CUMULATIVE RISK AND RISK-BASED ALTERNATIVE APPROACHES

Subcommittee 9
Concept Paper
March 1, 2023

Prepared for:
The Working Group established pursuant to Section 19 of Public Act 20-9 and
The Connecticut Department of Energy and Environmental Protection
79 Elm Street Hartford, CT 06106

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Subcommittee 9 Concept Paper
Cumulative Risk and Risk-Based Alternative Approaches

Appendices **End of Report**

Introduction

This Concept Paper has been prepared by Subcommittee 9 (Cumulative Risk and Risk-Based Alternative Approaches) appointed pursuant to Section 19 of Public Act 20-9. This subcommittee met on a weekly basis starting November 16, 2022 and was formed to assist the Release-Based Working Group to determine which components of cumulative risk assessment can be implemented in Connecticut while maintaining acceptable levels of human health risk at sites that have been remediated and to better evaluate the sources of unacceptable risk to human health to assist in remediation decision making.

The Connecticut Department of Energy and Environmental Protection (DEEP) provided questions for the Subcommittee to review to develop a Concept Paper on this topic. The weekly meetings were regularly attended by DEEP and Connecticut Department of Public Health (DPH) members, who supported and assisted the Subcommittee in the process of answering and evaluating questions posed by DEEP on this topic.

The subcommittee members included Connecticut Licensed Environmental Professionals (LEPs) and Massachusetts Licensed Site Professionals (LSPs), as well as representatives from DEEP and DPH, all of whom have varying degrees of cumulative risk assessment experience. Subcommittee 9 risk assessment experience ranged from being new to the topic of using the cumulative risk approach to evaluate risk to human health posed by environmental contamination at release sites to professional toxicologists with doctorate degrees.

Subcommittee 9 members and staff members from the DEEP and DPH who provided assistance to the Subcommittee are listed in *Appendix A*.

In addition to the topics listed in the following sections, Mr. Andrew Friedman from the Massachusetts Department of Environmental Protection (MassDEP) participated in a Subcommittee meeting that centered around the development, implementation and use of the Massachusetts Method 3 Short Form calculators.

The focus of the Subcommittee's meetings was the charge and eight questions posed by DEEP. The charge and these questions, along with the Subcommittee's evaluations, are provided below. It was the consensus of the Subcommittee that the ability to evaluate potential risk to human health associated with release sites via the cumulative risk approach is a necessary tool for environmental professionals in Connecticut. The Subcommittee also agreed that some form of cumulative risk characterization should be a self-implementing option for LEPs to use on environmental release sites in Connecticut.

Charge

The charge to this Subcommittee is to determine which components of cumulative risk assessment can be implemented without increasing the human health risk on sites that have been remediated.

While the charge of the Subcommittee was directed to sites that have been remediated, the consensus of the Subcommittee was that cumulative risk assessment is a valuable tool for evaluating sites that have been remediated and for determining the source of environmental risk to human health (i.e., the specific compounds that are resulting in unacceptable levels of risk) at release sites for remediation decision making. Since "release sites" is currently undefined, the Subcommittee proposed a definition of release sites to be locations where contamination resulting from a release has come to be located. Because multiple release sites may exist on a single parcel, the use of the cumulative risk approach under the release-based program will require the incorporation of data from all release sites that may be encountered by human receptors at contaminated properties.

If the proposed cumulative risk limits of an excess lifetime cancer risk (ELCR) of $1x10^{-5}$ and the hazard index (HI) of 1 are adopted, as recommended in the discussion for Question 3, the use of the cumulative risk approach for evaluating human health risk associated with environmental release sites will not result in unacceptable risk to human receptors. The preceding conclusion is based upon the assumption that all compounds of concern associated with a release site are evaluated as part of the cumulative risk assessment.

Question 1: What components of a cumulative risk assessment are LEPs qualified to perform under existing Connecticut law?

LEPs may prepare and complete cumulative risk assessments in accordance with their experience and expertise but will likely need to reach out to risk assessment professionals when faced with components of risk assessments outside their experience or expertise. Similar to an LEP's utilization of any specialist for investigation, evaluation, and/or remediation of a release site, it is incumbent upon the LEP to ensure that an individual or individuals utilized for risk assessment activities have the requisite qualifications and competency.

Question 2: Are there alternative exposure scenarios that may warrant evaluation and integration into the cleanup standards and what, if any, institutional controls would be necessary to keep these scenarios valid?

The subcommittee recommended that the following exposure scenarios evaluated within the MA Shortforms, along with their supporting exposure equations, be adopted by CT: Residential Soil, Residential Air, Office Worker/School Air. Beyond these exposure scenarios and the Residential and Industrial/Commercial exposure scenarios as currently evaluated within the CT Remediation Standard Regulations (RSRs) to develop default or alternate criteria, the subcommittee recommends that several additional exposure scenarios be included in a cumulative risk assessment framework for demonstrating compliance at a Site. There is general consensus among committee members that evaluation of alternate exposure scenarios may warrant evaluation and integration into the cleanup standards that will allow an exit from the program through the design of site-specific remediation options/technologies potentially combined with cumulative risk characterization. In addition to residential and commercial/industrial scenarios, alternative exposure scenarios such as:

Residential – passive use	Apartment/Condominium Complexes where access to soil is unlikely due to the physical setting. In this case, a No Disturbance/No Dig/No Garden (vegetable) option may allow a risk characterization with a lower exposure frequency for dermal exposure. The existing MassDEP Method 3 Shortforms for Residential Soil and Residential Air could be used to evaluate risk under this modified exposure scenario. The recommendation

	for using these Shortforms under a Residential – Passive exposure scenario would be to adjust the depth of soil to which these equations are applicable (i.e. 0-4' vs. 0-15') and/or exempt the use of these equations if an Engineered Control preventing direct contact is in place, rather than adjustments to the equations or exposure factors. This practice would be in line with guidance of Massachusetts and California. See Appendix C for the MassDEP Method 3 Residential Soil and Residential Air Shortforms. Note: Table RS-7 "Homegrown Produce Ingestion Rate" in Shortform sf12rs would not be applicable for this exposure scenario and would be eliminated in the characterization of risk.
Park visitor – passive use	Paved or unpaved walking and hiking trails and other open spaces where access to soil is unlikely or limited due to the physical setting and length of exposure. Note: this type of exposure scenario would not include sports or recreation fields. In this case, a risk characterization with a lower exposure frequency for dermal or inhalation exposure may be a viable option. See Appendix C for a recommended example based on an existing MassDEP Method 3 Shortform for Park Visitors.
Indoor Facility worker	Stores or factories where access to soil is unlikely due to the physical setting, which is typically paved/concrete. In this case, a risk characterization with a lower exposure frequency for dermal exposure may be a viable option. This exposure scenario would also capture exposure from the air inhalation exposure route, which would include exposure via vapor intrusion. See Equations C-3 in Appendix C for recommended examples of how to assess risk associated with this exposure scenario, based on equations United States Environmental Protection Agency (USEPA) uses to derive Regional Screening Levels.
Construction worker	Locations where access to soil is likely; however, the length of exposure may be for shorter period. According to the USEPA, "This is a short-term receptor exposed during the workday working around heavy vehicles suspending dust in the air. The activities for this receptor (e.g., dozing, grading, tilling, dumping, and excavating) typically involve on-site exposure to surface soils." See Equations C-4 in Appendix C for recommended examples of how to assess risk associated with this exposure scenario, based on equations USEPA uses to derive Regional Screening Levels.
Utility worker	Locations where access to soil is likely; however, the length of exposure may be for a limited period. The activities for this receptor (e.g., trenching, excavating) typically involve on-site exposure to surface soils. See Equations C-5 in Appendix C for recommended examples of how to assess risk associated with this exposure scenario, based on equations USEPA uses to derive Regional Screening Levels.

Best management practices (BMP), Environmental Use Restrictions (EURs), and activity use limitations may be needed to enforce the exposure scenarios. Additional options within the EUR may need to be developed in order to apply the exposure scenarios discussed above. In most cases, simple signage may be sufficient to alert receptors to potential hazards. In apartment/condominium complexes, language may also be included in lease agreement/association guidelines. For commercial/industrial settings, the facility health & safety officer can alert employees to potential hazards and apply administrative controls or the use of personal protective equipment as part of a written policy.

In addition to BMPs, activity use limitations can also be instituted such as EURs, as deed controls. These controls are already part of current regulations.

Question 3: Are there certain clean up standard risk adjustments that can be made by LEPs using a process similar to the "short forms" used in the Massachusetts Method 3 Risk Characterization process without the advice of a risk assessor or toxicologist?

