect of CN exposure (i.e., death) is the most sensitive adverse effect. Therefore, the residential DCC for CN is 12 ppm or 12,000 µg/Kg.

Acute Industrial Exposure Scenario

Since children are presumed not to be present at industrial properties, an adult worker is the receptor of concern for this exposure scenario. During the course of work activities, the receptor is assumed to ingest a quantity of soil over a short period of time. This receptor represents an average adult receptor.

Exposure Assumptions for Industrial Exposure Scenario:

- The ingested soil is assumed to weigh 0.5 grams (TSG, 1999).
- The adult weighs 70 Kg. This value is an approximation of the 50th percentile for the body weight of male adults (U.S. EPA, 1997).
- An absorption efficiency of 100% from ingested soil is used in this analysis. No adjustment is made for absorption efficiency from soil because the RfD is based upon an absorbed oral dose of *available* CN and this scenario is concerned with the identical route of exposure for *available* CN in soil.

The industrial soil direct contact criteria (DCC) protective of acute ingestion is calculated as

$$\text{DCC mg/Kg} = \frac{5.4\text{E-3 mg/Kg} \times 70\ \text{Kg} \times 1000\ \text{g/Kg}}{0.5\ \text{g}}$$

follows:

The resulting ***acute*** industrial DCC = 760 mg/Kg. This value is more restrictive than the calculated ***chronic*** industrial DCC of 99,000 ppm indicating that the acute effect of CN exposure (i.e., death) is the most sensitive adverse effect. Therefore, the calculated industrial DCC for CN is 760 ppm or 7.6E+5 ug/Kg.

Acute Commercial Exposure Scenario

In general, children are not expected to engage in activities that may lead to ingestion of relatively large amounts of soil while visiting commercial properties. The adult worker assumed for the industrial scenario is likely to be the most exposed receptor at commercial properties. The calculated CN DCC for the II, III, and IV sub-categories is therefore identical to that developed for industrial land use: 760 ppm or 7.6E+5 ug/Kg. However, site-specific circumstances may warrant the application of the residential DCC where land-use patterns indicate that children may be present at the site and engage in activities which pose a risk. Examples of situations that require professional judgement to determine the appropriate DCC include but are not limited to: an undeveloped commercial lot being used by children for recreational activities or commercial property located within residential areas where access is unrestricted.

Comparison of Soil Concentrations to Acute DCC

The soil DCC given above are based on an acute exposure scenario. As such, random exposure across a property or exposure unit may not be assumed. Point-by-point comparison of soil concentrations to the acute DCC for CN is therefore required to determine compliance. Discrete sampling locations that exceed the acute DCC for CN must be remediated.

Releasable Cyanide

The EPA recommended standard of 250 ppm for *releasable* CN, used as the default Part 201 criteria for CN, is intended to be protective of a scenario in which hydrogen cyanide (HCN) gas could be released from waste material. Both the 250 ppm standard and the analytical method for releasable CN are currently under EPA review and the analytical method has been informally withdrawn (EPA, 1998). EPA recommends that professional judgement be used to identify situations in which HCN may be released. Until more definitive guidance is available or until EPA issues a formal withdrawal of the guidance, the Part 201 criteria tables will continue to provide a default criterion for CN of 250 ppm where calculated values are greater.

CN concentrations in soil which comply with the Residential DCC of 12 ppm are not expected to generate HCN gas. However, the unintentional production of HCN from impacted soil is a concern for industrial and commercial properties where higher concentrations may be left in place. An accidental release of an acidic substance could result in an acute health concern if HCN gas is produced. In addition, CN in soil that is immobile and/or biologically unavailable under current conditions may become available for transport or for biological uptake. For example, low pH in impacted soil may render some CN compounds immobile. If the pH of the soil is altered either through an accidental release or intentionally to encourage the growth of lawns or other landscaping, CN will be mobilized and could leach to groundwater. To address these concerns, the notice of approved environmental remediation (NAER) filed on the property deed for industrial or commercial land use must include language in the acknowledgement section which describes the nature and extent of CN contamination left in place. This information will give current and future owners and operators the necessary knowledge to avoid situations that could result in the release of CN from impacted soil left on-site.

