TECHNICAL MEMORANDUM

RESIDENTIAL SOIL VOLATILIZATION TO INDOOR AIR INHALATION CRITERIA FOR TRICHLOROETHYLENE (CAS# 79-01-6)

Prepared for:

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rev.2

EXECUTIVE SUMMARY

This technical memorandum was prepared in response to a request from the Michigan State Housing Development Authority (MSHDA) to develop a range of soil volatilization to indoor air inhalation criteria (SVIIC) for trichloroethylene (TCE) to aid evaluation of health risks associated with subsurface vapor intrusion to buildings. Development of environmental cleanup criteria for TCE has been problematic and inconsistent within the U.S. Environmental Protection Agency (EPA), and among state health and environmental agencies, since EPA released a draft assessment of the toxicity of TCE in August 2001 (U.S. EPA, 2001). Toxicity values presented in the draft assessment, including a range of cancer potency estimates, indicate that TCE is more toxic than previously characterized. Studies of the mechanisms by which TCE's toxic effects occur also suggest that certain risk factors (e.g., disease) may make some populations more sensitive.

Although the EPA (2001) assessment and updated toxicity values were designated as draft when released for comment, several state and federal agencies began using the values in their programs, while other agencies chose not to adopt the values until they were finalized. As an example, the Michigan Department of Environmental Quality (MDEQ) is currently limited to using older toxicity data to develop cleanup criteria because the TCE criteria are currently promulgated into administrative rules. Partial acceptance of the draft toxicity values across agencies, and the absence of a formal interim policy from EPA advising which toxicity values to use for assessing inhalation exposure pathway risks, in particular, has led to considerable controversy and confusion. Absent a finalized EPA policy, and regulatory limitations precluding criteria modifications by the MDEQ, MSHDA has retained Hamp, Mathews & Associates, Inc. (HMA) to develop a range of TCE SVIIC which MSHDA may use in its environmental review process.

MSHDA "provides financial and technical assistance through public and private partnerships to create and preserve decent, affordable housing for low and moderate income Michigan residents." (MSHDA Mission Statement) All prospective developments are required to undergo a rigorous environmental review process to ensure that future

residents are not exposed to hazardous environments and that MSHDA has satisfied it's due diligence requirements as a lender. The MSHDA environmental review process encompasses the requirements of ASTM 1527-00, specific Authority standards, and various state and federal health and safety standards applicable to residential housing.

To fulfill MSHDA's request, HMA conducted a review and evaluation of the available information on currently applied risk management approaches by EPA and state agencies, the scientific literature on the health risks of TCE, and empirical data from case studies examining the subsurface vapor intrusion of TCE to indoor air from case studies.

TCE is a colorless, highly volatile liquid that is moderately soluble with water and a number of organic solvents (U.S. EPA, 1985). It is used mainly as a solvent to remove grease from metal parts, but it is also an ingredient in some household products, including adhesives, paint removers, typewriter correction fluids, and spot removers (ATSDR, 2003). TCE has entered the soil and groundwater at many sites in Michigan as a result of accidental release or improper disposal at commercial and industrial properties. While TCE readily evaporates from surfaces open to the outdoor air, once it enters subsurface soil and migrates to groundwater it can remain within these media for long periods of time. When soil or groundwater is contaminated with TCE, the chemical can change into a gas and move upward through the soil and into homes and buildings.

TCE in the gas or vapor-phase is readily absorbed from the lungs, and inhalation is the predominant route of exposure. TCE is heavier than air and if present at significant levels it may cause asphyxiation in poorly ventilated or enclosed spaces, and in low-lying areas. Children exposed to the same levels of TCE vapor as adults may receive a larger dose because they have greater lung surface area to body weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of TCE vapor found nearer to the floor or ground surface (ATSDR 2001).

TCE exposure is associated with a number of adverse health effects, including liver toxicity, kidney toxicity, developmental toxicity, neurotoxicity, toxicity to the immune system, endocrine effects and several types of cancer (U.S. EPA, 2001). The National

Toxicology Program's *Tenth Report on Carcinogens* reaffirmed the classification of TCE as "reasonably anticipated to be a human carcinogen" (NTP, 2002). Under EPA's proposed cancer guidelines of 1996 TCE is characterized as "highly likely to produce cancer in humans" (U.S. EPA, 2001).

As indicated above, differential application of the EPA draft assessment CSFs, and the absence of a formal policy from EPA directing their use has led to considerable controversy and confusion when assessing health risks associated with TCE exposure. To address this issue, EPA's Office of Solid Waste and Emergency Response (OSWER) distributed and discussed a "Conceptual Interim Risk Management Strategy for TCE" at their annual division directors meeting in March, 2004. The interim risk management strategy recommends evaluation of TCE vapor intrusion risk using the California EPA (Cal EPA) Air Toxics 1990 inhalation unit risk factor (IURF – i.e., the cancer potency estimate) of 2E-6 $(ug/m^3)^{-1}$ (Cal EPA, 2002), or the withdrawn IURF from IRIS of 1.7E-6 $(ug/m^3)^{-1}$, values which are very similar. Because of the uncertainty related to the cancer potency of TCE, EPA recommends setting site-specific cleanup levels for TCE at the most protective end of its acceptable risk range (i.e., 10^{-6}). EPA's Office of Air Quality Protection Standards and Ohio EPA's Voluntary Action Program have also chosen to use the Cal EPA IURF in their risk assessment processes.

A key additional component of the OSWER interim TCE strategy is the use of a residential indoor air action level of 1 – 2 ug/m^3, to identify the situations where vapor intrusion of TCE into buildings may be a problem. The OSWER interim TCE strategy states that the low end of this action level range (i.e., 1 ug/m^3) corresponds with a 10^{-6} cancer risk using the Cal EPA IURF (2E-6 $ug/m^3)^{-1}$) and standard residential exposure assumptions. In comparison, a residential indoor air concentration of approximately 2 ug/m^3 corresponds with a 10^{-4} risk using the highest CSF recommended in the 2001 draft assessment (i.e., 1.1E-4 $(ug/m^3)^{-1}$.