The general consensus of the Subcommittee is that certain types of cumulative risk assessments, such as Short Form calculators, should be able to be used as a self-implementing option under the proposed regulations. The Subcommittee recommends that either:

1. Shortform calculators be developed for use in Connecticut; or
2. The use of the most current version of the Massachusetts Method 3 Shortforms be allowed as a LEP implementing option under the new regulations.

The Subcommittee recognizes that the exposure scenarios evaluated within the Massachusetts Method 3 Shortforms do not encompass all of the exposure scenarios recommended by the Subcommittee (ex. Facility Worker, Utility Worker, Residential – Passive). In these cases, if existing Method 3 Shortforms were used as frameworks they would need to be modified with equations and exposure parameters appropriate to those exposure scenarios.

The Subcommittee also recognized that for the implementation of a cumulative risk approach for assessing human health in Connecticut, cumulative risk limits will need to be established for use throughout the State. While the current version of the RSRs includes a Commissioner approved alternative method for compliance with the Direct Exposure Criteria (DEC) that includes an ELCR limit of $1x10^{-5}$ (when 10 or more carcinogenic compounds are present at a release site) and $1x10^{-6}$ (when less than 10 carcinogenic compounds are present) and a non-cancer, hazard index (HI) of 1.0, the RSRs do not currently include information regarding acceptable ELCR or HI limits under a cumulative risk assessment process.

The USEPA defines an acceptable risk range to be an excess lifetime cancer risk (ELCR) between one (1) in ten-thousand (1.0E-4) and one (1) in one-million (1.0E-6) exposed. The subcommittee recommends establishing a cumulative ELCR of $1 \, x10^{-5}$ for exposure to multiple carcinogens, an ELCR of 1×10^{-6} for exposure to an individual carcinogen, and a cumulative HI of 1 (allowing for summation of non-cancer risk by target organ) within the RSRs to support a cumulative risk approach. These cumulative risk thresholds are consistent with those within the frameworks of Massachusetts as well as other states including Oregon, Pennsylvania, and New Hampshire.

This cumulative risk approach would apply to the summation of risk from all potential exposure pathways able to be evaluated under a cumulative risk process, including exposure via soil and soil vapor/indoor air media. The subcommittee expects that a cumulative risk assessment would include assessment of all appropriate exposure pathways via a risk assessment approach and would not allow for use of RSR criteria to evaluate compliance with respect to one media and risk assessment to evaluate compliance with respect to a different media. For example, if at a given site a receptor may be exposed to contaminants in both soil and soil vapor via vapor intrusion, compliance would need to be demonstrated via either a cumulative risk assessment evaluating risk from both media, or via compliance with individual RSR criteria for soil and soil vapor. The subcommittee acknowledges that evaluation of risk associated with exposure to groundwater via ingestion of drinking water will need to remain an evaluation via application of the groundwater protection criteria (GWPC), as many of these criteria are derived from USEPA Maximum Contaminant Levels (MCLs).

Question 4: Which parameters can be altered and what is a reasonable range of values that can be adjusted within the confines of a short form process? Would any of these parameters require consultation with professions with expertise beyond the expertise required of LEPs? What guidance is needed to support the use of such short forms?

The Massachusetts Method 3 Short Form is a calculator created with set parameters for exposures and toxicity. In Massachusetts a Method 3 risk characterization that uses only un-modified Short Forms is known as a Short Form Method 3 and is not subject to additional review by MassDEP staff. If the form is modified, MassDEP will review the modifications at a higher level. The Subcommittee recommends a similar approach should Connecticut adopt cumulative risk via a Shortform calculator.

Site-specific information that should be considered for modification in the Short Form include:

- Exposure scenarios to match current and reasonably foreseeable future site exposures;
- Likely Human Receptors
- Time spent on-site by individual receptors

The Subcommittee recommends that parameters needing consultation beyond LEP include: LEP work outside of their areas of experience and expertise and this is dependent on the qualifications of the LEP – some changes might need to involve a Risk Assessment specialist. Guidance needed to standardize approach to use of the Short Forms / Cumulative Risk process and should include: instructions/guidance on the specific use of the short form(s); general data requirements, exposure pathways and receptors and recommendations for exposure factors; and Exposure Point Concentration (EPC) calculation (maximum concentration, 95% Upper Confidence Limit (UCL), or arithmetic mean).

Currently, under the RSRs, default, “Method 3 Short Form-style risk characterizations” could only be completed for Residential and Commercial/Industrial soil in areas of GA and GB groundwater. Comparatively, in Massachusetts, the three different soil categories (S-1, S-2, and S-3) and three different groundwater categories (GW-1, GW-2, GW-3) allow “levels” of exposure risk.

In Connecticut, with all soil between the surface and 15 feet treated equally, there can only be risk characterizations for Residential and Commercial/Industrial for GA and GB groundwater. A Deed Restriction (EUR) is needed to eliminate Residential as a risk scenario in future use.

- The Subcommittee recommends variations for specific site conditions (Park Visitor, Trespasser, Indoor Facility Worker, Construction Work, Utility Worker etc. within the soil exposure scenarios, such that small sites or sites with a limited suite of constituents of concern (COCs) could achieve self-implementing closure/Verification.

Question 5: How should fees to support DEEP and DPH review of cumulative risk assessments be structured?

The fee structure should follow the current outline provided by DEEP for LEP Form filing for the Property Transfer Program. This will allow DEEP to provide funding to audit self-implemented short form risk-based and cumulative risk assessments without additional changes to the fee structure.

DEEP and DPH will have to determine level of effort on their end for reviewing non-self-implemented risk assessment submittals and fee structure.

Question 6: If a short form process is utilized in a release verification, what percentage of those verifications should be audited? What level of documentation is necessary to support those verifications?

The DEEP currently has an audit program in place for reviewing LEP Verifications for the Property Transfer and Voluntary Remediation Programs. This process allows DEEP to quickly identify Sites that would require additional justification for final Verification. This same process and **timeframe** in which DEEP is required to audit current Verifications is recommended to be used to audit Verifications under a Release-Based program where Short Forms are utilized.

With that said, the Subcommittee assumes that releases subject to the RCRA regulations would automatically be audited by the DEEP.

Per the level of documentation to support Verification, the LEP Verification Report and its supporting documents should be sufficient to support the Verification with a short form under a Released-Based program.

The Subcommittee recommends that guidance documents be prepared for Cumulative Risk Reporting to assist the environmental professional in obtaining a higher likelihood of DEEP and DPH approval of their assessments. We also recommend that an iterative approval process be formulated to allow for interim approvals prior to assessments being audited.

Question 7: Outside of short form process, is there an intermediary process for risk assessments that can be completed more expeditiously by the regulated community than the current process and reviewed by the state agencies?

The subcommittee discussed existing intermediary frameworks in other states such as Massachusetts and Rhode Island and considered existing resources within the RSRs as well. Several suggestions for a more expeditious review of risk assessments came from this discussion:

First, the subcommittee recommended publishing allowable Modifications to Shortforms. For example, preapproved equations, exposure parameters, and guidance provided by DEEP and DPH that could be used to modify the Shortforms outside of the default exposure parameters on the short form. In addition, the subcommittee recommends DEEP and DPH provide guidance on how to appropriately modify exposure parameters using a hierarchy of guidance. For example, DEEP and DPH could require that modifications are done in line with either the values provided in USEPA's Exposure Factors Handbook, by other states, or by the parameters used in the generation of USEPA's Regional Screening Levels, and that these published exposure parameters may be used under a shortform modification process.

Second, the subcommittee recommended DEEP and DPH allow derivation of risk-based criteria, based on site specific information, again using pre-approved and provided equations and guidance to modify default exposure parameters. The subcommittee notes that this would be similar to the MassDEP Method 2 process, as well as the CT RSR alternative soil DEC process.

Question 8: The Massachusetts Method 3 Risk Characterization includes the assessment of risk to the environment. How should ecological risk be considered under a release-based program?

The subcommittee considered existing frameworks within Massachusetts, Connecticut, and the USEPA when developing the following recommendations. Several suggestions came from this discussion, as follows:

The subcommittee acknowledged that ecological risk must be a component of any risk assessment. The subcommittee further recommended that the pending regulations be developed to reflect the use of several "stages" of ecological risk assessment as part of each site investigation. The first step would be a scoping level/stage 1 screening. For example, the Scoping Level / Stage 1 Ecological Risk Screening for each site would answer the defined questions below:

- Are ecological receptors present at the release area or site?
- Does a complete exposure pathway exist between the release area and the ecological receptor?
- Is there evidence of adverse environmental impact from the release present in the ecological receptor (i.e., sheens on surface water, non-aqueous phase liquid (NAPL) on surface water or deposited in sediment, stressed or dead biota…etc.)?