Laboratory Analysis for Comparison to Part 201 Criteria for Cyanide

The soil DCC given above are developed based on the toxicity of *available* CN. Analytical methods for CN should, therefore, be chosen to closely approximate relevant biological conditions (e.g., pH) which contribute to CN absorption. MDEQ is currently in the process of identifying the most appropriate analytical method for quantifying available CN concentrations for comparison to the soil DCC. In the interim, if total CN concentrations do not exceed the applicable DCC or the default value for releasable CN of 250 ppm, no further analysis is necessary to demonstrate compliance. Total analysis of CN in soil, which uses strong acid and heat conditions, most probably overestimates the quantity of available or releasable CN present in the sample. Therefore, comparison of total concentrations to the DCC for available CN or the default value for releasable CN represents a conservative screen for compliance.
If further analysis is necessary to demonstrate compliance with the soil DCC for CN, two options are currently acceptable: amenable CN analysis and/or the OIA-1677 method proposed under the Clean Water Act. Both these analyses use pH levels which approximate that of the human stomach. OIA-1677 is currently under review by EPA and final approval for its use is not yet available. Application may be made under the alternative test procedure (ATP) program as

specified at 40 CFR Part 136.4 and 136.5 for EPA approval to use this method in the interim (Gomez-Taylor, 1999).

Both the amendable CN and OIA-1677 methods require that soil samples be leached prior to analysis. CN concentrations in the resulting leachate are determined and these results are used to calculate the concentration of CN in soil. MDEQ is currently conducting a review to determine the appropriate leach test procedure for analysis of available CN. Further guidance may be provided in the future. In the interim, follow the leach test recommendations provided in Operational Memorandum #12, Revision #2 (January 5, 1995).

Other analytical protocols such as weak acid dissociable (WAD) analysis or microdiffusion that use more moderate pH levels of approximately 4.5 to 6 do not approximate the conditions of the human stomach. These protocols are, therefore, unacceptable to determine compliance with DCC for available CN.

The analytical protocol for releasable CN provided in SW-846 (EPA, 1990) is currently under EPA review. The procedure likely underestimates the quantity of HCN gas produced under test conditions and is, therefore, not a conservative screen for this concern. However, since no other protocol is available at this time, and since the test is not likely to result in false positives, Part 201 will continue to accept this test as a demonstration that soil concentrations comply with the 250 ppm standard for releasable CN.

Part 201 groundwater surface water interface (GSI) criteria are based on the toxicity of “free” cyanide. The MDEQ Surface Water Quality Division (SWQD) recommends the use of amenable analysis for comparison to GSI criteria. The OIA-1677 method will be an acceptable alternative when final. OIA-1677 may also be used in the interim with EPA approval under the ATP program.
Amenable analysis is recommended for groundwater samples for comparison to the drinking water criterion (DWC) for CN. The OIA-1677 method will be an acceptable alternative when final or in the interim with EPA approval under the ATP program.

The above recommendations for analysis of soil samples to determine compliance with the soil DCC are also applicable to the soil drinking water protection criterion (DWPC), the groundwater surface water interface protection criterion (GSIPC), and the groundwater contact protection criterion (GCCPC). Total CN analysis may be used as an initial screen followed by either the amendable CN or OIA-1677 method (if approved) when additional analytical testing is necessary to determine compliance.

References

Agency for Toxic Substances and Disease Registry. 1996. Toxicological Profile for Cyanide. U. s. Department of Health & Human Services, Public Health Services.

Barcroft, J. 1931. The Toxicity of Atmospheres Containing Hydrocyanic Acid Gas. Journal of Hygiene, 31:1-34.

