Virginia Unified Risk Assessment Model – VURAM User's Guide

For Risk Assessors

2016

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List of Acronyms and Abbreviations

CalEPA	California Environmental Protection Agency
CAS	Chemical Abstracts Service Registry Number
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DRO	Diesel Range Organics
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
GRO	Gasoline Range Organics
HI	Hazard Index
HQ	Hazard Quotient
HSWA	Hazardous and Solid Waste Amendments of 1984
MCL	Maximum Contaminant Level
NPL	National Priorities List
QA/QC	Quality Assurance/Quality Control
QRA	Quantitative Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
REAMS	Risk Exposure and Analysis Modeling System
RSL	Regional Screening Level
SL	Screening Level
SVOCs	Semi-volatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
UST	Underground Storage Tanks
VAC	Virginia Administrative Code
VDEQ	Virginia Department of Environmental Quality
VOCs	Volatile Organic Compounds
VRP	Voluntary Remediation Program
VSWMR	Virginia Solid Waste Management Regulations
VURAM	Virginia Unified Risk Assessment Model

NOTICE

VDEQ, through its Office of Remediation and Planning, funded and managed the project in this User's Guide. It has been peer reviewed by VDEQ and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation by VDEQ for use. The VURAM User's Guide is not intended to provide regulatory guidance or education. Use of any portion of VURAM that does not comply with the VURAM User's Guide is not recommended.

Disclaimer

With respect to VURAM distributed software and documentation, neither VDEQ nor any employees, assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed. The risk assessment information provided in this manual reflects the application of risk assessment to various programs at VDEQ. Use of VURAM assumes familiarity with the regulatory programs discussed herein. The VURAM User's Guide is not intended to provide regulatory guidance or education. Furthermore, software and documentation are supplied "as-is" without guarantee or warranty, expressed or implied, including without limitation, any warranty of merchantability or fitness for a specific purpose.

Acknowledgements

We wish to express our gratitude and thanks to our friends and colleagues who have contributed during the development of VURAM and to all of the people who reviewed, tested, and gave helpful suggestions throughout the development of the VURAM database model.

We wish to especially acknowledge VDEQ risk assessors including Patricia McMurray, Sonal Iyer, Kyle Newman, and Vrushali Gandhi, as well as the VDEQ technical project staff Hope Pelka, April Ni'Mary, and Allyson Lackey; beta-testing support staff of Pioneer Technologies Corp. and TechLaw for testing and reviewing VURAM and its associated documentation, and for providing helpful comments and suggestions. Special thanks go to Justin Williams, Chris Evans, Vince Maiden, Hasan Keceli, and Bob Nicholas of VDEQ, whose support made the development of VURAM possible.

Software Requirements

VURAM is a database model developed using Visual Basic for Applications under Microsoft Access 2007/2010 and is intended to be run as a Microsoft Windows application within Microsoft Access 2007 or later.

Contact

Visit VDEQ website http://www.deq.state.va.us/ or contact specific Project Manager for more details.
For risk assessment questions please contact VDEQ Risk Assessors: Sonal Iyer 804-698-4259; Kyle Newman 804-698-4452; or Vrushali Gandhi 804-698-4094.
For VURAM technical assistance contact: April Ni'Mary 804-698-4534.

Virginia Unified Risk Assessment Model (VURAM) and User's Guide

User's Guide

This User's Guide is intended to serve as a comprehensive reference for use of VURAM. It provides information on the application and interpretation of the model as well as instructions for its installation and use. Refer to the EPA RSL website, EPA exposure factors Handbook: 2011 Edition, EPA Superfund Soil Screening Guidance, and RAGS for supplemental information concerning the parameters and assumptions incorporated in VURAM.

Information in this manual is presented in three sections:

1. Introduction to Risk Assessment: Provides an outline of the regulatory programs covered by VURAM, general processes and assumptions of risk assessment, as well as information for developing model inputs.
2. How to Use VURAM: Provides a page by page tutorial for the user interface of the Access database model.
3. Understanding the Report: Documents and details the output format of VURAM and provides associated explanations of the results.
4. Appendices: Provide model inputs, assumptions, and calculations, as well as VURAM page images and VDEQ's Risk Based Closure Guidance.

Navigation through the manual is provided by hyperlinked text and images to various sections within the document as well as an interactive (clickable) table of contents. To the greatest extent possible references between various sections are included for ease of use.

Quick Start Guide

NOTE: Ensure VURAM model is updated to the newest available version before conducting risk assessment. Biannually updates from EPA are made to the RSL table and then updated to VURAM. Visit VDEQ's Risk Assessment website for the latest VURAM version. The currently available version supersedes all previous versions of VURAM.

SL (Under Development)

1	Launch VURAM Access Database and Select VURAM
2	Select Screening Levels
3	**SL Module Under Development**

QRA

1	Launch VURAM Access Database and Select VURAM
2	Select Quantitative Risk Assessment
3	Select A Regulatory Program
4	Select Study Area and COPCs for QRA
5	Enter Media COPCs and Concentrations for QRA
6	Calculate Media Specific Hazard/Risk
7	Calculate Total Hazard/Risk and Generate Final Report
8	Save All Outputs
9	Submit Outputs to VDEQ

Model Basics

VURAM is a mathematical database model developed in Microsoft Access 2007 and 2010 developed and made available through the VDEQ central office in Richmond, Virginia. The model utilizes four interrelated risk assessment concepts: concentration, exposure, toxicity, and risk characterization, to estimate the potential hazard/risk from exposure to contaminated media. It is recommended as the risk assessment tool to support risk based evaluations for RCRA Permitted and Corrective Action facilities, VRP/Brownfields, and Solid Waste under VSWMR. The purpose of VURAM is to provide a default calculator to assist remedial project managers, permit writers, risk assessors, and others involved in the decision making processes of solid and hazardous waste sites determine whether levels of contamination warrant further investigation, site cleanup or engineering/institutional controls, or whether no further investigation or action is required.

VURAM and the associated User's Guide are designed to be used by people knowledgeable in the science of risk assessment, data quality objectives, data quality assurance plans, exposure assessment, and toxicity terminology and considerations. VURAM does not include tools for developing a CSM, algorithms to calculate uncertainties, or QRA for ecological receptors. VURAM does not conduct probabilistic risk assessment. Outputs from VURAM are intended to be used for risk management/project management based decision making and for evaluating options available under different regulatory mechanisms. Risk assessment provides information on potential health or ecological risks, whereas risk management is the actions taken based on consideration of risk assessment and other information. Such information includes, but is not limited to, other scientific information, economic factors, social factors, laws, and regulations. VURAM provides calculated hazard/risk values using site-specific data and is only calculated for human receptors.

Recommended Use

Use of VURAM is a strongly recommended approach based on currently available risk assessment information and data for response actions at solid and hazardous waste sites. This document does not establish binding rules. Alternative approaches for risk assessment may be determined to be more appropriate at sites where specific circumstances do not match the underlying assumptions, conditions, and models of this tool. The reason for the use of an alternative approach, and a description of any such approach, should be documented and approved by VDEQ for sites where risk assessment is performed outside of VURAM. Comments received for an individual solid or hazardous waste site questioning the use of the approaches recommended in this User's Guide should be considered as a documented explanation for any selected alternative approach.

Neither VURAM nor the VURAM User's Guide is intended to be a risk assessment training or education resource. The risk assessment information provided in this manual reflects the manner in which selected programs at VDEQ apply risk assessments to program-specific needs. Use of VURAM and the VURAM User's Guide assumes familiarity with the regulatory programs discussed herein. The use of the tables or calculated results in this manual is at the sole discretion of the user and the understanding of the assumptions incorporated in these results, as well as the appropriate application of the same, is the responsibility of the individual using VURAM. The equations provided in this User's Guide, or available from EPA's RSL website, may be used for calculating hazard/risk for site-specific information, provided such approach has been documented, discussed, and approved by VDEQ.