If it can be documented that there are ecological receptors and complete exposure pathways based on the Stage I screening, ecological risk would proceed to the following stages, which would involve more comprehensive screening evaluations, ranging from collection of appropriate media and evaluation of compounds of potential ecological concern via a Screening Level Ecological Risk Assessment (SLERA) to performance of a Baseline Ecological Risk Assessment (BERA). Conversely, if there are no ecological receptors or completed exposure pathways at a release site, it can be concluded that environmental risk does not exist at the release site. (Evidence of adverse environmental impact would be indicative of the presence of unacceptable environmental risk requiring a remedy.)

The benefits of this staged and phased ecological risk assessment process include reducing the need to evaluate ecological risk further in developed areas/areas with small releases.

Other Considerations

Following the guidance similar to AULs in Massachusetts, below are ideas to simplify EURs and Verifications in Connecticut:

- The use of Best Management Practices for non-commercial gardening in a residential setting to minimize and control potential risk in lieu of an EUR;
- No EUR required if the concentrations of COCs at a site are consistent with Anthropogenic Background levels (but above RSRs);
- No EUR if the residual contamination is located within a public way or within a rail right-of-way;
- No EUR required (maybe just notice) if contamination located within a utility right-of-way.
- No EUR required if No Significant Risk can be demonstrated under an unrestricted exposure scenario (i.e.: residential).

To address issues currently considered as potentially hindering utilization of the EUR process provided below are some additional ideas:

- Waive subordination requirements from utilities.
- Waive subordination requirements from additional easements.
- Remove annual inspections, require inspections every five years and eliminate LEP Reporting every five years.
- Simplify Application process by reducing the Metes and Bounds of the property and not every subject area.
- Develop a Notice of Activity and Use Limitation (NAUL) "lite" that would simplify the application and potentially reduce provisions required.
- Tie in fees with EUR, Expedited Closure (same time frame). Waive EUR fees if EUR within one year of release discovery and remediation.
- Establish a framework and guidance where utilization of financial assurance can be accepted in lieu of an EUR to maintain applicable exposure scenario restrictions.
- Make financial assurance guidance more prescriptive (i.e.: excel spreadsheet examples).
- If State park – exempt from Financial Assurance, still need EUR, inspections. Ex. If there is another mechanism on the land records such as a land trust or use of the area as a park that equals maintenance of the exposure scenario.

- Need to develop additional standard EUR types to match the exposure scenarios evaluated within the Shortforms (i.e., beyond residential restriction).

The subcommittee recommends that the DEEP should consider a subcommittee specific to the EUR process.

Conclusions

The consensus of the Subcommittee is that the ability to evaluate potential risk to human health associated with release sites via the cumulative risk approach is a necessary tool for environmental professionals in Connecticut. The Subcommittee also agreed that some form of cumulative risk characterization should be a self-implementing option for LEPs to use on environmental release sites in Connecticut.

The following specific conclusions were made by the Subcommittee:

1. Subcommittee 9 was formed to determine which components of cumulative risk assessment can be implemented in Connecticut while maintaining an acceptable level human health risk at environmental release sites.
    a. The initial charge was limited to the evaluation to "sites that have been remediated" however the consensus of the Subcommittee is that cumulative risk assessment should also be available for use prior to remediation to determine sources of risk at a release and therefore drive future remediation. Cumulative risk assessment may also be used to determine that unacceptable risk is not present at a release site and therefore remediation is not required.

2. The consensus of the Subcommittee is that cumulative risk assessment is an important tool for evaluating potential risk to human health from environmental contamination and should be available to the regulated community and LEPs for use in Connecticut.
    a. The consensus of the Subcommittee is that the current LEP regulations are sufficient to allow LEPs to prepare cumulative risk assessments.
        i. LEPs may prepare and complete cumulative risk assessments in accordance with their experience and expertise but may need to reach out to other professionals when outside their experience or expertise.
        ii. It is incumbent upon the LEP to ensure that an individual or individuals utilized for risk assessment activities have the requisite qualifications and competency.

3. The general consensus of the Subcommittee is that certain types of cumulative risk assessments, such as Short Form calculators, should be able to be used as a self-implementing option under the future regulations.
    a. The Subcommittee recommends that either:
        i. Shortform calculators be developed for use in Connecticut; or
        ii. The use of the most current version of the Massachusetts Method 3 Shortforms be allowed as a LEP implementing option under the new regulations.

            1. If existing Method 3 Shortforms were used as frameworks they would need to be modified with equations and exposure parameters appropriate to those exposure scenarios.
    b. The use of either CT specific or Massachusetts Short Form Risk calculators would require the promulgation of cumulative risk limits in Connecticut.
        i. The Subcommittee recommends the establishment of a cumulative ELCR of 1 $x10^{-5}$ for exposure to multiple carcinogens, an ELCR of 1×10^{-6} for exposure to an individual carcinogen, and a cumulative HI of 1 (allowing for summation of non-cancer risk by target organ) within the future regulations to support a cumulative risk approach.

4. The consensus of the Subcommittee is that sites where cumulative risk assessment is employed should be subject to the same level of audit as sites where cumulative risk assessment has not been used.

5. The Subcommittee also recognized that cumulative risk assessments, either performed with a default short form, modified short form, or via a site-specific risk assessment will require more guidance for implementation.
    a. Types of guidance may include:
        i. Development of Exposure Point Concentrations, including evaluating soil exposure, calculating an appropriate dust inhalation concentration, and evaluating predicted indoor air concentrations from sub-slab soil gas concentrations via vapor intrusion. ii. Exposure assumptions for scenarios, including guidance on exposure equations, exposure parameters and how to evaluate sources of these values using a hierarchy process.
        ii. Toxicity data resources for compounds not included in the Short Forms
            1. CT values
            2. EPA values
            3. Hierarchy of sources beyond CT and EPA.

6. The focus of the Subcommittee was the use of cumulative risk assessments to determine human health risk. The Subcommittee recognizes that human health risk is not the only component of risk evaluations in Connecticut. Incorporation of the other components is necessary for a complete evaluation of risk posed by contamination at a release. The other items that should be incorporated include:
    a. Ecological risk considerations; and
    b. Maximum allowable contaminant levels (see charge for Subcommittee 7).

Appendix A

Subcommittee 9 Member List

Name	Company	Representing
Eric Boswell	Avangrid	Any other interested member of the public
George Gurney	Weston Solutions	Licensed Environmental Professionals
Marilee Gonzalez	Fuss & O'Neill, Inc	Licensed Environmental Professionals
W. Scott Burrus	Sovereign Consulting Inc.	Licensed Environmental Professionals
Philip Warner	Verdantas	Licensed Environmental Professionals
Gary Iadarola	Eversource Energy	Licensed Environmental Professionals
Malcolm Beeler	Weston & Sampson	Licensed Environmental Professionals
Kevin King	SLR Consulting	Licensed Environmental Professionals
Kate Engler*, PhD, LEP, DABT	Loureiro Engineering Associates, Inc.	Licensed Environmental Professionals
David Melycher*	EKI Environment & Water, Inc.	Licensed Environmental Professionals
Nelson Walter*	WSP	Licensed Environmental Professionals
Amber Trahan	DEEP	Agency Resource
Alessandra Alling	DEEP	Agency Resource
Peter Zaidel	DEEP	Agency Resource
Carl Gruszczak	DEEP	Agency Resource
Meg Harvey	DPH	Agency Resource
* = Subcommittee Co-Chair		

Appendix B

Mass Method 3 Shortform Guidance

MassDEP Shortforms for
Human Health Risk Assessment under the MCP

USER'S GUIDE

<u>In this User's Guide</u>

Shortform Applicability

The Shortforms are designed to streamline the Method 3 risk assessment and review process. While Method 3 risk assessments are site-specific, some exposure scenarios are sufficiently standardized for a template approach. MassDEP has assembled recommended exposure assumptions and toxicity information into the Shortform spreadsheets to calculate risk for each of these standard scenarios.

The Shortforms have important limitations. These include, but are not limited to:

1. <u>Exposure Assumptions</u> - It is the risk assessor's responsibility to verify that the exposure assumptions in each Shortform are appropriate for use at their site.
2. <u>Exposure Pathways</u> - The Shortforms may not cover all exposure pathways present at a site. For example, the Park Visitor Shortform for contaminated soil does not assess risks associated with inhalation of volatile compounds. At sites where this pathway might be of concern (e.g., athletic fields or parks established over former landfills), additional assessment would be needed.
3. <u>EPC Development</u> - Development of appropriate Exposure Point Concentrations (EPCs) for each exposure pathway is vital to ensuring that the results of the Method 3 Risk Assessment are valid. Regulations and guidance describing the development of EPCs can be found in 310 CMR 40.0900 and MassDEP's 1995 *Guidance for Disposal Site Risk Characterization*. If these requirements are not met, results from the Shortform are invalid.
4. <u>Generic IH Calculations</u> - The Shortforms use a generic approach to evaluating imminent hazards (IH). However, MassDEP's regulations at 310 CMR 40.0955(2)(c) call for chemical-specific approaches for certain hazardous materials. While some chemicals have reminders that pop up about a chemical-specific IH hazard quotient, it is the Shortform user's responsibility to identify contaminants that require a chemical-specific approach and evaluate them accordingly.
5. <u>Non-Calculated Risks</u> - Some risks are not included in the Shortforms. For instance, chromium(VI) in soils poses an imminent hazard due to contact dermatitis at a level of 200 mg/kg (rounded from 170 mg/kg), though the residential Shortform yields a hazard quotient of less than one for that concentration. All calculations should be reviewed to ensure that they comply with the MCP.