In August, 2004 the Colorado Department of Public Health and Environment (CDPHE) finalized an indoor air TCE policy, which also established indoor air concentrations for managing TCE vapor intrusion risk (CDPHE, 2004). CDPHE uses an indoor air concentration of 1.6 ug/m^3 of TCE as the level at which cleanup is required. In comparison to the EPA OSWER strategy, the indoor air concentration of 1.6 ug/m^3

corresponds with a 10^{-4} risk using the high end IURF from EPA's 2001 draft assessment, and standard residential exposure assumptions, which include an age-adjusted inhalation rate.

These risk management approaches effectively demonstrate that applying target background TCE indoor air concentrations is currently the most practical and protective approach for evaluating vapor intrusion risk given the uncertainties related to the cancer potency estimates from EPA's draft assessment. HMA recommends applying a similar risk management approach that is also based on the use of a target indoor air concentration range. Based on data from background indoor air studies HMA recommends using a lower target indoor air concentration range of 0.2 – 1.0 ug/m^3 than proposed by EPA OSWER. A lower concentration range is supported based on large datasets from two recent background indoor air studies involving TCE (Foster et al. 2002; Sexton et al. 2004). These recent data indicate a decreasing trend in background indoor air concentrations of TCE relative to data compiled from older studies by EPA (1998).

HMA believes that applying a lower target indoor air concentration is also appropriate because it indirectly addresses other toxicity concerns highlighted in EPA's draft assessment, such as protection of susceptible populations (i.e., children and those with certain diseases) and cumulative risk, reasons why the draft assessment recommends using the high end IURF for characterizing risks for sensitive subpopulations. Children exposure to hazardous substances has been the focus of several recent federal actions. In particular, Executive Order 13045 (1997) requires federal agencies to "make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children and shall ensure that their policies, programs, and standards address disproportionate risks that result from environmental health risks or safety risks." Accordingly EPA (U.S. EPA, 2001) has identified TCE as one of the twenty Tier 1 chemicals for evaluation in its Voluntary Children's Chemical Evaluation Program (VCCEP).

Applying a lower target indoor air concentration range for calculation of SVIIC in effect minimizes the amount of TCE in soil gas allowed to enter a home, and most importantly minimizes that which may be added to potentially existing indoor air background levels.

This is significant since evidence from several unpublished TCE vapor intrusion case studies have shown that indoor air concentrations of TCE are often greater than predicted by vapor modeling (AEHS, 2004).

HMA's approach of starting with a target indoor air concentration range to develop the corresponding residential TCE SVIIC involves algebraically rearranging the standard EPA/MDEQ risk assessment equation to derive IURFs. This approach allows comparison of the HMA-derived IURFs with EPA's past and current estimates. The range of IURFs corresponding to the recommended indoor air concentration range (0.2 to 1.0 ug/m^3), using standard residential exposure assumptions and a target risk level of 10^{-5}, is 1.2E-4 to 2.4E-5 $(ug/m^3)^{-1}$. Although these potency values are not derived from specific toxicological studies in the traditional sense, the IURFs are remarkably comparable with cancer potency estimates from the EPA draft assessment (i.e., 1.1E-4 to 5.7E-6 (ug/m^3). This is to be expected since selection of lower target indoor air concentrations implies a degree of health hazard or toxicity (i.e., in this case, cancer potency) associated with TCE exposure. Using the HMA recommended approach, the residential TCE SVIIC range from 100 to 500 ug/kg (ppb).

DATE: September 27, 2004

TO: Bruce Jeffries

SUBJECT: Residential Soil Volatilization to Indoor Air Inhalation Criteria for Trichloroethylene (CAS# 79-01-6), rev.2

PREPARED BY: Jeffrey Crum, Hamp, Mathews & Associates, Inc.

INTRODUCTION

This technical memorandum was prepared in response to a request from the Michigan State Housing Development Authority (MSHDA) to develop a range of soil volatilization to indoor air inhalation criteria (SVIIC) for trichloroethylene (TCE) to aid evaluation of health risks associated with subsurface vapor intrusion to buildings. Development of environmental cleanup criteria for TCE has been problematic and inconsistent within the U.S. Environmental Protection Agency (EPA), and among state health and environmental agencies, since EPA released a draft assessment of the toxicity of TCE in August 2001 (U.S. EPA, 2001); hereafter referred to as the “draft assessment.” The draft assessment proposed toxicity values, including a range of cancer potency estimates, which indicate that TCE is more toxic than previously characterized. Several state and federal agencies, including certain EPA offices and programs, quickly adopted the proposed values despite their being designated as draft when released for public comment. Partial acceptance of the draft toxicity values across agencies, and the absence of a formal interim policy from EPA advising the toxicity values to use for assessing inhalation exposure pathway risks, and other pathways, has led to considerable controversy and confusion. For example, the highest cancer potency estimate, applied by most agencies, produces risk-based indoor air concentrations below typical background levels of TCE in homes. Additionally, there is concern that certain assumptions employed to model subsurface vapor intrusion may underestimate vapor intrusion risk. This concern is based on a number of field studies which show that the migration and intrusion of TCE vapors into buildings is producing higher indoor air concentrations than those predicted from the Johnson and Ettinger (1991) model.

Absent a finalized EPA policy, and regulatory limitations precluding criteria modifications by the MDEQ, MSHDA has retained Hamp, Mathews & Associates, Inc. (HMA) to MSHDA has requested that Hamp, Mathews and Associates, Inc. (HMA) derive a range of SVIIC for TCE. To fulfill MSHDA's request, HMA conducted a review and evaluation of the available information on currently applied risk management approaches by EPA and state agencies, the scientific literature on the health risks of TCE, and empirical data from case studies examining the subsurface vapor intrusion of TCE to indoor air from case studies.