Introduction to Risk Assessment

Background

VDEQ's Division of Land Protection and Revitalization is responsible for carrying out the mandates of the Virginia Waste Management Act and meeting the Commonwealth of Virginia's obligations under RCRA and CERCLA. VDEQ's Division of Land Protection and Revitalization administers several programs designed to ensure that the cleanup of contaminated sites in the Commonwealth to achieve a satisfactory level of human health and environmental protection. VDEQ also has statutory authority to administer the VRP/Brownfields Land Renewal Program, and the RCRA Groundwater Corrective Action Program. Human and ecological risk assessments are conducted to ensure that the cleanups and risk management decisions adequately protect human health and environment.

VDEQ Programs

RCRA Hazardous Waste/RCRA Permitting and Corrective Action

EPA's hazardous waste permitting program, established by RCRA, helps ensure the safe treatment, storage, and disposal of hazardous wastes by establishing specific requirements that must be followed when managing hazardous wastes. RCRA Subtitle C establishes a federal program to manage hazardous wastes from cradle to grave. Permits for the treatment, storage, or disposal of hazardous wastes are issued by authorized states, including the Commonwealth of Virginia, or by EPA regional offices. Permits include applicable EPA regulations from the CFR Title 40 parts 260 through 270 and subparts.

Human health and ecological risk assessments are an integral part of risk based closure of permitted units as well as a tool for evaluating operating permits for Subparts O and H for waste combustion units and Subpart X facilities. Past risk assessment pertaining to RCRA permitted facilities, including closures in conjunction with VDEQ's Risk Based Closure Guidance, was conducted using "Guidance for development of health based cleanup goals using decision tree/REAMS program November 1, 1994 and subsequent updates as prepared by Old Dominion University developed by VDEQ". While the overall approach and assumptions provided in VDEQ's risk based closure guidance and REAMS manual remain valid and applicable. VURAM replaces and supersedes the risk assessment module of the REAMS software but does **NOT** replace the fate and transport modules of REAMS. In places where risk assessment assumptions are conflicting between REAMS and VURAM, VURAM will supersede. VURAM will be used for conducting risk characterization at permitted units.

For facilities that have releases of hazardous waste or constituents into soil, groundwater, surface water, and/or air, EPA and authorized states and territories, including the Commonwealth of Virginia, work with responsible facilities to investigate and clean up hazardous releases under RCRA Corrective Action. The RCRA Corrective Action program is a result of HSWA passed by Congress, which required the cleanup of contamination from improper waste management practices both prior to and after the passage of RCRA. The statute requires responsible parties that are seeking a permit to treat, store, or dispose of hazardous wastes to clean up environmental contaminants at their sites regardless of the time of release. EPA's Corrective Action authority was substantially expanded by HSWA, allowing the agency to address any releases of hazardous waste or hazardous waste constituents to all environmental media at both RCRA permitted and non-permitted facilities. Human health and ecological risk assessment is an integral part of the RCRA Corrective Action site cleanup process. The RCRA Corrective Action program may use risk assessment to assess baseline risk, establish cleanup levels, evaluate the effectiveness of remedial measures, and decide the end of cleanup activities. The Risk

Assessment Guidance for RCRA Corrective Action can be found on the VDEQ website. VURAM will be used for conducting risk characterization at these facilities.

CERCLA/Superfund

CERCLA, commonly known as Superfund, became law in December 1980 and establishes a program to identify sites from which releases of hazardous substances into the environment might occur or have already occurred, and to respond to abandoned sites and/or sites where the owner or operator went bankrupt. EPA administers the Superfund program in Virginia and the Department of Environmental Quality performs necessary activities mandated by the Superfund law. VDEQ is not involved in day-to-day activities of Superfund sites. However, VURAM may be used as a reference at these sites in Virginia as VURAM reflects calculation assumptions and algorithms used in federal facilities program. VURAM calculations may be used as a reference at these sites. Due to the scale and complexity of these sites the use of VURAM for facilities under the CERCLA process is dependent on approval from EPA/VDEQ project manager.

Federal Facilities under CERCLA

Federal Facilities that are significantly contaminated may be listed on the NPL. CERCLA Section 120 requires federal agencies with NPL sites to investigate and clean up the contamination. VDEQ is authorized to conduct regulatory oversight of environmental investigation, remediation, and restoration projects at federal facilities in Virginia. For this program, the user may consult EPA RAGS. VURAM reflects calculation assumptions and algorithms used in CERCLA risk assessment evaluation. VURAM calculations may be used as a reference at these sites. Due to the scale and complexity of these sites the use of VURAM for Federal Facilities is dependent on approval from VDEQ/EPA project manager.

RCRA Subtitle D- Solid Waste

This program focuses on state and local governments as the primary planning, regulating, and implementing entities for the management of non-hazardous solid waste, such as household garbage and non-hazardous industrial solid waste. VDEQ is responsible for administering the regulations governing the management of solid waste in the Commonwealth. The VSWMR governs solid waste management facilities. Under the VSWMR, solid waste management facilities include, but are not limited to, landfills; including sanitary landfills, industrial waste landfills, and construction and demolition debris landfills. Pursuant to VSWMR, these facilities may be required to monitor groundwater. The risk assessment guidance for Solid Waste can be found at VDEQ's website. VURAM will be used for conducting risk characterization at these facilities.

Brownfields and VRP

The Code of Virginia Title 10.1-1231, Brownfields restoration and Lands Renewal Policy and Programs states "it shall be the policy of the Commonwealth to encourage remediation and restoration of brownfields by removing barriers and providing incentives and assistance whenever possible." The purpose of the VRP is to encourage hazardous substance cleanups that might not otherwise take place. The regulatory basis for performing risk assessments under the Virginia VRP is found in the Voluntary Remediation Regulations Section, 9 VAC 20-160-70(A)(1)(a).

The risk assessment will include an evaluation of the risks to human health and the environment posed by the release or threatened release of contaminants into the environment. If the risk assessment shows that a removal or other remedial action is necessary then a proposed set of remediation levels as described in Section 9 VAC 20-160-90 will also be included. Note that certain exposure assumption considerations, such as the use of institutional control, used for this program which removes receptors

from further consideration does not apply to other regulatory programs. VURAM replaces and supersedes several of the interactive Microsoft Excel based risk assessment tables provided on VDEQ-VRP website. The VRP Risk Assessment Guidance and Excel tables can be found at VDEQ website. VURAM will be used for conducting risk characterization at these facilities.

Summary

All of the above regulatory programs at various stages of operation, closure, post closure care, remedial decision making and/or corrective action activities may need to perform Human Health Risk Assessment in order to demonstrate that the risk posed by contaminants attributed to the facilities are within acceptable limits thereby protecting public health, the environment, and the natural resources of the Commonwealth.