Shortform Set-Up

The Shortforms are comprised of Excel workbooks, each of which addresses a specific receptor (e.g., resident, trespasser, construction worker, etc.) exposed to oil or hazardous materials (OHM) in soil, indoor air, drinking water, or surface water. Each Shortform workbook contains several worksheets, the first of which is an index with a short description of each of the subsequent worksheets. The following worksheets provide information on Exposure Point Concentration (EPCs), equations to calculate cancer and noncancer risk ("C Eq" and "N Eq"), exposure assumptions ("Exp"), and chemical-specific information ("Chem") drawn from the Vlookup workbook. Tables in the worksheets are designed to be self-explanatory and compliment a written risk assessment report.

All Shortforms are linked to the same Vlookup workbook that contains chemical-specific information such as dose-response values and physical constants. The Shortforms and the Vlookup file are intimately linked. To keep this relationship intact and the Shortforms functional, anytime a new file is available, it's best to download all of the files again.

Using the Shortforms

The Shortforms and Vlookup files should be extracted to the same folder before being opened. In order to ensure that the workbooks link correctly, the Vlookup file should be opened first. Shortforms can then be opened subsequently.

Using each Shortform is a simple two-step process:

1. Select Contaminants of Concern (COCs) in the first column of the EPCs worksheet. COCs can be added using a drop-down menu that appears when a cell in that first column is selected.
2. Enter site-specific EPCs in the cell immediately to the right of each COC. Check to be sure the units of your data match those in the Shortform. Risks associated with each COC/EPC combination are calculated automatically and displayed in the cells to the right of the EPC. Risks are only displayed for pathways that might contribute significantly to overall risk.

The total site cancer (Excess Lifetime Cancer Risk, ELCR) and noncancer (Hazard Index, HI) risks for all of the COCs are summed at the top right of the EPC spreadsheet. If there is exposure to more than one medium (soil and groundwater, for example), the total risk must be calculated by adding the HIs and ELCRs from all of the applicable Shortform files.

Notes of caution: **Under no circumstances should columns or rows be deleted or inserted between existing ones in the Shortforms.** Doing so could disrupt the intra- and inter-worksheet links, thus compromising the validity of the risk calculations. Similarly, do not change the name of the Vlookup. The risk assessor is responsible for ensuring that the most recent versions of the Shortform and Vlookup files are downloaded from the MassDEP website when used to support a risk characterization report.

If the Shortform is submitted to fulfill a Method 3 Risk Assessment requirement, it must be submitted as a component of a report that includes a comprehensive site description, hazard identification, description of site activities and uses, identification of receptors and exposure points, discussion of the applicability of any Activity and Use Limitations (AULs), EPC estimation, risk characterization summary, and an uncertainty section. The Shortform is a risk calculation tool, intended for use by risk assessors in the context of a complete risk assessment.

Adding Non-listed Chemicals to the Shortforms

Risk assessors comfortable with Excel can use the Shortforms to include additional chemicals of concern. Other than adding COCs and their respective properties and EPCs, the spreadsheets must not be modified in any way if they are to be submitted as Shortforms. If toxicity values or exposures factors for listed chemicals are altered, any **modifications should be highlighted** through the use of bold text, changed titles, and text description that clarifies that the workbooks are no longer the standard MassDEP Shortforms. The risk assessor should also describe and provide technical justification for the changes in the accompanying text.

Risk assessors may add chemicals to the COC list, provided they have the required physical and toxicological information for that chemical. The instructions below are for use with MS Excel version 2007.

1. Open the applicable Shortform and the VlookUp file.

2. Add the chemical to the COC dropdown in the Shortform:
    a. Unhide Column A by dragging the column marker left of Column B to the right until chemical names show.

b. Add the chemical to the *bottom* of the dropdown list, adding “zz” before the name to protect the VlookUp alphabetizing, eg “zzEthylMethylTop”.
c. Click in column B under Oil or Hazardous Material to select the dropdown.
d. Go to the Data tab, choose Data Validation
e. Under Settings, change Source to include the new row, ie $A$126 instead of $A$125. Add more if adding more chemical rows, ending with $A$127 or $A$128 as applicable.
f. Check the box “Apply these changes to all other cells with the same settings”

3. Add the zz chemical to the Vlookup: in the last row of column A in tabs v1, v2, v3, and v4.

4. Add the necessary data for each tab. Only chemical data that is required for the media and exposures used in the Shortform that is being modified must be added.

5. Change the Vlookup named ranges used in the equations to include the new chemical info:
   a. In the Vlookup, select the Formulas Tab -> Name Manager.
   b. Select named range “physical_prop” -> edit.
   c. Change the “refers to” box from “='V4'!$A$2:$F$118” to “='V4'!$A$2:$F$119”
      - This includes the new row. Add more if adding more chemical rows, ending with $F$120 or $F$121 as applicable.
   d. Click “ok”
   e. Repeat steps b. through d. to expand the “refers to” for these other named ranges:
      - RAFs
      - toxicity
      - V4Constants
      - WaterPUF

6. Hide column A in the Shortform again. Select column A, right click, and select Hide.

7. Add COCs and EPCs as usual.

Contact Information

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Appendix C

Example Alternative Exposure Scenario Equations

C-1 Residential – Passive
Source: MassDEP Method 3 Shortforms sf12rs and sf12ra

Note: The existing MassDEP Method 3 Shortforms for Residential Soil and Residential Air could be used to evaluate risk under this modified exposure scenario. The recommendation for using these Shortforms under a Residential – Passive exposure scenario would be to adjust the depth of soil to which these equations are applicable (i.e. 0-4' vs. 0-15') and/or exempt the use of these equations if an Engineered Control preventing direct contact is in place, rather than adjustments to the equations or exposure factors. This practice would be in line with guidance of Massachusetts and California. Note: Table RS-7 "Homegrown Produce Ingestion Rate" in Shortform sf12rs would not be applicable for this exposure scenario and would be eliminated in the characterization of risk.

Method 3 Risk Assessment for Resident Exposed to Chemicals in Soil - Shortform 2012 (sf12rs)

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Resident - Soil: Table RS-1
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

ELCR (all chemicals) =
Chronic HI (all chemicals) =
Subchronic HI (all chemicals) =

Do not insert or delete any rows

Click on empty cell below and select OHM using arrow.

Oil or	EPC			Derm & Ing	Chronic		Derm & Ing	Subchronic		Derm & Ing
Hazardous Material	(mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	$ELCR_{total}$	HQ_{ing}	HQ_{derm}	HQ_{total}	HQ_{ing}	HQ_{derm}	HQ_{total}

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Resident - Soil: Table RS-2
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

*Vegetable uptake is informational only and NOT included in totals on EPC tab.

Do not insert or delete any rows

Click on empty cell below and select OHM using arrow.