The information considered in preparation of this memorandum is detailed below:

1. Current EPA policy – Specifically, how is EPA incorporating the draft health risk assessment (HRA) document and toxicity values into the development and implementation of cleanup values to address subsurface vapor to indoor air inhalation pathway risks?

2. *Trichloroethylene Health Risk Assessment: Synthesis and Characterization.* August 2001. External Review Draft. EPA. (http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=23249)

3. Several scientific publications on background indoor air concentrations of TCE.

4. *Review of Draft Trichloroethylene Health Risk Assessment: Synthesis and Characterization: An EPA Science Advisory Board Report.* December 2002. (http://www.epa.gov/science1/pdf/ehc03002.pdf)

5. Transcripts of the February 26-27, 2004 EPA Symposium on New Scientific Research Related to the Health Effects of Trichloroethylene. National Center for Environmental Assessment website. (http://cfpub2.epa.gov/ncea/cfm/recordisplay.cfm?deid=75934)

6. Risk assessment policies of various state health and environmental agencies regarding application of the draft toxicity values for assessment of subsurface vapor to indoor air inhalation pathway risks.

7. Trichloroethylene Panel Discussion at the Midwestern States Risk Assessment Symposium. August 25-27, 2004. Indianapolis, Indiana.

8. Field studies assessing measured versus modeled predictions for TCE subsurface vapor intrusion to buildings.

MSHDA BACKGROUND

MSHDA "provides financial and technical assistance through public and private partnerships to create and preserve decent, affordable housing for low and moderate income Michigan residents." (MSHDA Mission Statement) Certain development projects are proposed at locations where historical releases of hazardous substances, such as TCE, have occurred. Consequently, the subsurface migration of TCE vapors to indoor air is an important pathway for which risk-based criteria are needed for evaluating the potential health risk to future occupants of these properties and for assessing lender liability. All prospective developments are required to undergo a rigorous environmental review process to ensure that future residents are not exposed to hazardous environments and that MSHDA has satisfied it's due diligence requirements as a lender. The MSHDA environmental review process encompasses the requirements of ASTM 1527-00 (ASTM, 2000), specific Authority standards, and various state and federal health and safety standards applicable to residential housing.

TCE BACKGROUND

TCE is a colorless, highly volatile liquid that is miscible with water and a number of organic solvents (U.S. EPA, 1985). It is used mainly as a solvent to remove grease from metal parts, but it is also an ingredient in some household products, including adhesives, paint removers, typewriter correction fluids, and spot removers (ATSDR, 2003). In the past, it was used as a dry cleaning agent and for food extractions such as removal of caffeine from coffee. It also had limited use as an analgesic and an anesthetic agent, but is no longer used for these purposes because it is now recognized as a potential human carcinogen (ATSDR, 2001).

The largest source of TCE in the environment is evaporation from factories that use it to remove grease from metals. However, it has also entered the soil and groundwater at many sites in Michigan, as a result of accidental release or improper disposal at commercial and industrial properties. While TCE readily evaporates from surfaces open to the outdoor air, once it enters subsurface soil and migrates to groundwater it can remain within these media for long periods of time. When soil or groundwater is contaminated with TCE, the chemical can change into a gas and move upward through the soil and into homes and buildings.

TCE in the gas or vapor-phase is readily absorbed from the lungs, and inhalation is the predominant route of exposure. The recognition odor threshold of trichloroethylene is 110 ppm which is slightly higher than the Occupational Safety and Health Administrations (OSHA) Permissible Exposure Limit (PEL) of 100 ppm. As a result, odor generally provides an inadequate indication of hazardous concentrations. TCE is heavier than air and if present at significant levels it may cause asphyxiation in poorly ventilated or enclosed spaces, and in low-lying areas. Children exposed to the same levels of TCE vapor as adults may receive a larger dose because they have greater lung surface area to body weight ratios and increased minute volumes to weight ratios. In addition, they may be exposed to higher levels than adults in the same location because of their short stature and the higher levels of TCE vapor found nearer to the floor or ground surface (ATSDR 2001).

In the body, TCE can break down into dichloroacetic acid (DCA), trichloroacetic acid (TCA), chloral hydrate, and 2-chloroacetaldehyde. These products have been shown to be toxic to animals and are probably toxic to humans (ATSDR, 1997). EPA's recent draft assessment goes further, stating that much of TCE's toxicity may be attributable to its metabolites, as toxicity tests show that some metabolites cause effects similar to TCE (U.S. EPA, 2001).

TCE exposure is associated with a number of adverse health effects, including liver toxicity, kidney toxicity, developmental toxicity, neurotoxicity, toxicity to the immune system, endocrine effects and several types of cancer (U.S. EPA, 2001). The National Toxicology Program's *Tenth Report on Carcinogens* reaffirmed the classification of TCE as "reasonably anticipated to be a human carcinogen" (NTP, 2002). EPA's 2001 draft assessment, which involved review of recently published human and animal studies and metabolism and mechanistic studies, strengthens the evidence for TCE's potential to cause cancer in humans. This recent review of available toxicological data suggests that the cancer potency is greater than previously characterized in EPA assessments. Under EPA's proposed cancer guidelines of 1996 TCE is characterized as "highly likely to produce cancer in humans" (U.S. EPA, 2001).