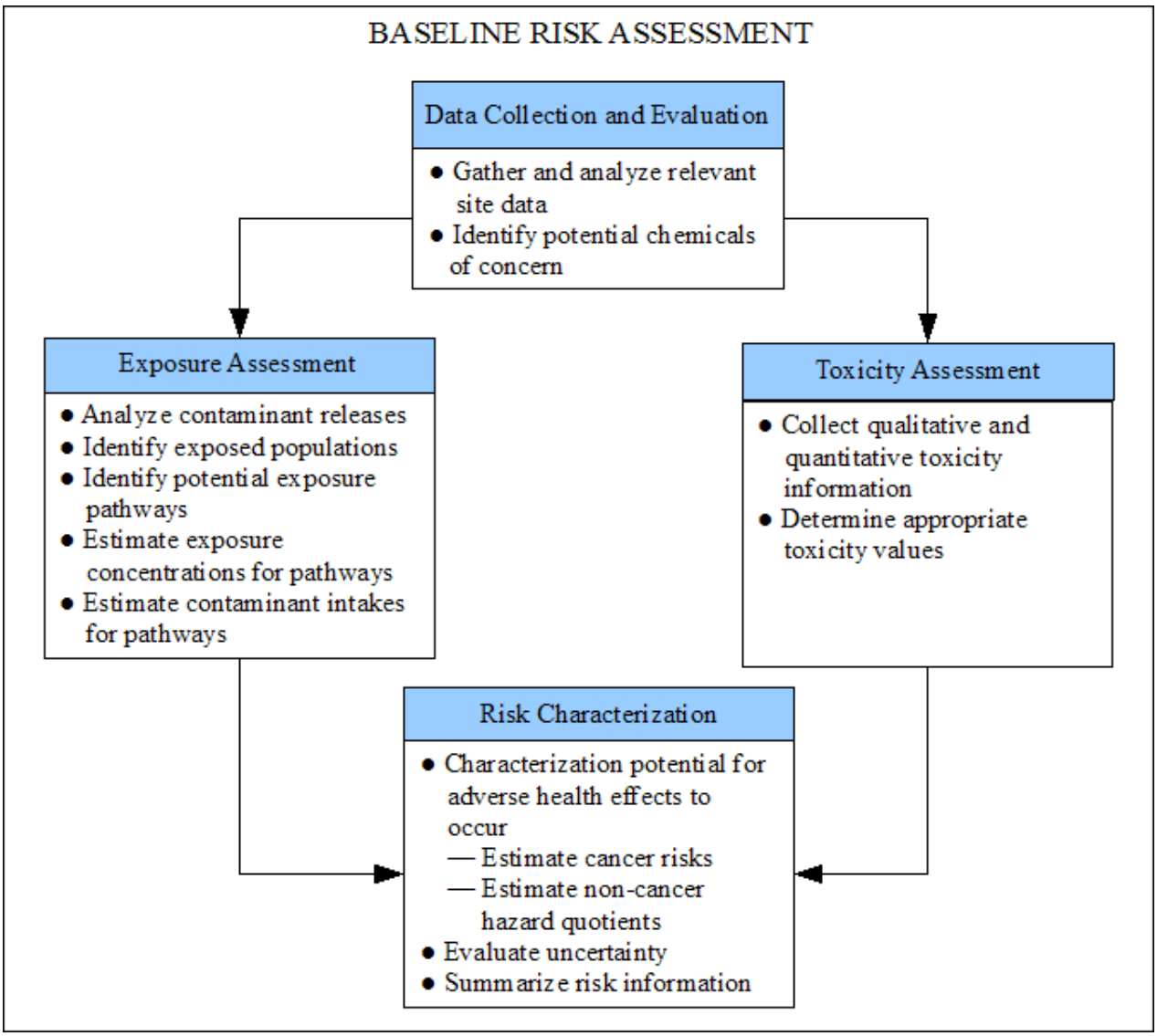
For the cleanup based programs the focus of the cleanup process is on assessing all sites for current and potential future risk to human health, and choosing cleanup levels using risk based information. Cleanup standards are implemented as remedial action goals. Different cleanup levels will be appropriate in different situations. Cleanup levels are best established as site-specific goals and as part of the cleanup and remedial action selection process. Public and private sector investigators have recognized the need for a systematic and scientifically valid process to aid in managing risk associated with exposure to environmental contaminants; a consistent approach to developing cleanup goals will expedite decisions concerning protection of public health.

Special note about Brownfields and VRP:

1. Under this program, the only ways to exclude particular receptors or pathways from QRA are:
    a. A commitment upfront to a viable and practical use restriction that would eliminate exposure to receptors, such as a residential use restriction. Assumptions regarding current or future use cannot be used to eliminate pathways.
    b. The offsite drinking water pathway may be eliminated if a letter can be provided from the municipality that supports a determination that local laws, ordinances, or regulations prevent the installation of private wells on affected properties.
2. Sites that anticipate using engineering controls (sub-slab depressurization system, capping, etc.) as remedies are still required to perform a risk assessment on affected media. The risk assessment is key to evaluating the viability of the remedy, as well the potential consequences of its failure.
3. Sites that have gone through VDEQ's UST program will still be required to evaluate SVOCs and VOCs. The UST program focuses on evaluations of mixtures that do not have reliable toxicity values such as TPH, DRO, and GRO. Subsequently, the program does not use QRA to meet its goals. As the VRP evaluates cumulative risks, residual risks from tanks for individual components of TPH, DRO, and GRO need to be evaluated if any sample remaining after the UST investigation exceeds 100 mg/kg TPH.

Risk Assessment Process Overview

Risk assessment is, to the highest extent possible, is a scientific process. See EPA's About Risk Assessment website for a basic overview of risk assessment. Each program has different requirements and risk management options, yet QRA models for each of these programs rely on similar input parameters and calculation algorithms. The ultimate purpose of all risk assessment is to develop risk based cleanup goals that protect human health and the environment, and restore the environment to the extent practicable. VDEQ follows the 4-step risk paradigm outlined in EPA RAGS and EPA RSL User's Guide: data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization. These steps are depicted in the figure below and are adopted from Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Part A, Interim Final.



Step-1: Data Collection and Evaluation

Data collection and evaluation is primarily concerned with the acquisition of necessary data from environmental media to identify COPCs and support the calculation of EPCs in the exposure assessment. The purpose and scope of a risk assessment is decided based on the regulatory program needs, which in turn dictates data quality objectives and data quality assurance plans. Once objectives are decided, media sampling is performed to develop and understand the current nature and extent of chemical contamination in the environment, and predict how the contaminants may behave in the future. Data collection and evaluation relies heavily on the CSM to identify which environmental media should be sampled, and at which locations.

Step-2: Exposure Assessment

An exposure pathway describes how a receptor may come into contact with a chemical source via an exposure route: ingestion, inhalation, and/or dermal. In this step, site data are used to estimate media-specific EPCs for receptors identified in the CSM. Chemical intake (dose) is then calculated as a function of the concentration of the chemical in an environmental medium and the characteristics and behaviors of the potentially exposed receptors. Land use assumptions and exposure factors are an important part of these calculations. Refer to Toxicity Values, Chemical Parameters, and Exposure Defaults for more details.

Step-3: Toxicity Assessment

The toxicity assessment uses data from published animal and human studies to identify adverse health effects which might be caused by exposure to the COPCs, as well as the dose at which harmful health effects may occur. Harmful effects are broadly categorized as either carcinogenic or noncarcinogenic. Refer to Toxicity Values, Chemical Parameters, and Exposure Defaults for more details.

Step 4: Risk Characterization

In this step, the toxicity assessment is integrated with the exposure assessment to quantify potential health risks. The risk characterization reveals which COPCs pose the most significant risks and which exposure pathways are important. VURAM reflects only this last step in the risk assessment process.

Prerequisites for Computation

The risk assessment process acknowledges that contaminant data and other site related information is usually limited and that only a small sampling of site-representative data are available to make human health and ecological risk decisions. This means risk assessors often have to make estimates and use professional judgment when performing risk calculations. Consequently all risk estimates have a certain degree of uncertainty. For this reason a key part of risk assessment is an open presentation of the uncertainties in the calculations and a characterization of how reliable, or unreliable, the resulting risk estimates truly are.

Uncertainty is present and inherent throughout the modeling process, this is termed model uncertainty. Model uncertainty arises from a lack of knowledge about natural processes, simplifying assumptions in mathematical formulations and associated parameters, and/or data coverage and quality. In order to ensure that risk is not underestimated, several assumptions used in the risk assessment process, at both the screening and quantitative level, are conservative. In order to ensure that the study area population is not exposed to unacceptable risk level, reasonable maximum exposure or reasonable worst case exposure scenarios are always employed. Refer to RAGS-Part A for more information.