ELCR (all chemicals) =
Chronic HI (all chemicals) =
Subchronic HI (all chemicals) =

Oil or Hazardous Material	EPC (mg/kg)	Chronic		Subchronic
		$ELCR_{vegetable*}$	$HQ_{vegetable*}$	$HQ_{vegetable*}$

Resident - Soil: Table RS-3
Equations to Calculate Cancer Risk for Resident (Age 1-31 years)

Vlookup Versionv0315

Cancer Risk from Ingestion

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

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

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

Cancer Risk from Dermal Absorption

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

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

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

Cancer Risk from Homegrown Produce

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

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

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

Parameter	Value	Units
CSF	OHM specific	$(mg/kg\text{-}day)^{-1}$
LADD	age/OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
$IR_{(1\text{-}8)}$	100	mg/day
$IR_{(8\text{-}15)}$	50	mg/day
$IR_{(15\text{-}31)}$	50	mg/day
$PIR_{(1\text{-}8)}$	12,099	mg/day
$PIR_{(8\text{-}15)}$	17,809	mg/day
$PIR_{(15\text{-}31)}$	24,420	mg/day
$RAF_{c\text{-}ing}$	OHM specific	dimensionless
$RAF_{c\text{-}derm}$	OHM specific	dimensionless
$RAF_{c\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.412	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
$EP_{(1\text{-}8)}$	7	years
$EP_{(8\text{-}15)}$	7	years
$EP_{(15\text{-}31)}$	16	years
C	0.000001	kg/mg
$BW_{(1\text{-}8)}$	17.0	kg
$BW_{(8\text{-}15)}$	39.9	kg
$BW_{(15\text{-}31)}$	58.7	kg
$AP_{(lifetime)}$	70	years
$SA_{(1\text{-}8)}$	2431	cm^2 / day
$SA_{(8\text{-}15)}$	4427	cm^2 / day
$SA_{(15\text{-}31)}$	5653	cm^2 / day
$SAF_{(1\text{-}8)}$	0.35	mg/cm^2
$SAF_{(8\text{-}15)}$	0.14	mg/cm^2
$SAF_{(15\text{-}31)}$	0.13	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

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Resident - Soil: Table RS-4
Equations to Calculate Chronic Noncancer Risk for Resident Child (Age 1-8 years)

Vlookup Versionv0315

Chronic Noncancer Risk from Ingestion

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

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

Chronic Noncancer Risk from Dermal Absorption

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

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

Chronic Noncancer Risk from Homegrown Produce

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

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

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
PIR	12,099	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$RAF_{nc\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.412	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
EP	7	years
C	0.000001	kg/mg
BW	17.0	kg
AP	7	year
SA	2431	cm^2 / day
SAF	0.35	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

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Resident - Soil: Table RS-5
Equations to Calculate Subchronic Noncancer Risk for Resident Child (Age 1-2 years)

Vlookup Versionv0315

Subchronic Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD_{subchronic}}$$

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

Subchronic Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{derm}}{RfD_{subchronic}}$$

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

Subchronic Noncancer Risk from Homegrown Produce

$$HQ_{produce} = \frac{ADD_{produce}}{RfD_{subchronic}}$$

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

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
PIR	10,900	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$RAF_{nc\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.714	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
EP	0.577	years
C	0.000001	kg/mg
BW	10.7	kg
AP	0.577	year
SA	1670	cm^2 / day
SAF	0.35	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

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Resident - Soil: Table RS-6
Definitions and Exposure Factors

Vlookup Versionv0315

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table RS-7
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	
HQ - Hazard Quotient	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
RfD - Reference Dose	chemical specific	mg/kg-day	see Table RS-7
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
ADE - Average Daily Exposure	chemical specific	mg/m^3	
EPC - Exposure Point Concentration	chemical specific	mg/kg	
PUF - Plant Uptake Factor	chemical specific	$(mg/mg)(mg/mg)^{-1}$	See Table RS-7; $(mg_{OHM}/mg_{plant})/(mg_{OHM}/mg_{soil})^{-1}$
$IR_{(1-2)}$ - Soil Ingestion Rate for age group 1-2	100	mg/day	MADEP. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate. (http://www.mass.gov/dep/ors/orspubs.htm)
$IR_{(1-8)}$ - Soil Ingestion Rate for age group 1-8	100	mg/day	Ibid
$IR_{(8-15)}$ - Soil Ingestion Rate for age group 8-15	50	mg/day	Ibid
$IR_{(15-31)}$ - Soil Ingestion Rate for age group 15-31	50	mg/day	Ibid
$PIR_{(1-2)}$ = Produce Ingestion Rate for age group 1-2	10,900	mg/day	see Table RS-6
$PIR_{(1-8)}$ = Produce Ingestion Rate for age group 1-8	12,099	mg/day	see Table RS-6
$PIR_{(8-15)}$ = Produce Ingestion Rate for age group 8-15	17,809	mg/day	Ibid
$PIR_{(15-31)}$ = Produce Ingestion Rate for age group 15-31	24,420	mg/day	Ibid
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	
$EF_{subchronic}$ - Exposure Frequency for subchronic ingestion or dermal exposure	0.714	event/day	5 days/week
$EF_{chronic}$ - Exposure Frequency for chronic ingestion or dermal exposure	0.412	event/day	5 days/week, 30 weeks/year
EF_{cancer} - Exposure Frequency for cancer, ingestion or dermal exposure	0.412	event/day	5 days/week, 30 weeks/year
$EF_{produce}$ - Exposure Frequency for produce ingestion, cancer and noncancer	1.00	event/day	
ED - Exposure Duration	1	day/event	
$EP_{(1-2)}$ - Exposure Period for age group 1-2	0.577	years	30 weeks
$EP_{(1-8)}$ - Exposure Period for age group 1-8	7	years	
$EP_{(8-15)}$ - Exposure Period for age group 8-15	7	years	
$EP_{(15-31)}$ - Exposure Period for age group 15-31	16	years	
$BW_{(1-2)}$ - Body Weight for age group 1-2	10.7	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(1-8)}$ - Body Weight for age group 1-8	17.0	kg	Ibid
$BW_{(8-15)}$ - Body Weight for age group 8-15	39.9	kg	Ibid
$BW_{(15-31)}$ - Body Weight for age group 15-31	58.7	kg	Ibid
$AP_{subchronic}$ - Averaging Period for subchronic noncancer	0.577	years	30 weeks
$AP_{chronic}$ - Averaging Period for chronic noncancer	7	years	
AP_{cancer} - Averaging Period for lifetime	70	years	
$SA_{(1-2)}$ - Surface Area for age group 1-2	1670	cm^2 / day	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-2.
$SA_{(1-8)}$ - Surface Area for age group 1-8	2431	cm^2 / day	Ibid
$SA_{(8-15)}$ - Surface Area for age group 8-15	4427	cm^2 / day	Ibid
$SA_{(15-31)}$ - Surface Area for age group 15-31	5653	cm^2 / day	Ibid
$SAF_{(1-2)}$ - Surface Adherence Factor for age group 1-2	0.35	mg/cm^2	All SAFs developed for ShortForm according to procedure outlined in MA DEP Technical
$SAF_{(1-8)}$ - Surface Adherence Factor for age group 1-8	0.35	mg/cm^2	Update:Weighted Skin-Soil Adherence Factors, April 2002
$SAF_{(8-15)}$ - Surface Adherence Factor for age group 8-15	0.14	mg/cm^2	
$SAF_{(15-31)}$ - Surface Adherence Factor for age group 15-31	0.13	mg/cm^2	

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Resident - Soil: Table RS-7
Homegrown Produce Ingestion Rate

Data on mean produce ingestion rates (wet weight, ww) in the Northeast was obtained from the 1994-1996 Continuing Survey of Food Intakes by Individuals (USDA). Data for both genders were used for children under 6, while data for males was used for individuals 6 and older. The mean ingestion rates presented in the survey represent the arithmetic average of all individuals surveyed, regardless of whether or not they had consumed the produce item (e.g., an individual that did not consume the produce item was assigned a rate of 0 g/day). To determine the mean ingestion rate for individuals who ate each produce item, the ingestion rate for all individuals (consumers and nonconsumers) was divided by the percentage of individuals who ate the item (Table RS-7A). These mean ingestion rates for the produce consumers were summed to determine the total produce ingestion rate for each age-group and converted to dry weight assuming the produce items were all 90% water.

To convert mean ingestion rates for the age-groups studied in the survey to age-groups used in risk calculations, each age-group ingestion rate from the survey (i.e., 1 - 2 year olds, 3 - 5 year olds, 6 - 11 year olds, 12 - 19 year olds, and 20 - 39 year olds) was weighted according to the number of years spent in the risk calculation age group (i.e., 1 - 8 year olds, 8 - 15 year olds, and 15 - 31 year olds) (Table RS-7B). It was assumed that 25% of produce ingested was home-grown (Table RS-7C).

Table RS-7

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

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

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Table RS-7a (continued)

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

Table RS-7B

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

Table RS-7C

Produce Intake, dry weight	Child 1-2 years g/day	Child 1-8 years g/day	Child 8-15 years g/day	Adult 15-31 g/day
All Produce:	43.6	48.4	71.2	97.7
Homegrown:	10.9	12.1	17.8	24.4

Resident - Soil: Table RS-8
Chemical-Specific Data

Oil or Hazardous Material	CSF (mg/kg-day)$^{-1}$	RAF_{c-ing}	RAF_{c-derm}	RAF_{c-prod}	Chronic RfD mg/kg-day	Subchronic RfD mg/kg-day	Chronic RAF_{nc-ing}	Chronic $RAF_{nc-derm}$	Subchronic RAF_{nc-ing}	Subchronic $RAF_{nc-derm}$	$RAF_{nc-prod}$	PUF

Resident - Soil: Table RS-9
Cyanide Calculations

The soil cyanide concentration limit set to protect a child resident against an acute, potentially lethal one-time dose of cyanide from incidental ingestion of contaminated soil is 100 mg/kg soil. This is the concentration of available cyanide in soil below which acute human health effects would not be expected following a one-time exposure. This soil concentration is calculated using the equation below with a pica-type soil ingestion of 1000 mg_{soil} and an available cyanide dose limit of 0.01 $mg/kg_{body\ weight}$.