HISTORY OF TCE TOXICITY ASSESSMENT AND REGULATIONS

In 1985 and 1987 EPA conducted hazard assessments characterizing the potential human health effects associated with TCE exposure (U.S. EPA, 1985, 1987). Based on only laboratory studies available at that time, EPA classified TCE as a Probable Human Carcinogen (Group B2). EPA derived an oral cancer slope factor (CSF) of 1.1E-2 $(mg/kg\text{-}day)^{-1}$, and an inhalation unit risk factor (IURF) of 1.7E-6 $(ug/m^3)^{-1}$. These values were entered into EPA's toxicological database, the Integrated Risk Information System (IRIS). In 1989, EPA withdrew these toxicity values from IRIS because of issues raised by EPA's Science Advisory Board (SAB). The SAB believed that the weight of evidence for TCE's human carcinogenicity was not sufficiently resolved, indicating that the evidence suggests a classification between possible carcinogen (Group C) and probable human carcinogen (Group B2). There was also uncertainty related to the underlying biological causes of toxicity in the animal experiments and how relevant these risk estimates may be to humans at low environmental exposure levels. Despite this action, EPA and state health and environmental agencies continued to use the withdrawn IRIS cancer toxicity values until updated values were developed and approved.

In 2001, EPA's National Center for Environmental Assessment (NCEA) published an external review draft assessment of the health risks posed by TCE (U.S. EPA, 2001). Based on a review of 16 state-of-the-science papers published in May 2000, as Supplement 2 of *Environmental Health Perspectives* Volume 108, EPA derived several "oral" CSFs. The oral CSFs ranged from 2E-2 to 4E-1 $(mg/kg\text{-}day)^{-1}$. Although many of the underlying studies evaluated the effects associated with inhalation exposure to TCE, IURFs were not recommended by EPA, though some estimates were derived and presented in a footnote below a table of cancer estimates. Since IURFs are necessary for assessment of vapor intrusion risk, the absence of these toxicity values has been problematic. Presentation of various route-to-route extrapolation approaches in the draft assessment has created further confusion in terms of identifying the appropriate oral-to-inhalation extrapolation to use for deriving IURFs. The EPA (2001) draft assessment proposed updated oral-to-inhalation extrapolation approaches from those presented in EPA's 1985 and 1987 health assessments (U.S. EPA 1985, 1987). These extrapolation approaches, based on TCE's metabolites, are different than the standard oral-to-inhalation route extrapolation approach, which relies on default body weight and inhalation rate assumptions. The updated extrapolation approaches, however, have been disregarded and the standard extrapolation approach (U.S. EPA, 1989) has been used by several EPA regional offices and state agencies to convert oral CSFs to IURFs for assessment of vapor intrusion risk.

The highest IURF (converted from the oral CSF using the standard route-to-route extrapolation approach) was adopted by most EPA regional offices despite several issues raised in a 2002 report by EPA's SAB (U.S. EPA, 2002a). The SAB identified several critical scientific issues in the EPA draft assessment which may affect the CSF range. EPA Region 8 toxicologists have evaluated the draft assessment and the SAB comments and agree with a number of the concerns raised by the SAB. In fact, Region 8 developed several position papers (U.S. EPA, 2003a) summarizing the technical and practical concerns with applying the oral CSF range from the draft assessment, and has elected to continue using the withdrawn IRIS/California EPA (Cal EPA) cancer toxicity values until a new entry for TCE is made into IRIS (U.S. EPA, 2003b). In 2003, the Colorado Department of Public Health and Environment (CDPHE), located within the geographical area of EPA Region 8, recommended the high end CSF from the EPA draft assessment, 4E-1 $(mg/kg\text{-}day)^{-1}$, as a provisional value for use in screening level risk evaluations (CDPHE, 2003). CDPHE finalized its risk management policy for TCE in August, 2004, establishing an indoor air screening concentration that is based on the high end CSF, but at a 10^{-4} risk level (CDPHE, 2004).

CURRENT RISK MANAGEMENT APPROACHES FOR TCE VAPOR INTRUSION

As indicated above, differential application of the EPA draft assessment CSFs, and the absence of a formal policy from EPA directing their use has led to considerable controversy and confusion when assessing health risks associated with TCE exposure. To address this issue, EPA's Office of Solid Waste and Emergency Response (OSWER) distributed and discussed a "Conceptual Interim Risk Management Strategy for TCE" at their annual division directors meeting in March, 2004. Although the strategy outlined in this document has not been released as official EPA policy it represents EPA's current practice for evaluating vapor intrusion and other relevant exposure pathway risk (Crum, 2004; personal communication with David Cooper, EPA Headquarters). This practice has also been documented previously in an e-mail correspondence between David Copper and Nita Nordstrom, Site Coordinator from Ohio EPA (Appendix A).

Specifically, the EPA OSWER interim risk management strategy recommends evaluation of TCE vapor intrusion risk using the Cal EPA Air Toxics 1990 IURF of 2E-6 $(ug/m^3)^{-1}$ (Cal EPA, 2002) or the withdrawn IURF from IRIS of 1.7E-6 $(ug/m^3)^{-1}$, values which are very similar. However, because of the uncertainty related to the cancer potency of TCE, EPA recommends setting site-specific cleanup levels for TCE at the most protective end of its acceptable risk range (i.e., 10^{-6}). OSWER notes that this strategy is consistent with the 10^{-6} point of departure used to develop remediation goals and as stated in the National Contingency Plan (NCP) for Superfund decisions (40 CFR 300.430(e)(2)(i)(A)(2)). Additionally, this approach is consistent with the *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (OSWER Directive 9355.0-30, April 22, 1991). This document states that a “risk manager may also decide that a lower level of risk to human health is unacceptable and that remedial action is warranted where, for example, there are uncertainties in the risk assessment result.” The ongoing uncertainty of the cancer potency of TCE, and anticipated discussion of the draft assessment with the National Academy of Sciences, which may result in changes to the draft toxicity values, along with field evidence of TCE vapor intrusion into homes, warrants application of a conservative risk management strategy.

The use of Cal EPA toxicity values by EPA is consistent with the approach recommended in OSWER Directive 9285.7-53, which establishes the hierarchy of human health toxicity values for use in risk assessments. The sources of toxicity information and hierarchy of consideration that should be used in performing human health risk assessments is as follows:

> **Tier 1: EPA’s Integrated Risk Information System (IRIS)**
> OSWER notes that “IRIS normally represents the official Agency scientific position regarding the toxicity of the chemicals based on the data available at the time of the review.”