Fate and Transport

VURAM does not, at present, incorporate fate and transport modeling from soil to groundwater, soil to surface water, groundwater to surface water, soil/groundwater to soil gas/air, detailed groundwater to shower air, and soil gas/sub-slab gas to indoor air. However, fate and transport modeling is an integral path of the risk assessment model. As such, the evaluation of pathways, along with risk assessment evaluation, is required. For further information on fate and transport evaluations refer to EPA Superfund Exposure Assessment Manual or contact VDEQ.

Site Characterization and Data Requirements

A **thorough and complete site characterization** must be performed to obtain the site-specific data required for VURAM input parameters. A site characterization is used to identify and characterize the presence and extent of hazardous substances at a site and any associated threat to human health and the environment. All variables influencing contaminant movement, direct and indirect, via fate and transport must be taken into account to accurately develop a CSM. This will ensure a viable simulation of the present extent of contamination and prediction of future conditions.

A separate CSM may need to be developed for onsite and offsite exposures as well as for current and future potential uses of the site. In order to use VURAM to generate an applicable QRA the site characterization must include data and information that matches the CSM. Refer to RAGS Part A, the Soil Screening Guidance for Superfund: Users Guide (EPA 1996) Part 2 and Attachment A for more information on developing a CSM. Site characterization includes an investigation of saturated and unsaturated zones, surface and subsurface soil, unfiltered groundwater, unfiltered surface water, sediments, subsurface geology and hydrogeology, air (ambient, sub-slab, and indoor soil-gas, and indoor air), and demographics, including population and past, present, and potential future land use information. Additionally the CSM includes the nature of contamination and the lateral and vertical extent of contamination. More than one round of sampling data may be needed for thorough site characterization. The CSM provides valuable data used in determining site-specific risk based cleanup goals. Proper sampling and analysis of **all potentially contaminated media**, including unfiltered groundwater, unfiltered surface waters, surface and subsurface soils, sediments, air (ambient, sub-slab, soil-gas, and indoor air), wastes and sludge, and food for a wide range of compounds is necessary to produce validated, high quality data.

IMPORTANT! Reliable results from VURAM QRA are dependent upon the quality of the data and information entered into the calculation procedures. Therefore the use of valid and reliable input data is absolutely necessary. Incomplete or inaccurate data and information will yield results with a high degree of uncertainty.

Further information on the quality of data appropriate for use in risk assessment and modeling is available from the following:

- Guidance for Data Useability in Risk Assessment Final Part A
- Data Quality Objectives for Remedial Response Activities
- Soil Screening Guidance: Technical Background Document
- Risk Assessment Guidance for Superfund, Volume I- Human Health Evaluation Manual (Part A)
- OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils, Appendix E (Subsurface Vapor Intrusion Guidance)
- Vapor Intrusion Pathway: A Practical Guidance

Statistical Analysis

Statistical analysis is an integral part of risk assessment data evaluation. For SL risk assessments, maximum detected media concentrations are used. For QRA, either maximum detected media concentration or 95% upper confidence limit of the mean is used. VDEQ recommends using EPA's Statistical Software ProUCL for statistical analysis. Refer to the following resources for more information on sampling and statistical evaluation approach:

- Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance
- ProUCL User Guide: Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations
- Chemical Concentration Data near the Detection Limit
- Risk Assessment Guidance for Superfund: Volume I - Parts A, B, C, D, E, and F

Acceptable Noncancer Hazard and Cancer Risk

The QRA in VURAM requires an acceptable level of cancer risk to be determined based on site-specific factors. Except for RCRA permitted units and facilities the range of cumulative acceptable cancer risk performance standard/goal is 1E-4 to 1E-6. The recommended individual risk is at or below 1E-6. For noncarcinogens both the HQ from individual noncarcinogens, and HI from all noncarcinogens, performance standards/goals are below 1. Cleanup goals are calculated within the VURAM for these default hazard levels. Options to select individual and cumulative risk goals are provided in the VURAM interface and may be different from those stated.

For RCRA permitted units and facilities the acceptable combined risk performance standard/goal from all carcinogenic risk from all exposure pathways and media for a given receptor is 1E-04. For individual carcinogenic risk performance standard/goal from all exposure pathways and media for a given receptor is 1E-6. For noncarcinogens HQ and HI performance standard/goal is less than 1 for a given receptor.

Toxicity Values, Chemical Properties, and Exposure Defaults

Exposure parameters are obtained from the RSL User's Guide where available. Primary sources of chronic and subchronic toxicity values included in VURAM are obtained from the following references, in the order of preference and hierarchy:

- EPA's Integrated Risk Information System (IRIS)
- Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV)
- The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs)
- Office of Environmental Health Hazard Assessment's (OEHHA) Chronic Reference Exposure Levels (chRELs) as of June 2014
- Technical Support Document for Cancer Potency Factors 2009
- Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values
- Decision Making at Contaminated Sites: Issues and Options in Human Health Risk Assessment: Appendix A
- Health Effects Assessment Summary Tables (HEAST): FY 1997 Update

However, VURAM uses EPA RSL table to update toxicity and chemical properties. Chemical parameters and toxicity values from the RSL table will be updated by VDEQ to reflect updates to toxicity values and other chemical parameters in the VURAM database. A new version of VURAM will be released once periodic updates are made. New releases of VURAM need to be downloaded and installed in order to calculate risk assessments with the most recent RLS data.

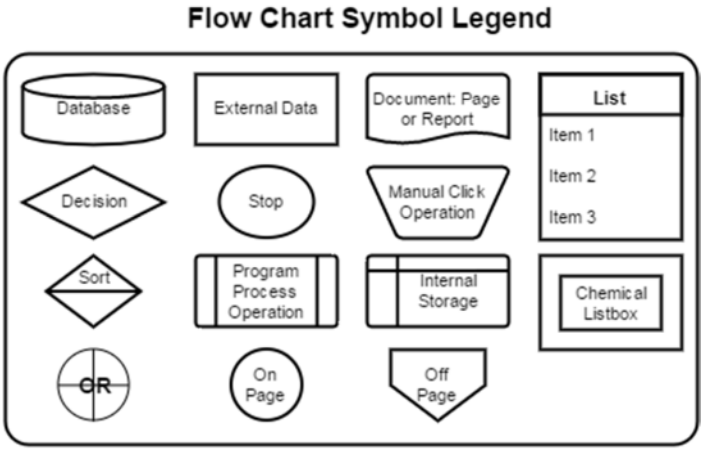
For chemicals included in EPA RSL that have no CAS, or have a duplicate CAS with distinct chemical properties, then an unofficial value is assigned in VURAM to facilitate database function. A table of these chemicals and the assigned CAS value is included in Appendix 5: VDEQ CAS revisions. These values are contrived by VDEQ to be indicative of the compound or substance they reflect, this may include an official CAS, but are not reflective of the Chemical Abstract Service assigned number.

For some chemicals with similar toxicity properties proxy values are used. The proxy chemicals list was developed using "Langley Air Force Base Remedial Investigation Report for IRP Sites LF-01, LF-05, LF-15, LF-18, LF-22, and FT-41, Radian, November 1998." A table of these chemicals is included in Appendix 5: Proxy Chemicals.