Bonsall, J. L. 1984. Survival Without Sequleae Following Exposure to 500 mg/m^3 of Hydrogen Cyanide. Human Toxicology, 3:57-60.

EPA (U.S. Environmental Protection Agency). 1998. Personal communication from Diana Love, Director, NEIC to David Bussard, Director, HWID and Barnes Johnson, Director, EMRAD. April 21, 1998.

EPA (U.S. Environmental Protection Agency). 1997. Integrated Risk Information System Substance File- Cyanide, free (CAS # 57-12-5). March 1, 1997.

EPA (U.S. Environmental Protection Agency). 1997. Exposure Factors Handbook, Update to Exposure Factors Handbook (May 1989). EAP/600/8-89/043.

EPA (U.S. Environmental Protection Agency). 1990. Test Methods for Evaluating Solid Wastes. Vol. 1C: Laboratory Manual, Physical Chemical Methods. SW-846.

EPA (U.S. Environmental Protection Agency). 1988. Drinking Water Criteria Document for Cyanide, External Review Draft, Office of Drinking Water, ECAO-CIN-442, April 1988.

Flury, F. and F. Zenik. 1931. Cyanwasserstoff. Schadliche Gase, J. Springer, Berlin, pp 400-409, as referenced in MADEP, 1992.

Gettler, A.O. and Baine, J.O., 1938. The Toxicology of Cyanide. American Journal of Medical Sciences, 195:182-198.

Gomez-Taylor, Maria. 1999. Personal communication.

Hayes, W.T. 1967. The 90-Dose LD_{50} And A Chronicity Factor As Measures Of Toxicity. Toxicol. Appl. Pharmacol. 11:327-335.

Howard, J.W. and Hanzel, R.F. 1955. Chronic Toxicity for Rats of Food Treated with Hydrogen Cyanide. J. Agric. Food Chem. 3:325-329.

MA DEP (Massachusetts Department of Environmental Protection). 1992. Background Documentation for the Development of an “Available Cyanide” Benchmark Concentration. October 1992.

TSG (MDEQ Toxics Steering Group). Meeting Discussion. September 8, 1999

ATTACHMENT P

BACKGROUND DOCUMENT

SUBJECT: CRITERIA FOR LEAD

Residential Criteria

The residential soil direct contact criterion (DCC) and drinking water criterion (DWC) for lead are 1.9E+5 ppb (190 ppm) and 1.0 ppb, respectively. The statewide default background level of lead in soil is 11,000 ppb (11 ppm).

Integrated Exposure Uptake Biokinetic (IEUBK) Model
The U.S. Environmental Protection Agency (USEPA) developed a lead biokinetic model (Model) for evaluating children's exposure to lead from multiple media (USEPA, 2010). The Michigan Department of Environmental Quality (MDEQ) has used this Model historically to develop the soil DCC and DWC for lead and most recently, to develop the current, updated lead criteria. The Model uses known or estimated lead levels in air, soil, house dust, diet, drinking water, and maternal blood to estimate blood lead levels for children (ages 0-7 years old). It also includes the probability that a child's blood lead level would exceed a specified threshold, in this case, the U.S. Centers for Disease Control and Prevention's (CDC) reference level. The DEQ generic DCC for lead in soil of 190 ppm (equivalent to 1.9E+5 ppb) was developed using a combination of the USEPA and DEQ default values as the exposure assumptions in the Model. The soil criterion represents a 5% or lower risk that a child will have a blood lead level above the CDC reference level of 5 micrograms of lead per deciliter of blood (µg/dL).

The parameters presented in Table 1 identify the exceptions to the USEPA's default Model assumptions.

Table 1. MDEQ-modified parameters and the values used in the Model to derive the generic residential DCC and DWC water criteria for lead.