Tier 2: EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical specific basis when requested by EPA's Superfund program.

Tier 3: Other Toxicity Values
As noted in EPA's guidance, Tier 3 includes both additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed. The guidance specifically notes that among the sources for such information are: Cal EPA, the Agency for Toxic Substances and Disease Registry (ATSDR), and the EPA Health Effects Assessment Summary Tables (HEAST) toxicity values.

Consistent with this OSWER directive, EPA's Office of Air Quality Protection Standards and Ohio EPA's Voluntary Action Program have also chosen to use the Cal EPA (2002) IURF (i.e., Tier 3 toxicity values) in their risk assessment processes.

A key additional component of the OSWER interim TCE strategy is the use of a residential indoor air action level of 1 to 2 ug/m^3, to identify the situations where vapor intrusion of TCE into buildings may be a problem. EPA considers this concentration range as a practical and attainable level that is above laboratory detection limits, and which is discernable from typical background indoor air concentrations. OSWER notes that urban background concentrations range from 0.1 to 1.0 ug/m^3. The OSWER interim TCE strategy states that the low end of the indoor air action level range (1 ug/m^3) corresponds with a 10^{-6} cancer risk using the Cal EPA IURF (2E-6 ug/m^3)$^{-1}$ and standard residential exposure assumptions. In comparison, a residential indoor air concentration of approximately 2 ug/m^3 corresponds with a 10^{-4} risk using the highest CSF recommended in the EPA draft assessment (i.e., 1.1E-4 (ug/m^3)$^{-1}$ as converted from the oral CSF of 0.4 (mg/kg-day)$^{-1}$). OSWER concludes that this action level range balances the need to provide a protective remedy for actual measurable exposures, while acknowledging the uncertainty related to the cancer potency. Overall, this risk management approach gives credibility to the full range of documented CSFs, but is largely implemented through applying indoor air concentrations of TCE that balance the toxicity and background indoor air issues.

In August, 2004, CDPHE finalized an indoor air TCE policy, which also established indoor air concentrations for managing TCE vapor intrusion risk (CDPHE, 2004). CDPHE uses an indoor air concentration of 1.6 ug/m^3 of TCE as the level at which cleanup is required. This concentration tends more toward the upper end of the recommended OSWER indoor air action level range. In comparison to the EPA OSWER strategy, the indoor air concentration of 1.6 ug/m^3 corresponds with a 10^{-4} risk using the high end CSF from EPA's draft assessment and standard residential exposure assumptions, which include an age-adjusted inhalation rate.
For TCE levels ranging from 0.8 to 1.6 ug/m^3, the department will conduct further study to determine the need for remedial action. The TCE concentration of 0.8 ug/m^3 corresponds with a 5 x 10^{-5} risk, midway between 10^{-4} and 10^{-5} risk. An important component of this additional investigation involves testing to determine whether indoor air concentrations are the result of subsurface contaminant vapor intrusion or are attributable to background sources of TCE. Investigations conducted by CDPHE in the metropolitan area of Denver at numerous homes show that typical background concentrations of TCE in homes range from 0.2 to 0.5 ug/m^3. Based on these common background levels, an indoor air concentration of 0.8 ug/m^3 is a reasonable trigger level for conducting further evaluation of vapor intrusion risk.

In summary, both the EPA and CDPHE approaches are largely driven by establishing target indoor air concentrations. At this time, this approach is the most feasible given the need to differentiate background concentrations of TCE from those attributable to true vapor intrusion, and to reflect the uncertainties of the cancer potency of TCE. The EPA and CDPHE indoor air concentration ranges are also very similar, which is expected given that both agencies are representing standard residential exposures and drawing from the same toxicological databases. The Connecticut Department of Environmental Protection (CDEP) uses an indoor air background-based TCE concentration of 1 ug/m^3 to develop “volatilization criteria” for groundwater and soil vapor (CDEP, 2003). CDEP references numerous background indoor air studies that were considered in developing the TCE target indoor air concentration. At the 2004 Midwestern States Risk Assessment Symposium in Indianapolis several case studies were presented demonstrating the importance of differentiating background sources of indoor air contamination from that attributable to vapor intrusion – a critical distinction for making appropriate risk management decisions.

RECOMMENDED RISK MANAGEMENT APPROACH FOR TCE VAPOR INTRUSION

The above risk management approaches effectively demonstrate that applying target background TCE indoor air concentrations is currently the most practical and protective approach for evaluating vapor intrusion risk given the uncertainties related to the cancer potency estimates from EPA's draft assessment. Equally, this approach allows application of the entire range of EPA reported cancer potency values, as demonstrated by the OSWER risk management strategy. HMA is recommending a similar risk management approach that is also based on the use of a target indoor air concentration range. This approach is used to back-calculate TCE soil concentrations protective of indoor air (i.e., SVIIC).

HMA is recommending a lower target indoor air concentration range of 0.2 – 1.0 ug/m^3 than proposed by EPA OSWER. A lower concentration range is supported based on large datasets from two recent background indoor air studies involving TCE (Foster et al. 2002; Sexton et al. 2004). Foster et al. (2002) analyzed data from over 300 homes in Denver, Colorado and reported a 95% upper confidence limit TCE concentration of 0.224 ug/m^3 (the geometric mean concentration was 0.155 ug/m^3). Sexton et al. (2004) reported a 90th percentile concentration of 0.8 ug/m^3 and an average concentration of 0.5 ug/m^3. These recent data indicate a decreasing trend in background indoor air concentrations of TCE relative to data compiled from older studies by EPA (1998). This is likely due to technological advances in field sampling devices and analytical laboratory techniques and detection limits, but also because TCE has been removed from several household products. Indoor air concentrations may also be decreasing in concert with reductions in ambient air concentrations of TCE. Data compiled by Wu and Schaum (2000) show that mean yearly ambient air concentrations of TCE are declining, with a mean concentration of 0.88 ug/m^3 reported for 1998.