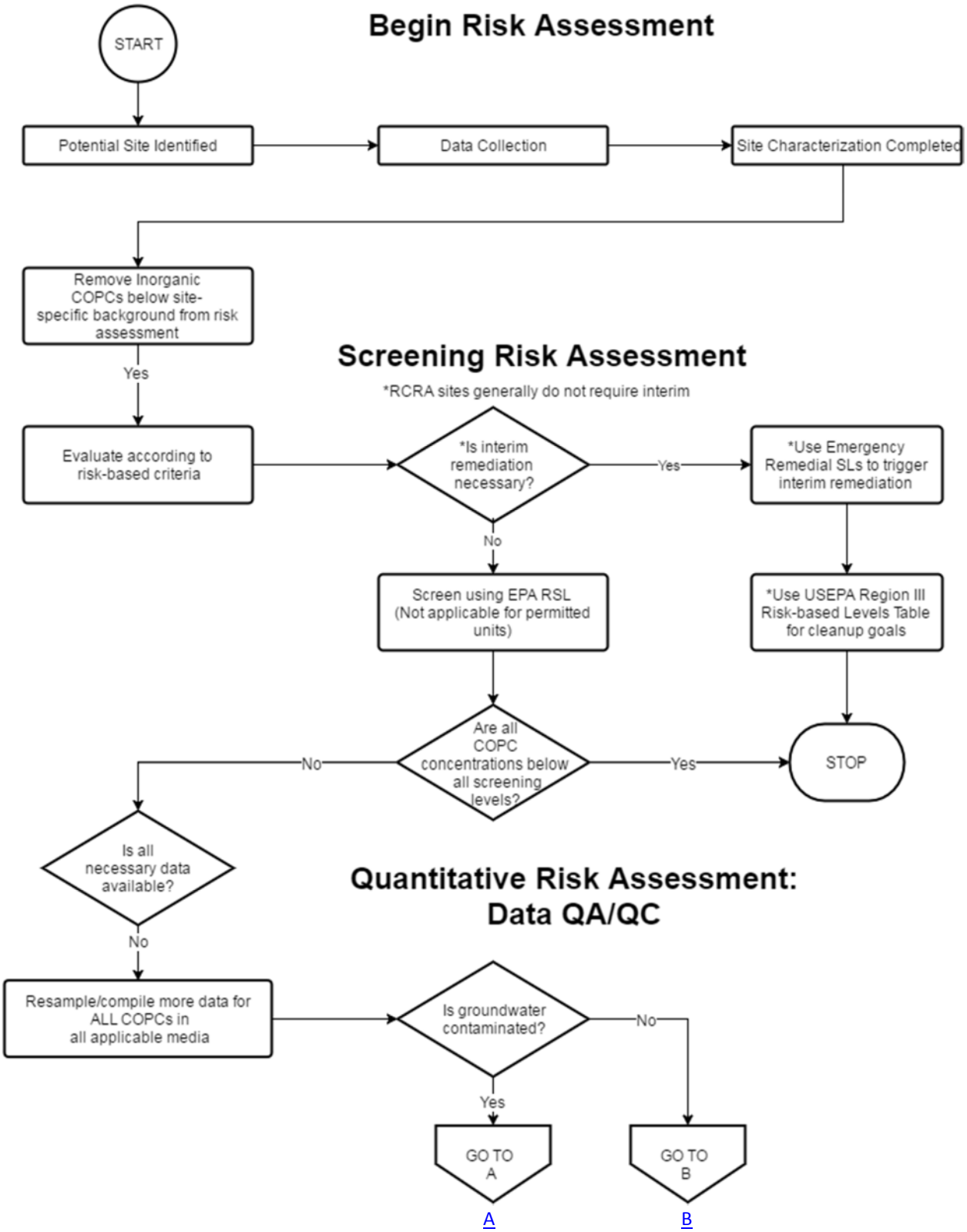
Approach to Risk Assessment

VURAM uses a logic flow approach to calculating hazard/risk based on site specific chemical lists, study area, and human exposure related criteria to establish risk based cleanup standards for contaminated soil, groundwater, air, surface water, sediment, and food.

An outline of risk assessment is provided in flow charts below. Each step of the risk assessment logic flow is determined by the CSM for site specific conditions. Decisions in the flow chart must be evaluated against the CSM for accurate application calculated HI/Risk. Risk assessments should be performed in accordance with project specific agreements and work plans approved by VDEQ project manager. VURAM output report provides the information required in RAGS Part D tables.



This document does not establish binding rules, but provides a recommended risk assessment process which incorporates the use of risk assessment methodology described in RAGS Part A through E and EPA Regional SL Guidance.


Begin Risk Assessment
START
Potential Site Identified
Data Collection
Site Characterization Completed
Remove Inorganic COPCs below site-specific background from risk assessment
Yes
Screening Risk Assessment
*RCRA sites generally do not require interim
Evaluate according to risk-based criteria
*Is interim remediation necessary?
Yes
*Use Emergency Remedial SLs to trigger interim remediation
No
Screen using EPA RSL (Not applicable for permitted units)
*Use USEPA Region III Risk-based Levels Table for cleanup goals
Are all COPC concentrations below all screening levels?
No
Yes
STOP
Is all necessary data available?
No
Quantitative Risk Assessment: Data QA/QC
Resample/compile more data for ALL COPCs in all applicable media
Is groundwater contaminated?
No
Yes
GO TO A
GO TO B
A
B

Begin Risk Assessment

Use of VURAM assumes a site contaminated with hazardous substances has been identified and investigated resulting in a full site characterization with data quality objectives and assessment as described in Data Quality Objectives for Remedial Response Activities or other Quality Assurance/Quality Control programs deemed acceptable by VDEQ.

Note: For inorganic constituents (metals) VDEQ highly recommends collecting site or unit specific natural background data. VDEQ considers background data only for naturally occurring inorganics and not for organic and anthropogenic chemicals.

Note: VURAM does not include fate and transport evaluation. However, residual soil contamination must be evaluated for potential movement from soil to groundwater and, if applicable, residual groundwater contamination must be evaluated for potential movement from groundwater to surface water. Consult VDEQ for accepted methods of evaluating fate and transport.

Screening Risk Assessment

Sites applying for closure of permitted facilities under RCRA using risk based cleanup goals that also pose imminent and substantial endangerment to human health and the environment may use the EPA's RSL residential values or other interim cleanup guidance as approved by VDEQ as **interim cleanup goals**. VDEQ requires no interim cleanup for a RCRA site undergoing clean closure, which is unrestricted/residential future use. Neither RSLs nor any other SLs are used for permitted facilities.

The RSL table provided by EPA is used as a risk based screen for Superfund/CERCLA, RCRA Corrective Action, and Federal Facility sites. VRP SLs are adjusted appropriately to meet regulatory requirements. SL values are computed using toxicity values and standard exposure scenarios to determine chemical concentrations corresponding to a fixed level of risk. The RSL table does not combine risk across various media and/or contaminants. The RSL table and SLs are generic screening values, not de facto cleanup standards. While the list is not to be used for permanent site-specific cleanup levels, the information provided is useful for determining interim cleanup measures. The information in the RSL table is updated bi-annually as new toxicological data are published. Risk Assessment is required to use the most recent update of the RSL table available at the time of data analysis and to note the date of the RSL table used. VURAM's SLs module will provide more information and instruction on SL risk assessment.

Risk Assessment Data QA/QC

If applicable, once interim cleanup/SL risk assessment is completed, COPCs which fail SL risk assessment as well as COPCs left behind after interim action has been performed are assessed using QRA. The data quality objectives as well as the CSM for QRA may be different from the initial or preliminary site investigations/RCRA Facility Investigation Phase-I/site characterization. Therefore the quantity and quality of data needed may differ from the existing and available data. If the information is incomplete the site must be resampled and/or the information necessary for entry into VURAM must be compiled or obtained. This can include additional sampling, data collections, and/or statistical analysis.