Model Input Parameters	Parameter Values
Blood lead concentration reference level (µg/dL)	5[1]
Maternal blood lead concentration at childbirth (µg/dL)	0.8[2]
Outdoor air lead concentration (µg/m^3)	0.01[3]
Drinking water concentration (µg/L)	1.0
Drinking water ingestion rates (L/day)[4]	
0-1 year	0.320
1-2 year	0.271
2-3 year	0.317
3-4 year	0.327
4-5 year	0.327
5-6 year	0.327
6-7 year	0.414

[1] CDC, 2012
[2] CDC, 2015
[3] MDEQ, 2011-2014
[4] USEPA, 2011

Blood Lead Concentration Reference Level:

In 2012, the CDC revised its blood lead level of concern, reducing the level from 10 µg/dL to 5 µg/dL, based on recommendations from the Advisory Committee on Childhood Lead Poisoning Prevention (CDC, 2012). The reference level is used to identify children with blood lead levels that require follow-up actions due to the fact that their blood lead levels are higher than those of most children. It has been shown that blood lead levels at concentrations lower than previously thought, affect IQ, academic achievement, and a child's ability to pay attention. The new CDC reference level (5 µg/dL) is based on the U.S. population of children, ages one to five years old, whose blood lead levels tested in the highest 2.5%. The basis for the reference level is the 97.5th percentile of the National Health and Nutrition Examination Survey's blood lead level distribution in children (CDC, 2012).

Maternal Blood Lead Concentration at Childbirth:

The maternal blood lead level of 0.8 µg/dL is based on the geometric mean blood concentration for U.S. females from the 2011-2012 National Health and Nutrition Examination Survey (CDC, 2015).

Outdoor Air Lead Concentration:

In 2008, the USEPA lowered the National Ambient Air Quality Standard (NAAQS) for lead from 1.5 µg/m^3 to 0.15 µg/m^3. At that time, the City of Dearborn had the only ambient air monitoring site in Michigan. The MDEQ added more monitoring sites to ascertain specific neighborhood and source-oriented impacts.

Monitoring sites in the cities of Grand Rapids and Allen Park were added to MDEQ's network, and along with Dearborn, are still currently in operation. In 2013, the highest rolling 3-month average lead level (total suspended particulates) at these three sites was 0.01 µg/m^3. In 2014 and 2015, the highest value reported at the Grand Rapids and Allen Park sites was 0.01 µg/m^3 and 0.02 µg/m^3 was the highest reported value at the Dearborn site.

Five source-oriented sites were added between 2010-2012 in the Michigan cities of East Jordan, Vassar, Belding (2 sites), and Port Huron. The East Jordan and Vassar sites were shut down due to low lead concentrations (3- month averages between 0.01 and 0.03 µg/m^3). The Port Huron monitoring site and the two sites in Belding were located near brass foundries. The two Belding sites initially had 3-month averages above the 0.15 µg/m^3 NAAQS. However, over the past four years no NAAQS violations have occurred and the 3-month average concentrations have ranged from 0.01 to 0.06 µg/m^3.

A monitoring site was also added at the Oakland County Airport to ascertain the impact of leaded aviation fuel on ambient air quality. The site operated between 2011 and 2012 with a 3-month average lead concentration of 0.02 µg/m^3, which is similar to lead concentrations observed at the non-source oriented sites.

An evaluation of the data summarized above from the 2011-2014 Michigan Annual Air Quality Reports (MDEQ, 2011-2014) indicated that the Model's outdoor air lead concentration default value of 0.1 µg/m^3 is overly conservative and that 0.01 µg/m^3 is a more representative value for Michigan. While a slightly higher air lead level was obtained from source-oriented sites, the observed elevated levels of lead were localized to the nearby sources.

Drinking Water Ingestion Rates:

The mean per capita drinking water ingestion rates were obtained from Table 3-1 of the USEPA Exposure Factors Handbook (USEPA, 2011). The 0-1 year ingestion rate represents a weighted average of four different ingestion rates for four age ranges less than one year old. The drinking water intakes are age-specific and based on national averages.