These data indicate that a more practical and attainable indoor air background range than recommended by EPA OSWER is supported. HMA believes that applying a lower target indoor air concentration is also appropriate because it indirectly addresses other toxicity concerns highlighted in EPA's draft assessment, such as protection of susceptible populations (i.e., children and those with certain diseases) and cumulative risk. These concerns are highlighted in the draft assessment as support for choosing the high end IURF to assess risk for sensitive subpopulations. Children exposure to hazardous substances has been the focus of several recent federal actions. In particular, Executive Order 13045 (1997) requires federal agencies to "make it a high priority to identify and assess environmental health and safety risks that may disproportionately affect children and shall ensure that their policies, programs, and standards address disproportionate risks that result from environmental health risks or safety risks." Accordingly EPA (U.S. EPA, 2001) has identified TCE as one of the twenty Tier 1 chemicals for evaluation in its Voluntary Children's Chemical Evaluation Program (VCCEP).

Applying a lower target indoor air concentration range for calculation of SVIIC also provides exposure control strategy until the toxicity of TCE is better understood. This approach in effect minimizes the amount of TCE in soil gas allowed to enter a home, and most importantly minimizes that which may be added to potentially existing indoor air background levels. This will reduce the likelihood of indoor air concentrations of TCE exceeding unacceptable levels in buildings even after TCE from vapor intrusion and background indoor air levels are combined. This is significant considering that the highest EPA IURF (converted from the oral CSF of 0.4 $(mg/kg\text{-}day)^{-1}$) of the draft assessment) produces a risk-based indoor air concentration of 0.2 ug/m^3 at 10^{-5} risk, a concentration within typical TCE background levels in buildings. Finally, a lower target indoor air concentration range is appropriate based on evidence from several unpublished TCE vapor intrusion case studies which demonstrate that indoor air concentrations of TCE are often greater than predicted by vapor modeling (AEHS, 2004). Inaccurate predictions were the result of model inputs not being adequately conservative for screening vapor intrusion problems rather than a fault of the model (Johnson and Ettinger, 1991) itself.

HMA's approach of starting with a target indoor air concentration range to develop the corresponding residential TCE SVIIC involves algebraically rearranging the standard EPA/MDEQ risk assessment equation to solve for the IURF. Although this approach is not the standard way in which IURFs are derived, it provides a means for judging the credibility of HMA's approach, by observing how comparable the IURFs are with EPA's past and current estimates. This equation is shown below:

$$IURF = \frac{TR \times AT}{ED \times EF \times TIAC}$$

where,

TR	(Target risk)	= 10^{-5}
AT	(Averaging time)	= 25,550 days (70 x 365)
$IURF$	(Inhalation unit risk factor)	= chemical-specific, $(\text{ug/m}^3)^{-1}$
EF	(Exposure frequency)	= 350 days/year (Residential)
ED	(Exposure duration)	= 30 years (Residential)
$TIAC$	(Target Indoor air concentration range)	= 0.2 to 1.0 ug/m^3

The acceptable or target risk level is set at 10^{-5}, the mid-point of EPA's acceptable risk range (i.e., 10^{-4} to 10^{-6}), for consistency with Michigan's Part 201 environmental regulations (MDEQ, 2001). The averaging time (AT) represents the number of days over which the exposure is averaged. For carcinogenic compounds such as TCE, exposures are calculated by prorating the total dose over a lifetime. The approach is based on the assumption that a high dose of a carcinogen received over a short period of time is equivalent to a corresponding low dose spread over a lifetime. The exposure frequency (EF) represents the number of days per year that a resident is in their home; it assumes that people spend approximately 15 days per year away from their homes for vacations or other reasons. The exposure duration (ED) of 30 years represents the national upper-bound time (90th percentile) at one residence (EPA, 1989).

The range of IURFs corresponding to the recommended indoor air concentration range (0.2 to 1.0 ug/m^3), using standard residential exposure assumptions and a target risk level of 10^{-5}, is 1.2E-4 to 2.4E-5 $(\text{ug/m}^3)^{-1}$. Although these potency values are not derived from specific toxicological studies in the traditional sense, as stated above, the IURFs are remarkably comparable with cancer potency estimates from the EPA draft assessment (i.e., 1.1E-4 to 5.7E-6 (ug/m^3). This is to be expected since selection of lower target indoor air concentrations implies a degree of health hazard or toxicity (i.e., in this case, cancer potency) associated with TCE exposure. The highest (most potent)

IURF (1.2E-4 $(ug/m^3)^{-1}$), which corresponds with the low end of the target indoor air concentration range, 0.2 ug/m^3, is nearly equivalent to EPA's (2001) high end value (i.e., 1.1E-4 $(ug/m^3)^{-1}$) from the draft assessment. The lowest HMA derived IURF (2.4E-5 $(ug/m^3)^{-1}$) is fairly comparable with two of three IURFs derived directly from inhalation exposure studies, reported in a footnote of the EPA (2001) draft assessment – the EPA IURFs, based on liver cancer, kidney cancer and non-Hodgkin's lymphoma, are 9E-7, 3E-5 and 9E-5 $(ug/m^3)^{-1}$, respectively. In contrast, the cancer potency value range derived from the HMA approach is approximately one to two orders of magnitude more potent than the Cal EPA and withdrawn IRIS IURF recommended by EPA OSWER.

To derive the range of TCE residential SVIIC corresponding to the target indoor air concentration range, a series of additional calculations must be completed which incorporate the IURFs together with generic residential assumptions in the Johnson and Ettinger (1991) model. These calculations are presented in the MDEQ (2002) Part 201 Administrative Rule 724 (Appendix B).