MassDEP's guidance on evaluating the risk from a one-time cyanide dose considers cyanide's potentially lethal effects as well as information on cyanide metabolism:

> Cyanides are detoxified rapidly by the body, and a large acute dose which overwhelms the detoxification mechanism is potentially more toxic than the same dose distributed over a period of hours. (MassDEP *Background Documentation for the Development of an Available Cyanide Benchmark Concentration* , originally dated October 1992, Modified August 1998)

Assessment of a potential one-time dose requires an estimate of the maximum soil concentration the receptor could contact at any one time. The average soil concentration within a typical exposure area will underestimate the potential one-time dose. Therefore, to assess the acute risk of a one-time potentially lethal dose, the EPC for cyanide should be a conservative estimate of the maximum soil concentration.

The residential soil concentration limit to protect against adverse effects from an acute (one-time) exposure to cyanide is 100 mg/kg.

Concentration Calculation for Cyanide

$$\text{Concentration} = \frac{\text{HQ} \times \text{Acute Dose Limit} \times \text{BW}}{\text{IR} \times \text{RAF} \times \text{Conversion Factor}}$$

Parameter	Value	Units
HQ (Hazard Quotient)	1	(unitless)
Acute Dose Limit	0.01	mg avail. CN/ kg BW
BW (Body Weight) $_{1\text{-}2}$	10.7	kg
IR (1-time reasonable max)	1000	mg
Conversion Factor	1.0E-06	kg soil / mg soil
RAF	1	(unitless)

The toxicological basis for estimating an allowable one-time dose is documented in MassDEP's 1992 *Background Documentation for the Development of an "Available Cyanide" Benchmark Concentration,* which is published at:
http://www.mass.gov/eea/docs/dep/toxics/stypes/dscyanide.pdf

Method 3 Risk Assessment for Resident Exposed to Chemicals in Indoor Air - Shortform 2012 (sf12ra)

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NC Eq	Table RA-3: Equations to calculate noncancer risks.
Exp	Table RA-4: Definitions and exposure factors.
Chem	Table RA-5: Chemical-specific data.

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Resident - Indoor Air: Table RA-1
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer) and 1-8 (Noncancer)

ShortForm Version 10-12

Vlookup Versionv0315

ELCR (all chemicals) =
HI (all chemicals) =

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

Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC ($\mu g/m^3$)	$ELCR_{air}$	HQ_{air}

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Resident - Indoor Air: Table RA-2

Equations to Calculate Cancer Risk for Resident (Age 1-31 years)

Cancer Risk from Inhalation

$$ELCR_{air} = LADE_{(1-31)} * URF$$

$$LADE = \frac{[OHM]_{air} * EF * ED * EP}{AP_{lifetime}}$$

Vlookup Versionv0315

Parameter	Value	Units
URF	OHM specific	$(\mu g/m^3)^{-1}$
LADE	age/OHM specific	$\mu g/m^3$
$[OHM]_{air}$	OHM specific	$\mu g/m^3$
EF	1.00	event/day
ED	1	day/event
EP	30	years
$AP_{lifetime}$	70	years

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Resident - Indoor Air: Table RA-3
Equations to Calculate Noncancer Risk for Resident Child (Age 1-8 years)

Vlookup Versionv0315

Noncancer Risk from Inhalation

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

$$ADE = \frac{[OHM]_{air} * EF * ED * EP * C}{AP}$$

Parameter	Value	Units
RfC	OHM specific	mg/m^3
ADE	OHM specific	mg/m^3
$[OHM]_{soil}$	OHM specific	$\mu g/m^3$
EF	1.00	event/day
ED	1	day/event
EP	7	years
C	0.001	mg/ug
AP	7	year

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Resident - Indoor Air: Table RA-4
Definitions and Exposure Factors

Vlookup Versionv0315

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	
URF - Unit Risk Factor	chemical specific	$(\mu g/m^3)^{-1}$	see Table RA-5
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	see Table RA-2
HQ - Hazard Quotient	chemical specific	dimensionless	
RfC - Reference Concentration	chemical specific	mg/m^3	see Table RA-5
ADE - Average Daily Exposure	chemical specific	mg/m^3	see Table RA-3
EPC - Exposure Point Concentration	chemical specific	$\mu g/m^3$	see Table RA-1
EF - Exposure Frequency	1.00	event/day	
ED - Exposure Duration	1	day/event	
$EP_{(1-8)}$ - Exposure Period age group 1-8 (noncancer)	7	years	
$EP_{(1-31)}$ - Exposure Period for age group 1-31 (cancer)	30	years	
$AP_{(noncancer)}$ - Averaging Period for noncancer	7	years	
$AP_{(lifetime)}$ - Averaging Period for lifetime	70	years	

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Resident - Indoor Air: Table RA-5
Chemical-Specific Data

Vlookup Versionv0315

Oil or Hazardous Material	URF $(ug/m^3)^{-1}$	RfC mg/m^3

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C-2 Park Visitor – Passive
Source: MassDEP Shortform sf12ps.xls

Method 3 Risk Assessment for Park Visitor Exposed to Chemicals in Soil - Shortform 2012 (sf12ps)

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Park Visitor - Soil: Table PS-1
Exposure Point Concentration (EPC)
Based on Visitor Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

ShortForm Version 10-12

Vlookup Version v0315

ELCR (all chemicals) =

Chronic HI (all chemicals) =

Subchronic HI (all chemicals) =

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

Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	$ELCR_{total}$	Chronic			Subchronic		
					HQ_{ing}	HQ_{derm}	HQ_{total}	HQ_{ing}	HQ_{derm}	HQ_{total}

Park Visitor - Soil: Table PS-2

Equations to Calculate Cancer Risk for Visitor (Age 1-31 years)

Cancer Risk from Ingestion

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

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

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

Cancer Risk from Dermal Absorption

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

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

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

Vlookup Version v0315

Parameter	Value	Units
CSF	OHM specific	$(mg/kg\text{-}day)^{-1}$
LADD	age/OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
$IR_{(1\text{-}8)}$	100	mg/day
$IR_{(8\text{-}15)}$	50	mg/day
$IR_{(15\text{-}31)}$	50	mg/day
$RAF_{c\text{-}ing}$	OHM specific	dimensionless
$RAF_{c\text{-}derm}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.247	event/day
ED	1	day/event
$EP_{(1\text{-}8)}$	7	years
$EP_{(8\text{-}15)}$	7	years
$EP_{(15\text{-}31)}$	16	years
C	0.000001	kg/mg
$BW_{(1\text{-}8)}$	17.0	kg
$BW_{(8\text{-}15)}$	39.9	kg
$BW_{(15\text{-}31)}$	58.7	kg
$AP_{(lifetime)}$	70	years
$SA_{(1\text{-}8)}$	2431	cm^2/day
$SA_{(8\text{-}15)}$	4427	cm^2/day
$SA_{(15\text{-}31)}$	5653	cm^2/day
$SAF_{(1\text{-}8)}$	0.35	mg/cm^2
$SAF_{(8\text{-}15)}$	0.14	mg/cm^2
$SAF_{(15\text{-}31)}$	0.13	mg/cm^2

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Park Visitor - Soil: Table PS-3
Equations to Calculate Chronic Noncancer Risk for Visitor (Age 1-8 years)

Vlookup Version v0315

Chronic Noncancer Risk from Ingestion

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

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

Chronic Noncancer Risk from Dermal Absorption

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

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

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.247	event/day
ED	1	day/event
EP	7	years
C	0.000001	kg/mg
BW	17.0	kg
AP	7	year
SA	2431	cm^2/day
SAF	0.35	mg/cm^2

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Park Visitor - Soil: Table PS-4
Equations to Calculate Subchronic Noncancer Risk for Visitor (Age 1-2 years)

Vlookup Version v0315

Subchronic Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD_{subchronic}}$$

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

Subchronic Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{derm}}{RfD_{subchronic}}$$

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

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
RAF_{nc-ing}	OHM specific	dimensionless
$RAF_{nc-derm}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.428	event/day
ED	1	day/event
EP	0.577	years
C	0.000001	kg/mg
BW	10.7	kg
AP	0.577	year
SA	1670	cm^2/day
SAF	0.35	mg/cm^2

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Park Visitor - Soil: Table PS-5
Definitions and Exposure Factors