Drinking Water Lead Concentration:

A conservative drinking water input value is appropriate for use in the Model since the effects of lead ingestion in children are significant and irreversible. The concentration of lead in water leaving most municipal water treatment systems is less than the analytical detection of 1.0 part per billion (ppb). MDEQ conducted an analysis of the Model using drinking water concentration inputs of 0.0 ppb and 1.0 ppb. There was minimal difference in the corresponding acceptable soil direct contact values (196 ppm versus 190 ppm). Therefore, the MDEQ selected the lead concentration of 1.0 ppb as the drinking water input value in the Model since that level is achievable by most analytical laboratories. A concentration of 1.0 ppb lead in drinking water will also serve as the drinking water cleanup criterion for both residential and nonresidential land uses under Michigan's cleanup program.

A Federal or State of Michigan drinking water standard for lead is not available; however, the Federal Lead and Copper Rule (LCR) was promulgated in 1991 by the USEPA to monitor and control lead and copper in municipal water systems. The LCR requires the owner/operator of public water systems to monitor for concentrations of lead and copper in water out coming out of customer taps. If lead concentrations exceed an action level of 15 ppb in more than 10% of the customer taps sampled, the owner/operator of the public water system must undertake a number of actions to control corrosion, inform the public about steps they should take to protect their health, and may have to replace lead service lines under their control. EPA is considering substantive changes to the LCR to improve the protection of public health and streamline the rule requirements.

Nonresidential Criteria

The nonresidential soil DCC and DWC are 3.3E+5 ppb (330 ppm) and 1.0 ppb, respectively. The justification for the nonresidential lead DWC of 1 ppb is provided above.

The nonresidential soil DCC was derived using the USEPA Adult Lead Methodology (ALM) spreadsheet version June 21, 2009 (USEPA, 2009a). The methodology focuses on estimating fetal blood lead concentrations in women exposed to lead-contaminated soils (USEPA, 2009b). The ALM default parameters were used to determine the nonresidential soil DCC except where identified with a footnote in Table 2, i.e., the first three parameters.

Table 2. Input parameter values used in the ALM spreadsheet to derive the nonresidential soil direct contact criterion.

ALM Input Parameter	Parameter Description	Parameter Value
$PbB_{fetal,\ 0.95}$	95th percentile Blood Lead Level (PbB) in the fetus (µg/dL)	5[1]
PbB_0	Baseline PbB (µg/dL)	0.8[2]
IR_s	Soil and dust ingestion rate (g/day)	0.089[3]
GSD_i	Geometric standard deviation PbB	2.1
$AF_{S,D}$	Absorption fraction (same for soil and dust)	0.12

ALM Input Parameter	Parameter Description	Parameter Value
$EF_{S,D}$	Exposure frequency (same for soil and dust) (days/yr)	219
$AT_{S,D}$	Averaging time (same for soil and dust) (days/yr)	365

[1] CDC, 2012. [2] CDC, 2015 [3] MDEQ, 2016

Maternal Soil and Dust Ingestion Rate:

The maternal soil and dust ingestion rate (0.089 grams/day) is based on a time-weighted average soil and dust ingestion rate for adults in a nonresidential scenario (MDEQ, 2016). There are no published data available with which to assess whether pregnant women might ingest more or less soil than other adult workers.

REFERENCES:

MDEQ, 2011-2014. The 2011, 2012, 2013, and 2014 Annual Air Quality Reports: http://www.michigan.gov/deq/0,1607,7-135-3310---,00.html

MDEQ, 2015. Generic Exposure Assumption Values Update Technical Support Document on Soil and Dust Ingestion (IRSD), September 23, 2015.