The resulting residential TCE SVIIC range from 100 to 500 ug/kg (ppb). This soil concentration range is recommended to MSHDA for risk management decision-making purposes at properties where TCE is present in soil.

UNCERTAINTIES

TCE Vapor Intrusion Field Studies

It cannot be determined if HMA's recommended approach sufficiently accounts for the greater infiltration of TCE vapor into homes reported from several field studies. A review of the field data on TCE vapor intrusion from many sites was conducted by HMA to assess the reliability/protectiveness of the current MDEQ assumptions used in the Johnson and Ettinger (1991) model. Unfortunately, the measured versus model predictions were done for volatilization of TCE from groundwater and soil gas to indoor air, instead of volatilization from a soil medium. As a result, evaluation of the current generic model assumptions used to derive the SVIIC and determination of the protectiveness of these assumptions cannot be completed at this time.

Implications of Current EPA Vapor Intrusion Guidance

It is important to note that if model input values presented in EPA's (2002b) draft vapor intrusion guidance document were applied to HMA SVIIC calculations, lower SVIIC would be generated. Due to the benefits of consistency between federal and state environmental agency approaches it is anticipated that MDEQ will incorporate many of the EPA model input assumptions into development of revised generic indoor air criteria once the EPA guidance is finalized. This evolution should be carefully monitored to assure that the most scientifically supported and appropriate SVIIC are being used to protect the public health.

Implications of Other EPA Guidance

Lastly, it should also be recognized that the TCE toxicity values presented in the EPA draft assessment for TCE are incorporated into a number of EPA guidance documents which may continue to be used in the investigation and evaluation of sites. For example, EPA Region 9 has developed Preliminary Remediation Goal (PRGs) using the high end CSFs. The EPA (2002b) draft vapor intrusion guidance and related spreadsheets on the internet also rely on the high end CSF to calculate groundwater and soil vapor screening criteria for protection of indoor air.

SUMMARY AND COMPARATIVE ANALYSIS

HMA has presented the basis for recommending a slightly more protective risk management approach than currently used by EPA OSWER. The key elements underlying HMA's recommendation are outlined below:

1. Data indicate decreasing background indoor air concentrations of TCE supporting use of lower target indoor air concentrations for development of residential SVIIC.

2. Indirectly addresses other toxicity concerns highlighted in EPA's draft assessment, such as protection of susceptible populations (i.e., children and those with certain diseases) and cumulative risk.

3. Empirical evidence from several studies demonstrates higher indoor air concentrations of TCE than predicted from modeling.

Applying a lower target background indoor air concentration range for the development of TCE SVIIC, results in minor differences with the EPA OSWER risk management strategy. This is because EPA OSWER chose a 10^{-6} risk level compared to 10^{-5} risk level applied by HMA. The EPA OSWER approach of using a lower (i.e., more protective) acceptable risk for setting cleanup levels nearly accounts for the differences in target indoor air concentrations and IURFs used between the OSWER and HMA approaches. HMA's recommendation of a slightly lower target indoor air concentration than used in the EPA OSWER risk management strategy is supported by recent background indoor air studies. HMA's approach is also similar to approaches recently adopted in Connecticut and Colorado. Overall, this approach is a prudent risk management strategy considering the uncertainties associated with the characterization of TCE's health risks, and uncertainties related to TCE vapor intrusion.

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Appendix A

E-mail correspondence between

Nita Nordstrom (Site Coordinator, Ohio EPA)

and

David Cooper (U.S. EPA Headquarters, Office of Superfund Remediation and Technology Innovation)

Nita Nordstrom <nita.nordstrom@epa.s

To: DavidE Cooper/DC/USEPA/US@EPA
tate.oh.us>
cc:

Subject: tier hiearchy for TCE... 09/16/03 02:02 PM

Hello Dave,

thought i'd email you re: the TCE slope factor since i spoke with you recently about this a couple of weeks ago... now i have another question re: TCE slope factors - jayne michaud referred me to you (guess no one wants to touch this one and jayne say's you're it :) re: the NCEA hiearchy - was under the impression that the tier ii would be values that were provisional, peer reviewed, etc. and tier iii would be heast. is this changing also?? it sounds like this entire issue is dynamic - think when i spoke with you last you said something might be out in oct.? was that including the hiearchy issue as well?

dr. chiu informed me that he's heard discussion re: the tier hiearchy is not finalized, but still being discussed. i've been tasked by my chief to determine in which tier the cal epa TCE slope factor is and the new TCE slope factor as well. are they both in tier ii? or one in tier iii?? and any recommendation on which to use?? i realize this issue has been elevated to levels that are possibly higher than epa, but was hoping that you might be able to clarify the tier questions.

thanks so much for any light you can shed on all this - we were to have our recommendation to our director aug 15! and we have TCE 2 sites that

are negotiating orders at this time. can imagine that you are at least
as frustrated as we are here! Cheers!

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David E. Cooper, USEPA Headquarters, OSRTI (GS15)
Email below:

At last a question I can answer... well, sort of.
The hierarchy is not actually very dynamic at all; however, tier 3 is pretty inclusive. Tier 1 is IRIS, Tier 2 is Provision, peer reviewed Tox values that the Superfund Tech Support Center does for us; and tier 3 includes Cal EPA and HEAST, and maybe the Dutch RIVM if we like the numbers. Ad hoc recommendations from the STSC and draft ORD reassessment values do not appear explicitly in the hierarchy, but neither are they currently excluded. For example, we have already adopted the use of the tox information on PCE from Cal EPA, instead of even considering what is going into the ORD reassessment for PCE. But draft ORD values would have fallen into tier 3, along with many other thing. Tier 3 can be thought of as "other credible sources" and might include other state values or international values that have been peer reviewed and for which the analysis is publicly available.