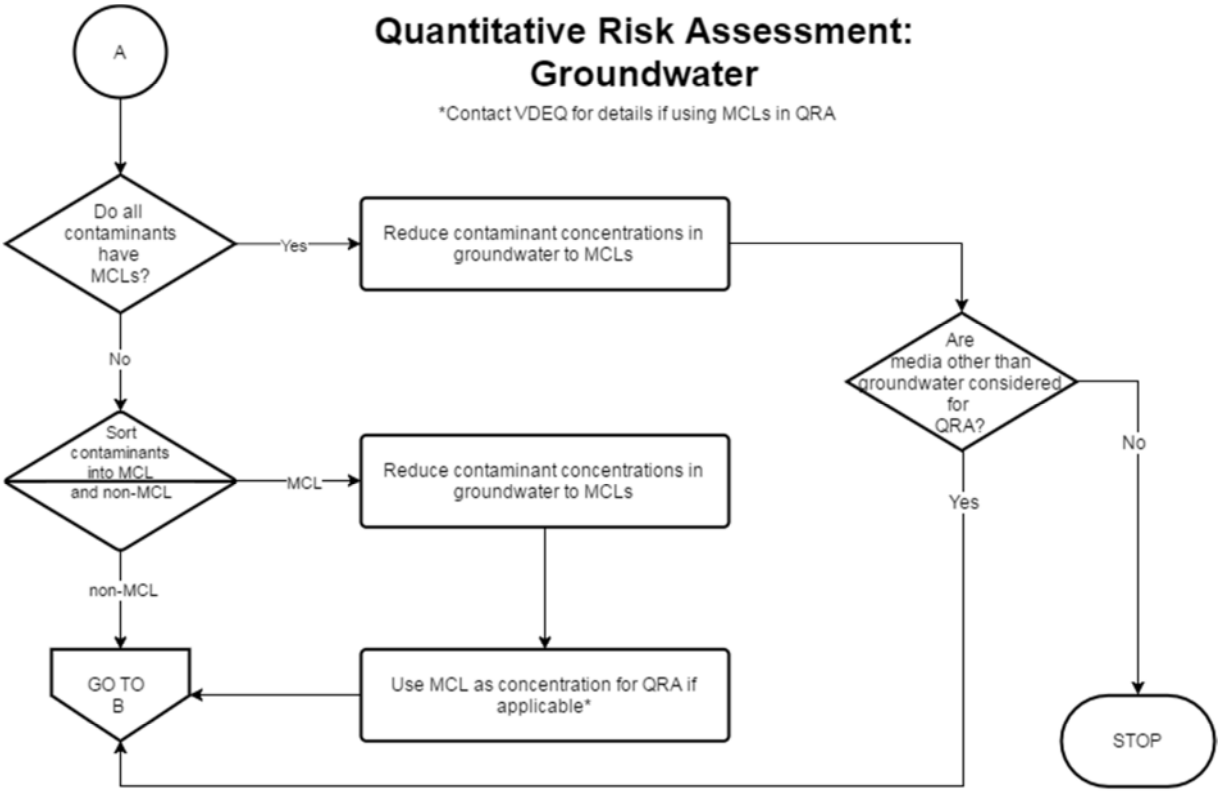
The evaluation of appropriateness, representativeness, and qualification of analytical data generated during investigation is not incorporated in VURAM. Consult RAGS Part A for data qualifiers and their use in risk assessment. Generally, data without qualifiers are considered appropriate for risk assessment purposes. Based on overall data density and quality, other qualifiers may also be included in risk assessment.

QRA

If information is complete and groundwater is contaminated, regardless of the contamination detected in other environmental media, then follow QRA: Groundwater flowchart connector A.

If information is complete and the groundwater is either: not contaminated **OR** the chemicals in groundwater do not have MCL **OR** the proposed cleanup is not MCL and chemicals have not migrated offsite, then proceed to QRA: Calculations flowchart connector B.

VURAM calculates site-specific risk based cleanup/remediation goals using the base line risk assessment results and default or selected acceptable hazard/risk levels.



B

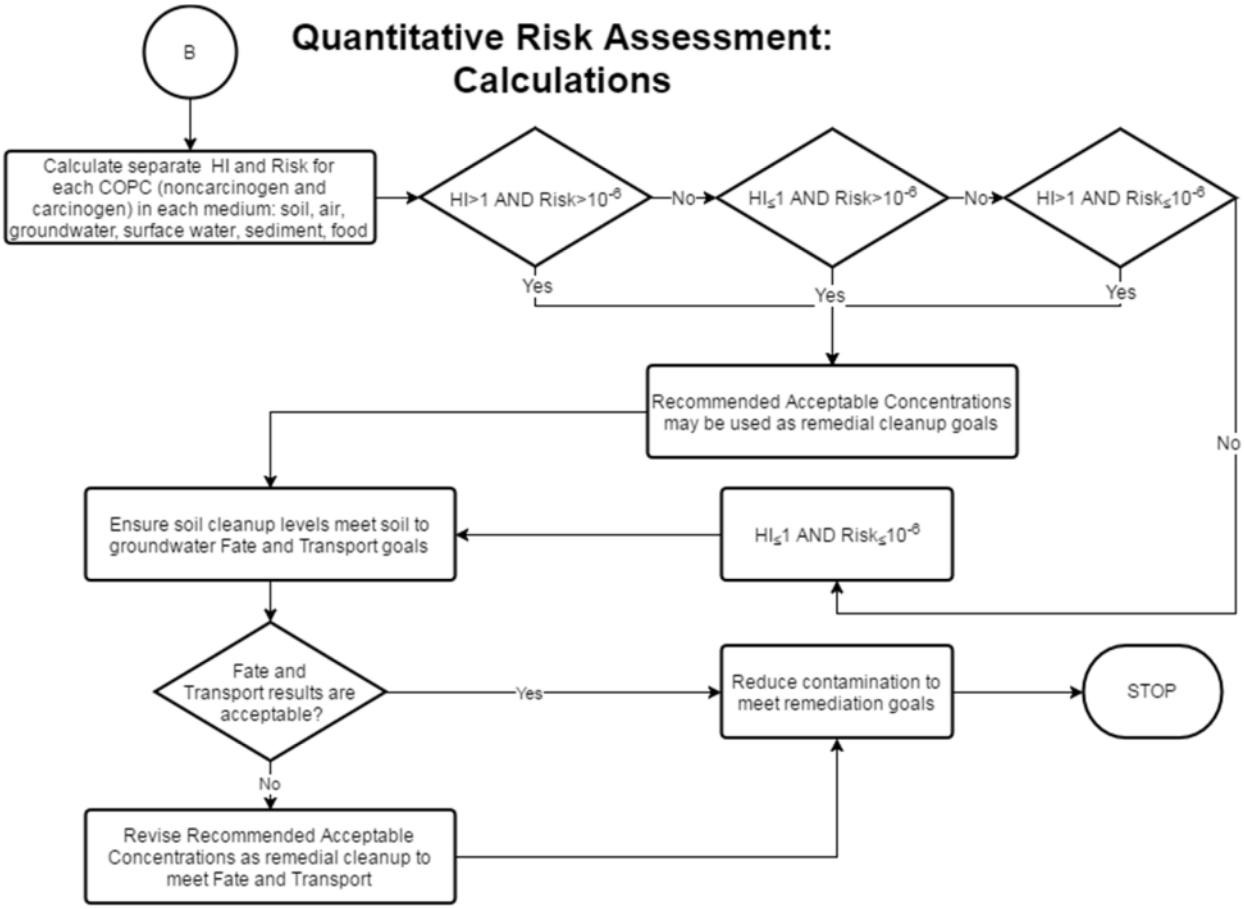
QRA: Groundwater

First, determine if all of the contaminants in groundwater have MCLs under 40 CFR 141, National Primary Drinking Water Regulations (EPA, 1992). If yes, then the contaminant concentrations must be reduced to the MCLs. Once concentrations for groundwater are reduced to or below MCLs, use these MCLs as EPCs for groundwater QRA along with measured non-MCL COPCs in groundwater and other applicable media concentrations to determine site-wide risk. Due to the time required to reduce COPCs to MCLs for some sites detected concentrations may be used in QRA instead of MCLs. Contact VDEQ for regulatory program and project specific requirements and risk/project management based decisions. Proceed to QRA: Calculation flowchart connector B.

Note: For inorganic chemicals only, if the responsible party can demonstrate to VDEQ that the site specific background levels of the contaminant in groundwater are higher than the MCLs, then an exception may be granted. If the site-specific background levels are higher than the MCLs the contaminant concentration are reduced to background. These chemicals will no longer be included in QRA. Detected concentrations may be used instead of MCL due to the time required for COPCs to reduce to MCLs for some sites. Contact VDEQ for site-specific needs.