Vlookup Version v0315

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table PS-6
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
HQ - Hazard Quotient	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal)
RfD - Reference Dose	chemical specific	mg/kg-day	see Table PS-6
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
EPC - Exposure Point Concentration	chemical specific	mg/kg	
$IR_{(1-2)}$ - Soil Ingestion Rate for age group 1-2	100	mg/day	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-3.
$IR_{(1-8)}$ - Soil Ingestion Rate for age group 1-8	100	mg/day	Ibid
$IR_{(8-15)}$ - Soil Ingestion Rate for age group 8-15	50	mg/day	Ibid
$IR_{(15-31)}$ - Soil Ingestion Rate for age group 15-31	50	mg/day	Ibid
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	Adjusts estimated dose to conform to the revelant CSF. See Table PS-6
RAF_{NC} - Relative Absorption Factor for non-Cancer Effects	chemical specific	dimensionless	Adjusts estimated dose to conform to the revelant RfD. See Table PS-6
$EF_{subchronic}$ - Exposure Frequency for subchronic exposure	0.428	event/day	3 events/week
$EF_{chronic,lifetime}$ - Exposure Frequency for chronic or lifetime exposure	0.247	event/day	3 events/week, 30 weeks/year
ED - Exposure Duration	1	day/event	
$EP_{(1-2)}$ - Exposure Period for age group 1-2	0.577	years	30 weeks
$EP_{(1-8)}$ - Exposure Period for age group 1-8	7	years	
$EP_{(8-15)}$ - Exposure Period for age group 8-15	7	years	
$EP_{(15-31)}$ - Exposure Period for age group 15-31	16	years	
$BW_{(1-2)}$ - Body Weight for age group 1-2, subchronic	10.7	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(1-8)}$ - Body Weight for age group 1-8	17.0	kg	Ibid
$BW_{(8-15)}$ - Body Weight for age group 8-15	39.9	kg	Ibid
$BW_{(15-31)}$ - Body Weight for age group 15-31	58.7	kg	Ibid
$AP_{subchronic}$ - Averaging Period for subchronic noncancer	0.577	years	30 weeks
$AP_{chronic}$ - Averaging Period for chronic noncancer	7	years	
$AP_{lifetime}$ - Averaging Period for cancer/lifetime	70	years	
$SA_{(1-2)}$ - Surface Area for age group 1-2	1670	cm^2/day	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females. MADEP 1995 Guidance for Disposal Site Risk Characterization, Appendix Table B-2.
$SA_{(1-8)}$ - Surface Area for age group 1-8	2431	cm^2 / day	Ibid
$SA_{(8-15)}$ - Surface Area for age group 8-15	4427	cm^2 / day	Ibid
$SA_{(15-31)}$ - Surface Area for age group 15-31	5653	cm^2 / day	Ibid
$SAF_{(1-2)}$ - Surface Adherence Factor for age group 1-2	0.35	mg_{soil} / cm^2	All SAFs developed for ShortForm according to procedure outlined in MADEP Technical
$SAF_{(1-8)}$ - Surface Adherence Factor for age group 1-8	0.35	mg_{soil} / cm^2	Update: Weighted Skin-Soil Adherence Factors, April 2002
$SAF_{(8-15)}$ - Surface Adherence Factor for age group 8-15	0.14	mg_{soil} / cm^2	
$SAF_{(15-31)}$ - Surface Adherence Factor for age group 15-31	0.13	mg_{soil} / cm^2	

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Park Visitor - Soil: Table PS-6 Chemical-Specific Data

Vlookup Version v0315

Oil or Hazardous Material	CSF (mg/kg-day)$^{-1}$	$RAF_{c\text{-}ing}$	$RAF_{c\text{-}derm}$	Chronic RfD mg/kg-day	Subchronic RfD mg/kg-day	Chronic $RAF_{nc\text{-}ing}$	Chronic $RAF_{nc\text{-}derm}$	Subchronic $RAF_{nc\text{-}ing}$	Subchronic $RAF_{nc\text{-}derm}$

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Park Visitor - Soil: Table PS-7
Cyanide Calculations

The soil cyanide concentration limit set to protect a child park visitor against an acute, potentially lethal one-time dose of cyanide from incidental ingestion of contaminated soil is 100 mg/kg_{soil}. This is the concentration of available cyanide in soil below which acute human health effects would not be expected following a one-time exposure. This soil concentration is calculated using the equation below with a pica-type soil ingestion of 1000 mg_{soil} and an available cyanide dose limit of 0.01 $mg/kg_{body\ weight}$.

MassDEP's guidance on evaluating the risk from a one-time cyanide dose considers cyanide's potentially lethal effects as well as information on cyanide metabolism:

> Cyanides are detoxified rapidly by the body, and a large acute dose which overwhelms the detoxification mechanism is potentially more toxic than the same dose distributed over a period of hours. (MassDEP *Background Documentation for the Development of an Available Cyanide Benchmark Concentration* , originally dated October 1992, Modified August 1998)

Assessment of a potential one-time dose requires an estimate of the maximum soil concentration the receptor could contact at any one time. The average soil concentration within a typical exposure area will underestimate the potential one-time dose. Therefore, to assess the acute risk of a one-time potentially lethal dose, the EPC for cyanide should be a conservative estimate of the maximum soil concentration.

The soil concentration limit to protect park visitors against adverse effects from an acute (one-time) exposure to cyanide is 100 mg/kg.

Concentration Calculation for Cyanide

$$\text{Concentration} = \frac{\text{HQ x Acute Dose Limit x BW}}{\text{IR x RAF x Conversion Factor}}$$

Parameter	Value	Units
HQ (Hazard Quotient)	1	(unitless)
Acute Dose Limit	0.01	mg avail. CN/ kg BW
BW (Body Weight) 1-2	10.7	kg
IR (1-time reasonable max)	1000	mg
Conversion Factor	1.0E-06	kg soil / mg soil
RAF	1	(unitless)

The toxicological basis for estimating an allowable one-time dose is documented in MassDEP's 1992 *Background Documentation for the Development of an "Available Cyanide" Benchmark Concentration,* which is published at:
http://www.mass.gov/eea/docs/dep/toxics/stypes/dscyanide.pdf

C-3 Industrial Commercial Facility Worker
Source: US EPA RSL Equations (2022)

Soil Exposure

Noncarcinogenic

Ingestion

$$SL_{ind-sol-ingn}\left(\frac{mg}{kg}\right)=\frac{THQ\times AT_{ind-a}\left(\frac{365\ days}{yr}\times ED_{ind}(25\ yr)\right)\times BW_{ind}(80\ kg)}{\left(\frac{RBA}{RfD_o\left(\frac{mg}{kg-day}\right)}\right)\times\left(\frac{10^{-6}\ kg}{mg}\right)\times EF_{ind}\left(\frac{250\ days}{yr}\right)\times ED_{ind}(25\ yr)\times IRS_{ind}\left(\frac{50\ mg}{day}\right)}$$

Inhalation

$$SL_{ind-sol-inhn}\left(\frac{mg}{kg}\right)=\frac{THQ\times AT_{ind-a}\left(\frac{365\ days}{yr}\times ED_{ind}(25\ yr)\right)}{\left(\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\right)\times EF_{ind}\left(\frac{250\ days}{yr}\right)\times ED_{ind}(25\ yr)\times ET_{ind}\left(\frac{8\ hrs}{day}\right)\times\left(\frac{1\ day}{24\ hrs}\right)\times\left(\frac{1}{VF_{ulim}\left(\frac{m^3}{kg}\right)}+\frac{1}{PEF\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{ind-sol-totn}\left(\frac{mg}{kg}\right)=\frac{1}{\frac{1}{PRG_{ind-sol-ingn}}+\frac{1}{PRG_{ind-sol-inhn}}}$$

Carcinogenic

Ingestion

$$SL_{ind\text{-}sol\text{-}ingc}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{ind}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right) \times BW_{ind}\,(80\ kg)}{CSF_{o}\left(\frac{mg}{kg-day}\right)^{-1} \times \left(\frac{10^{-6}\ kg}{mg}\right) \times RBA \times EF_{ind}\left(\frac{250\ days}{yr}\right) \times ED_{ind}\,(25\ yr) \times IRS_{ind}\left(\frac{50\ mg}{day}\right)}$$

Inhalation

$$SL_{ind\text{-}sol\text{-}inhc}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{ind}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{ind}\left(\frac{250\ days}{yr}\right) \times ED_{ind}\,(25\ yr) \times ET_{ind}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times \left(\frac{1}{VF_{ulim}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{ind\text{-}sol\text{-}totc}\left(\frac{mg}{kg}\right) = \frac{1}{\frac{1}{PRG_{ind\text{-}sol\text{-}ingc}} + \frac{1}{PRG_{ind\text{-}sol\text{-}inhc}}}$$