I think, in the future, we will require that peer review comments have been addressed in a new publicly available draft reassessment before we would consider such a tox value suitable for use. I would expect to see such language in the hierarchy memo when it does come out. This would remove the draft TCE reassessment from the table until it is farther along in the process, which would have been a good thing for us all, I believe. EPA's Office of Air Quality Protection Standards has also explicitly chosen to use the Cal EPA values for the air toxics program, with the rationale that until the peer review comments have been addressed, it isn't ripe. There will be some further meetings "above my pay grade" as is the phrase around here, about what to do about TCE in the interim, since we are already in the mire on this one. I don't think we will see a decision on which way we will go in Superfund for a couple of months, but I think (perhaps naively) that we will actually get an interim direction in that time frame.

Hope that is helpful.
Cheers,

DECoop

Appendix B

Part 201 Administrative Rule 724

Procedure for calculating soil volatilization to indoor air inhalation criteria (SVIIC)

R 299.5724 Generic cleanup criteria for soil based on indoor inhalation of hazardous substance vapors volatilized from soil.

Rule 724. (1) Indoor inhalation of hazardous substance vapors volatilizing to indoor air from soil shall be considered a reasonable and relevant exposure pathway only for hazardous substances that have a Henry's law constant greater than or equal to 0.00001 atm-m^3/mole.

(2) Except as provided in subrule (1) of this rule, if any of the following conditions exist, the generic criteria developed pursuant to this rule shall not apply and a site-specific evaluation of indoor inhalation risks shall be conducted:

(a) There is a structure present or planned to be constructed at the facility which does not have a concrete block or poured concrete floor and walls.

(b) There is a sump present that is not completely isolated from the surrounding soil by its materials of construction.

(3) Soil cleanup criteria based on indoor inhalation of volatile emissions from hazardous substances in soil shall be called soil volatilization indoor air inhalation criteria ("SVIIC"). The SVIIC is determined by the following series of calculations, except as provided in R 299.5734(3):

EQUATION FOR CARCINOGENIC EFFECTS:

$$\text{SVIIC} = \frac{\text{TR} \times \text{AT X AIR}}{\text{IURF} \times \text{EF} \times \text{ED} \times \text{CR}_{\text{building}}}$$

where,

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

		= 21 years (commercial/industrial)
$CR_{building}$	(Ratio of indoor air concentration to soil concentration)	= chemical-specific, $(ug/m^3)/(ug/kg)$

EQUATION FOR NONCARCINOGENIC EFFECTS:

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

where,

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

The contaminant vapor concentration in the building indoor air is written as:

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

where,

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

The vapor-phase contaminant concentration at the source for soil is written as:

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

where,

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

The intrusion rate of hazardous substance vapors into buildings is predicted using an analytical solution which couples both diffusive and convective transport of vapors emanating from subsurface soil into enclosed spaces. An attenuation coefficient (α) is calculated that is expressed as the ratio of building indoor air concentration to the vapor-phase concentration at the source. Values of α are calculated assuming infinite source conditions. For infinite source conditions α is written as follows:

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

where,

α	(Attenuation coefficient)	= unitless

D_v^{eff}	(Effective diffusion coefficient through vadose zone)	= chemical-specific, cm^2/s
D^{crack}	(Effective diffusion coefficient through crack)	= cm^2/s, ($D^{crack} = D_v^{eff}$, see equation for D_v^{eff} below)
A_b	(Area of enclosed space below grade)	= 1.96E+6 cm^2 (residential) = 3.83E+6 cm^2 (commercial/ industrial)
$Q_{building}$	(Building ventilation rate)	= 1.51E+5 cm^3/s (residential) = 5.04E+5 cm^3/s (commercial/ industrial)
L_{crack}	(Building foundation thickness)	= 15 cm
L_T	(Source-building separation distance)	= 15 cm (All land use categories)
Q_{soil}	(Volumetric flow rate of soil vapor into the building)	= 0.81 cm^3/s (residential) = 2.10 cm^3/s (commercial/ industrial)
A_{crack}	(Total area of cracks below grade)	= 196 cm^2 (residential) = 383 cm^2 (commercial/ industrial)
exp(p)	(The base of the natural logarithm raised to power p)	= e^p

The effective diffusion coefficient calculation for the vadose zone (D_v^{eff}) is written as:

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

where,

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

(4) Facility-specific measurements of the following parameters may be substituted individually for the generic assumptions and still allow the facility to satisfy the categorical criteria in section 20120a(1)(a) to (e) of the act:

(a) Dry soil bulk density.

(b) Fraction of organic carbon in soil.

(c) Soil vapor permeability.

(d) Temperature adjustment factor for Henry's law constant.

Facility-specific measurements shall be based on representative characterization. documentation of all facility specific values shall be provided in the remedial action plan.

(5) The department may approve of methods to demonstrate compliance with criteria for this exposure pathway if those methods are more representative of in-situ conditions at the facility. Methods acceptable to the department may include, but are not limited to, evaluation of representative soil gas concentrations.

(6) A site-specific SVIIC may be developed for remedial action plans prepared pursuant to section 20120a(2) of the act that is based on demonstration of compliance with 1974 PA 154, MCL 408.1001 et seq. and the rules promulgated pursuant to that act. This subrule shall apply only when all of the following conditions are satisfied:

(a) The risk being evaluated results from inhalation by workers of hazardous substances in indoor air within an active workplace that is regulated by 1974 PA 154, MCL 408.1001 et seq. and the rules promulgated pursuant to that act.

(b) The exposure to hazardous substances from environmental contamination is a portion of the exposure to which workers are otherwise subject from process-related sources of the same hazardous substance.

(c) The risk to the non-worker population, if any, from inhalation of indoor air at the property has been evaluated using generic residential GVIIC or a site-specific evaluation has been conducted for the non-worker population according to methods acceptable to the department, and the risk is not unacceptable on the basis of the risk management objectives set forth in section 20120a of the act.