CDC, 2012. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention. http://www.cdc.gov/nceh/lead/acclpp/final_document_030712.pdf

CDC, 2015. The Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables, February, 2015. http://www.cdc.gov/biomonitoring/pdf/FourthReport_UpdatedTables_Feb2015.pdf

USEPA, 2009a. Adult Lead Model Spreadsheet, version date 6/21/2009. https://www.epa.gov/sites/production/files/2015-09/alm_2009.xls

USEPA, 2009b. Technical Review Workgroup for Lead, Adult Lead Risk Assessment Committee. Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil. https://semspub.epa.gov/work/11/174559.pdf

USEPA, 2010. Integrated Exposure Uptake Biokinetic Model for Lead in Children, Windows® version (IEUBKwin v1.1 build 11). The Technical Review Workgroup for Metals and Asbestos, Office of Land and Emergency Management. https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals#overview

USEPA, 2011. Exposure Factors Handbook 2011 Edition (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

ATTACHMENT Q

BACKGROUND DOCUMENT

SUBJECT: BASIS FOR METHANE SCREENING LEVEL

Methane (chemical formula = CH_4) is the lightest of all hydrocarbons (specific gravity = 0.555) and diffuses very rapidly in air. It is a colorless, odorless, tasteless, flammable gas that is produced as a result of the microbial or thermal alteration of organic matter and is widely distributed in nature. Methane is not known to be toxic; the principle health and safety concerns are its explosive, flammable and asphyxiant properties. Since methane is a simple asphyxiant, acting by displacement of oxygen, no threshold limit value (TLV), permissible exposure limit (PEL), or recommended exposure limit value (REL) have been established.

HAZARD:

Fire and explosion can result if methane accumulates in a confined space, at concentrations between 5 and 15 percent by volume in air, and is exposed to an ignition source (e.g., electrical outlets and appliances, static electricity, pilot lights, or open flames). Methane concentrations above 15 percent by volume in air should also be considered dangerous, since such concentrations can dilute to explosive levels.

METHANE IN VAPOR AND GROUNDWATER:

Methane can exist in the subsurface both in the gas phase and dissolved in groundwater.

As a gas, methane can be present in the unsaturated zone and/or as small bubbles trapped in the groundwater. The migration of methane gas in the subsurface is controlled by many different parameters; however, the general predominant transport mechanisms for methane are driven by concentration and pressure. When flow rates are extremely low, diffusion can also be a prominent factor in the transport of methane. Each process is independent of topography or hydraulic gradient. Methane does not partition to soil particles and will move easily through the subsurface in a direction of decreasing concentration and pressure. Methane concentrations and pressures are generally higher within the source areas than in the surrounding areas, which causes methane to move from the source areas to the surrounding areas; areas of decreasing concentration and pressure. Although methane is lighter than air as a gas, pressure gradients can cause methane to move in other directions.

At standard temperature and pressure the solubility of methane in groundwater is 22.7 mg/L. In the dissolved phase, methane will follow the same path as the groundwater. Methane will not react with substances commonly found in groundwater and dissolved in water. Dissolved in water, methane is not explosive. Methane does not impair the odor, taste or color of the water, nor does it affect the potability of water. The hazard presented by dissolved methane is its ability to become a gas if the water is agitated or if the pressure is reduced.

METHANE GENERATION:

There are two processes that form methane. Biogenic or bacterial methane is formed from the bacterial decomposition of organic materials in the subsurface. Anaerobic conditions may also produce biogenic methane. Thermogenic methane occurs from geologic processes where rocks are compressed and heated. The methane produced by both processes is the same in composition.

METHANE SCREENING LEVELS:

DISSOLVED IN GROUNDWATER

Pursuant to R 299.49(1)(AA), due to insufficient toxicity data health-based criteria cannot be developed for methane dissolved in groundwater. Instead the department has adopted a groundwater screening level of 10,000 µg/L (10 mg/L). This value can be used to evaluate the potential explosive risk of methane when the following conditions **DO NOT** exist:

- Methane dissolved in groundwater is under pressure;
- Groundwater is entering a structure, enclosed or confined space;
- Dissolved methane is present in a drinking water well; and
- There is an additional source(s) of methane.