<u>**Indoor Air Inhalation Exposure**</u>

Noncarcinogenic

The air land use equation, presented here, contains the following exposure routes:

Inhalation

$$SL_{ind-air-inhn}\left(\frac{\mu g}{m^3}\right) = \frac{THQ \times AT_{ind-a}\left(\frac{365\ days}{yr} \times ED_{ind}(25\ yr)\right)}{\left(\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\right) \times \left(\frac{mg}{1000\ \mu g}\right) \times EF_{ind}\left(\frac{250\ days}{yr}\right) \times ED_{ind}(25\ yr) \times ET_{ind}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right)}$$

Carcinogenic

The air land use equation, presented here, contains the following exposure routes:

Inhalation

$$SL_{ind-air-inhc}\left(\frac{\mu g}{m^3}\right) = \frac{TR \times AT_{ind}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times EF_{ind}\left(\frac{250\ days}{yr}\right) \times ED_{ind}(25\ yr) \times ET_{ind}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right)}$$

C-4 Construction Worker
Source: USEPA RSL Equations (2022)

Note: The exposure equations below assume active and intensive construction activities. According to the USEPA, "This is a short-term receptor exposed during the work day working around heavy vehicles suspending dust in the air. The activities for this receptor (e.g., dozing, grading, tilling, dumping, and excavating) typically involve on-site exposure to surface soils." The exposure length evaluated in this scenario is 1 year (50 weeks).

Soil Exposure

Noncarcinogenic

Ingestion

$$SL_{con\text{-}sol\text{-}ingnsa}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right) \times BW_{con}(80\ kg)}{\left(\frac{RBA}{RfD_o\left(\frac{mg}{kg-day}\right)}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times IRS_{con}\left(\frac{330\ mg}{day}\right)}$$

Dermal

$$SL_{con\text{-}sol\text{-}dernsa}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right) \times BW_{con}(80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg-day}\right) \times GIABS}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times SA_{con}\left(\frac{3,527\ cm^2}{day}\right) \times AF_{con}\left(\frac{0.3\ mg}{cm^2}\right) \times ABS_d}$$

Inhalation

$$SL_{con\text{-}sol\text{-}inhnsa}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right)}{\left(\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times ET_{con}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times \left(\frac{1}{VF_{ulim}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF'_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{con\text{-}sol\text{-}totnsa}\left(\frac{mg}{kg}\right) = \frac{1}{\frac{1}{PRG_{con\text{-}sol\text{-}ingnsa}} + \frac{1}{PRG_{con\text{-}sol\text{-}inhnsa}} + \frac{1}{PRG_{con\text{-}sol\text{-}dernsa}}}$$

Carcinogenic

Ingestion

$$SL_{con-sol-ingcsa}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{con}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right) \times BW_{con}(80\ kg)}{CSF_o\left(\frac{mg}{kg-day}\right)^{-1} \times \left(\frac{10^{-6}\ kg}{mg}\right) \times RBA \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times IRS_{con}\left(\frac{330\ mg}{day}\right)}$$

Dermal

$$SL_{con-sol-dercsa}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{con}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right) \times BW_{con}(80\ kg)}{\left(\frac{CSF_o\left(\frac{mg}{kg-day}\right)^{-1}}{GIABS}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times SA_{con}\left(\frac{3,527\ cm^2}{day}\right) \times AF_{con}\left(\frac{0.3\ mg}{cm^2}\right) \times ABS_d}$$

Inhalation

$$SL_{con-sol-inhcsa}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{con}\left(\frac{365\ days}{yr} \times LT(70\ yrs)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times ET_{con}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times \left(\frac{1}{VF_{ulim}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF'_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{con-sol-totcsa}\left(\frac{mg}{kg}\right) = \frac{1}{\frac{1}{PRG_{con-sol-ingcsa}} + \frac{1}{PRG_{con-sol-inhcsa}} + \frac{1}{PRG_{con-sol-dercsa}}}$$

C-5 Utility Worker

Source: USEPA RSL Equations (2022) Construction Worker Soil Exposure to Standard Vehicle Traffic

Note: According to the EPA, the activities for this receptor (e.g., trenching, excavating) typically involve on-site exposure to surface soils. This exposure scenario assumes a standard exposure duration of 1 year (50 weeks) but could be altered according to the length of the project.

Soil Exposure

Noncarcinogenic

The construction worker soil land use equation, presented here, contains the following exposure routes:

Incidental ingestion of soil

$$SL_{con\text{-}sol\text{-}ingn}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right) \times BW_{con}(80\ kg)}{\left(\frac{RBA}{RfD_o\left(\frac{mg}{kg-day}\right)}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times IRS_{con}\left(\frac{330\ mg}{day}\right)}$$

Dermal exposure

$$SL_{con\text{-}sol\text{-}dern}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right) \times BW_{con}(80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg-day}\right) \times GIABS}\right) \times \left(\frac{10^{-6}\ kg}{mg}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times SA_{con}\left(\frac{3{,}527\ cm^2}{day}\right) \times AF_{con}\left(\frac{0.3\ mg}{cm^2}\right) \times ABS_d}$$

Inhalation of volatiles and particulates emitted from soil

$$SL_{con\text{-}sol\text{-}inhn}\left(\frac{mg}{kg}\right) = \frac{THQ \times AT_{con\text{-}a}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times \left(\frac{7\ days}{wk}\right) \times ED_{con}(1\ yr)\right)}{\left(\frac{1}{RfC\left(\frac{mg}{m^3}\right)}\right) \times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right) \times DW_{con}\left(\frac{5\ days}{wk}\right)\right) \times ED_{con}(1\ yr) \times ET_{con}\left(\frac{8\ hrs}{day}\right) \times \left(\frac{1\ day}{24\ hrs}\right) \times \left(\frac{1}{VF_{ulim}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

Total

$$SL_{con\text{-}sol\text{-}totn}\left(\frac{mg}{kg}\right) = \frac{1}{\frac{1}{PRG_{con\text{-}sol\text{-}ingn}} + \frac{1}{PRG_{con\text{-}sol\text{-}inhn}} + \frac{1}{PRG_{con\text{-}sol\text{-}dern}}}$$

Carcinogenic

The construction worker soil land use equation, presented here, contains the following exposure routes:

Incidental ingestion of soil

$$SL_{con-sol-ingc}\left(\frac{mg}{kg}\right)=\frac{TR\times AT_{con}\left(\frac{365\ days}{yr}\times LT(70\ yrs)\right)\times BW_{con}(80\ kg)}{CSF_{o}\left(\frac{mg}{kg-day}\right)^{-1}\times\left(\frac{10^{-6}\ kg}{mg}\right)\times RBA\times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right)\times DW_{con}\left(\frac{5\ days}{wk}\right)\right)\times ED_{con}(1\ yr)\times IRS_{con}\left(\frac{330\ mg}{day}\right)}$$

Dermal exposure

$$SL_{con-sol-derc}\left(\frac{mg}{kg}\right)=\frac{TR\times AT_{con}\left(\frac{365\ days}{yr}\times LT(70\ yrs)\right)\times BW_{con}(80\ kg)}{\left(\frac{CSF_{o}\left(\frac{mg}{kg-day}\right)^{-1}}{GIABS}\right)\times\left(\frac{10^{-6}\ kg}{mg}\right)\times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right)\times DW_{con}\left(\frac{5\ days}{wk}\right)\right)\times ED_{con}(1\ yr)\times SA_{con}\left(\frac{3,527\ cm^{2}}{day}\right)\times AF_{con}\left(\frac{0.3\ mg}{cm^{2}}\right)\times ABS_{d}}$$

Inhalation of volatiles and particulates emitted from soil

$$SL_{con-sol-inhc}\left(\frac{mg}{kg}\right)=\frac{TR\times AT_{con}\left(\frac{365\ days}{yr}\times LT(70\ yrs)\right)}{IUR\left(\frac{\mu g}{m^{3}}\right)^{-1}\times\left(\frac{1000\ \mu g}{mg}\right)\times EF_{con}\left(EW_{con}\left(\frac{50\ wks}{yr}\right)\times DW_{con}\left(\frac{5\ days}{wk}\right)\right)\times ED_{con}(1\ yr)\times ET_{con}\left(\frac{8\ hrs}{day}\right)\times\left(\frac{1\ day}{24\ hrs}\right)\times\left(\frac{1}{VF_{ulim}\left(\frac{m^{3}}{kg}\right)}+\frac{1}{PEF_{sc}\left(\frac{m^{3}}{kg}\right)}\right)}$$

Total

$$SL_{con-sol-totc}\left(\frac{mg}{kg}\right)=\frac{1}{\frac{1}{PRG_{con-sol-ingc}}+\frac{1}{PRG_{con-sol-inhc}}+\frac{1}{PRG_{con-sol-derc}}}$$