Note: For sites with a single detected contaminant for which a MCL has been promulgated under Section 1412 of the Safe Drinking Water Act Title 40 CFR 141, the MCL for that constituent will be the acceptable cleanup level. For sites with multiple detected contaminants for which MCLs have been promulgated, the potential cumulative risk for carcinogens shall not exceed 1E-4 for risk from carcinogens at MCL and the risk from all remaining carcinogens combined. The HI for noncarcinogens at MCL and remaining noncarcinogens combined shall not exceed 1. MCLs are promulgated by EPA for use

by public water systems to protect public health by limiting the levels of contaminants in drinking water. MCLs are not intended for use as risk-based screening criteria. Therefore, if a chemical at MCL is identified as a risk driver, reduction in concentration to meet risk-based criteria may be required.



QRA: Calculations Contamination Limited to Onsite Media

For sites where contamination is limited to onsite media and has not migrated offsite, the data for all applicable media are based on the CSM. This module directs the calculation of hazard and risk.

IMPORTANT! For sites where COPCs have migrated offsite contact VDEQ for offsite data requirements before using VURAM for QRA.

An HQ for each noncarcinogenic contaminant and individual risk for each carcinogen in each medium is calculated by combining routes of exposure for the contaminant in each medium. For example, exposure to contaminated soil involves potential ingestion, inhalation of particulates and volatiles, and dermal contact. Therefore, the HQ and risk for a contaminant in soil is a combination of the hazard and risk associated with all three routes of exposure.

VURAM has all routes of exposure for each medium either preselected or as a selection option based on the study area and media. The details of these options are provided on the VURAM Calculation page. HQs and individual risk for all exposure pathways are combined to yield a HI total and Risk total for each COPC calculated.

VURAM automatically calculates acceptable concentrations for each chemical in each media where individual hazard/risk is exceeded for Residential and Industrial (composite worker) scenarios. For chemicals that have concentrations that exceed acceptable HQ and individual risk, the calculated acceptable concentration may serve as final remediation/cleanup goal.
Note: For soil, and groundwater as applicable, recommended acceptable concentration data must be evaluated for fate and transport. VURAM does **NOT** include fate and transport evaluations. If contamination is expected to reach groundwater and/or surface water within 30 years, then fate and transport based calculated groundwater /surface water contaminant concentration(s) can be entered into the risk assessment portion of VURAM to assess if the predicted concentration will be within acceptable hazard/risk level. If predicted concentrations fail acceptable hazard/risk levels, the soil/groundwater acceptable concentrations may need to be revised to meet fate and transport based requirements. If contamination will not reach groundwater and/or surface water within 30 years at unacceptable levels, then the concentrations of COPCs in soil are acceptable according to human health risk based criteria.

Note: Risk Calculations in VURAM do not consider ecological risk assessment although some SL evaluations include some ecological considerations. If the CSM indicates potential exposures to ecological receptors a separate ecological risk assessment must be performed. Refer to:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments - Interim Final
- Guidelines for Ecological Risk Assessment
- EPA Ecological Soil SL (Eco-SSL) Guidance and Documents

The calculated acceptable goal obtained from VURAM may be used to evaluate potential ecological risk to ensure that the chosen remediation/cleanup goals are protective of ecological receptors. Contact VDEQ for further details on ecological risk assessment.

Note: Lead is currently not included for QRA in VURAM. If lead is a chemical of potential concern use IEUBK model and ALM model.

How to Use VURAM

Getting Started

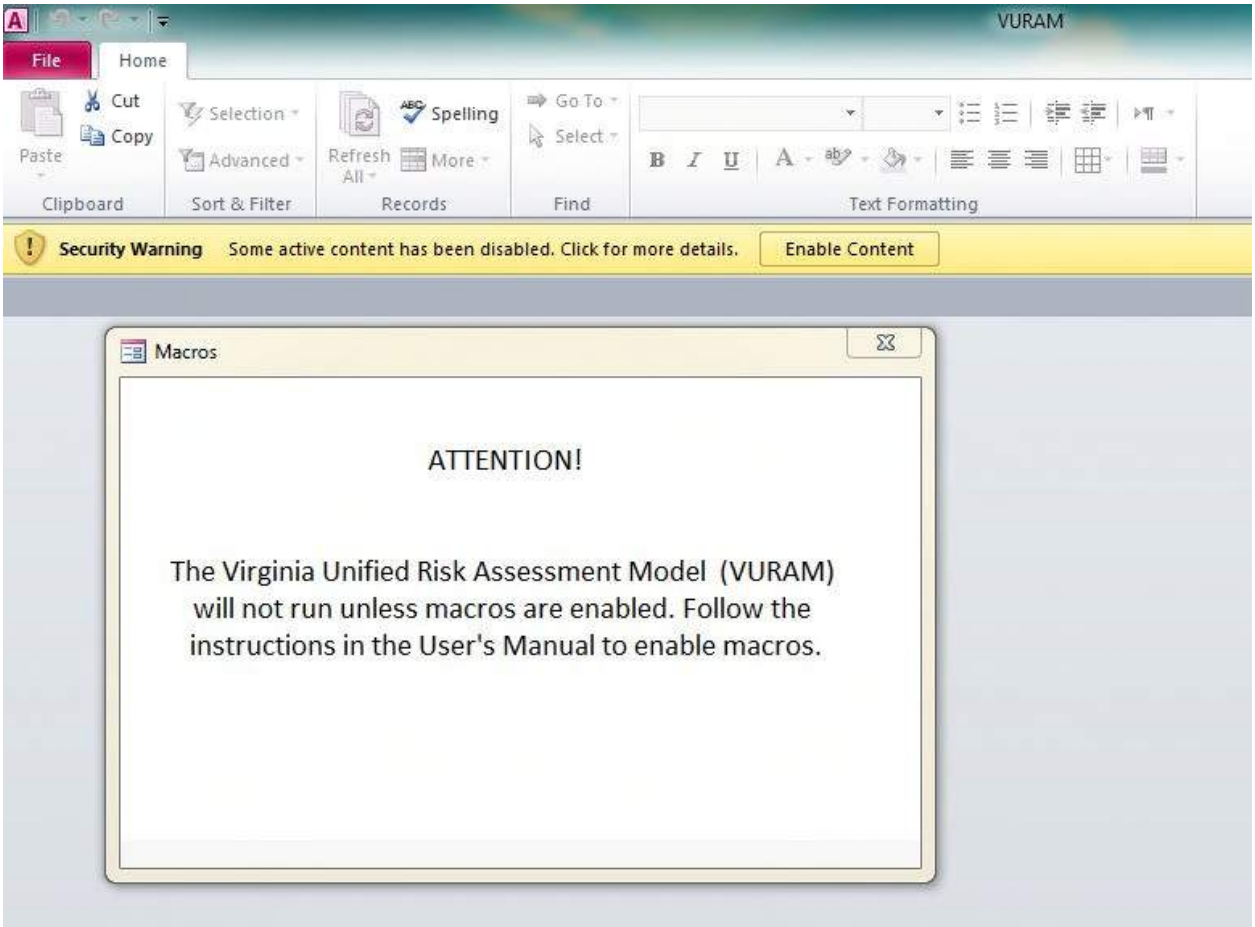
Obtain the current VURAM database from VDEQ website, if necessary, and save it to a local drive.

To launch VURAM double click the downloaded VURAM database. If the VURAM database is saved in an Access Trusted Location then the program will start automatically. Otherwise follow instructions provided below to Enable Macros.

WARNING! Using VURAM over a network or shared drive location can cause database performance problems. Always save a local copy when using VURAM.

Enable Macros

If the program is not in a trusted location you will see a message informing you that macros are not enabled and the database cannot run. To run VURAM click **Enable Content**.



NOTE: Other versions of Access may encounter a different set of *Enable Macros* or compatibility warnings dialogue. Follow the prompts in Access to *Allow/Enable* VURAM.