Concentrations that exceed 10,000 µg/L (10 mg/L) or the existence of any of the above conditions shall require further evaluation of the potential acute risk pursuant to R 299.4(10) and R 299.27(5)(c).

Table 1 below presents the regulatory levels used by USEPA Region 5 states and other agencies to evaluate methane in groundwater.

Table 1: REGULATORY LEVELS OF METHANE IN GROUNDWATER

State/Agency	Category	Groundwater
Indiana Department of Environmental Management	Action Level for water wells	<10 mg/L requires periodic monitoring to see if methane concentrations are changing; no mitigation required. http://www.in.gov/isdh/files/MethaneInWellWater.pdf
Ohio Department of Health	Recommended level for well water	Ohio Administrative Code Chapter 3701-28 requires that wells that produce methane >10 mg/L shall be vented to the atmosphere to prevent explosive conditions and minimize human health exposures. http://water.ohiodnr.gov/portals/soilwater/pdf/wells/wellconguide.pdf
Minnesota Dept of Health	No action or recommended level available	MDH states: "Methane in water of as little as 1 mg/L can lead to explosive levels if the gas is allowed to accumulate in a poorly ventilated confined space. http://www.health.state.mn.us/divs/eh/wells/waterquality/methanemn.htm

State/Agency	Category	Groundwater
Champaign-Urbana Public Health District	No action or recommended level available	For methane evaluation refers to Minnesota Department of Health's methane guidance. http://www.c-uphd.org/water-wells.html
Wisconsin Dept of Health Services	No action or recommended level available	https://www.dhs.wisconsin.gov/chemical/methane.htm
West Virginia	Action Levels for water wells	<10 mg/L requires periodic monitoring to see if methane concentrations are changing; no mitigation required. >10 mg/L and <28 mg/L indicates that methane concentrations may be increasing to dangerous levels in GW.
US Dept of Interior, Office of Surface Mining	Action Levels for groundwater	<10 mg/L requires periodic monitoring to see if methane concentrations are changing; no mitigation required. >10 mg/L, but <28 mg/L, contact local county health department for further assistance and might consider removing ignition sources from the immediate area. http://pubs.usgs.gov/fs/2006/3011/; http://www.osmre.gov/resources/library/ghm/methane.pdf (accessed 4/2106)

IN SOIL GAS

Pursuant to R 299.49(1)(GG), due to insufficient toxicity data health-based criteria cannot be developed for methane in soil gas. An acceptable soil gas concentration to address methane's flammability and explosivity was derived utilizing 25 percent of the lower explosive limit for methane. This equates to 1.25 percent by volume or 8.4E+6 $\mu g/m^3$. For the evaluation of potential risk from methane in the subsurface, the site conditions must be characterized and a complete and accurate conceptual site model must be developed.

APPLICATION

In general, methane groundwater concentrations in excess of 10 mg/L or soil gas concentrations in excess of 1.25 percent (12,500 ppmv or 8.4E+6 ug/m3) are a cause for concern. Monitoring is needed to determine if an adequately oxygenated vadose zone exists to allow mitigation of the methane or if additional measures are necessary to protect any potential receptors.

In the absence of sufficient oxygen, methanogenic conditions can exist and present an added risk. Under such conditions soil gas monitoring and a mitigation contingency plan should be proposed. Soil gas concentrations exceeding 12,500 ppmv indicate the need for monitoring and

additional evaluation. Likewise, if anaerobic conditions are induced in the vicinity of subsurface confined spaces, the condition should be evaluated to determine the necessity for mitigation.

ATTACHMENT R

BACKGROUND DOCUMENT

SUBJECT: Volatilization to Indoor Air Building Foundation Sensitivity Analysis

UNDER DEVELOPMENT