Using VURAM Software Model

VURAM is designed to guide the risk assessment process with a series of user interface pages used to select chemicals, study area, and receptor parameters for calculation. The final output of VURAM is a printable report which gives the total HQ and/or cumulative risk for each chemical by exposure pathway and by media.

IMPORTANT! Before conducting VURAM risk assessment modeling a thorough CSM must be performed and all applicable model parameters complete. All image option selections, COPCs, and concentration values are for demonstrative purposes **ONLY** and do not represent any actual site data or analysis. Individual model runs of VURAM will be site-specific.

Troubleshooting Common Errors

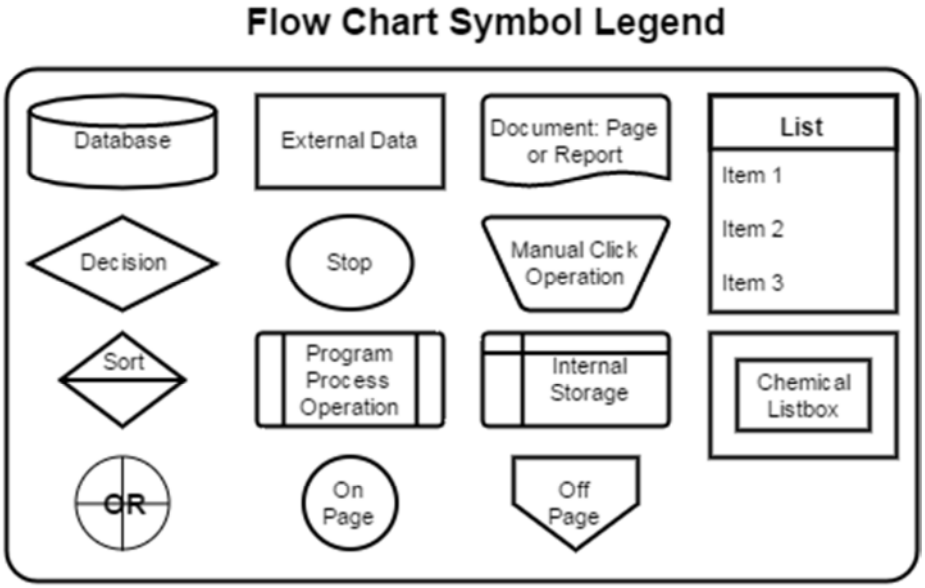
Some errors can occur in and with Access. The most common is database corruption due to interruption of the Access shut down process. If you suspect the database is corrupt delete it and download a new copy from the VDEQ website.

VURAM page size does not automatically accommodate screen resolution. The page size can be adjusted using standard Window's mouse navigation to move and size each form (excluding the VURAM Splash Page).

WARNING! Force Quitting Access while VURAM is open can cause database corruption. If database corruption is suspected delete VURAM and download a fresh copy from the VDEQ website.

Flow Chart Legend

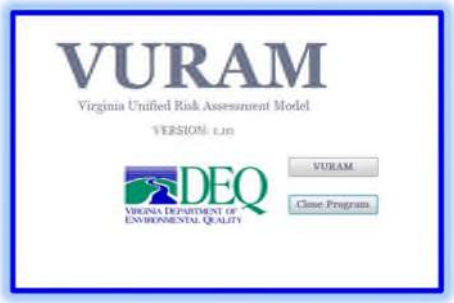
In the following section each page of the VURAM user interface is detailed by a flow chart diagram, which provides information on selection options and program flow and function.



NOTE: On-page and off-page connectors reference each other, as begin and go to locations. Not all options are required. For example **Quit** and **Go Back** may be selected from each page, but not required to be selected. Some options are pre-set and may not be available for selection.

Hyperlink Images

The flow diagram is accompanied by a **PREVIEW** of the associated VURAM page. A full view version of each page is hyperlinked to the preview and is referenced in Appendix 1. Appendix images are hyperlinked to return to the detailed description. The VURAM Splash Page is provided here as an example.



NOTE: Display resolutions may change the appearance of the pages of VURAM. All pages, except the VURAM Main Page, can be moved, sized, and can be scrolled.

Warnings, Errors, and Icons

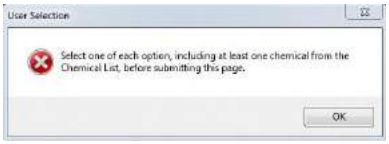
The VURAM interface has several user feedback messages in the form of pop-ups and icons that appear when errors have occurred, actions have been completed, or further action is required. Error messages and icons ensure proper presets before proceeding in the model.

Green Check Mark: Shown when a media calculation is completed.

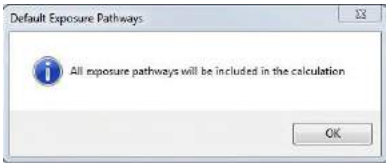
Grey Information Triangle: Shown when a media is not available for calculation due to the selected study area

Red X: Shown where inputs need to be selected or entered before continuing.

Blue Information Circle: Interactive icon containing information message.



Warning Messages: These messages contain important information about proceeding. These may have a cancel option that will cancel the preceding action.



Information Messages: These massages contain important information on the risk assessment process or program parameters.

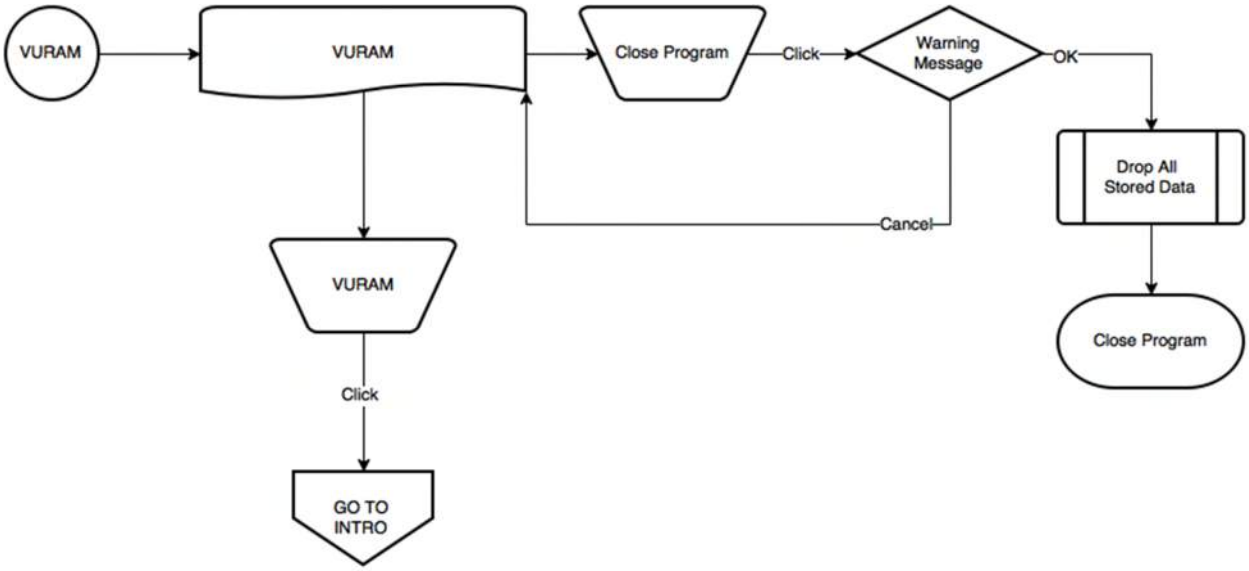
WARNING! Do **NOT** interrupt the close program process or data corruption can occur.

VURAM Splash Page

VURAM will auto-load when opening the VURAM database from a trusted location. If VURAM opens and this page is not displayed see Enable Macros.

The VURAM splash page serves as a background for all other pages and will remain open throughout the program.

Use the **Close Program** command located on this page to exit VURAM at any time.

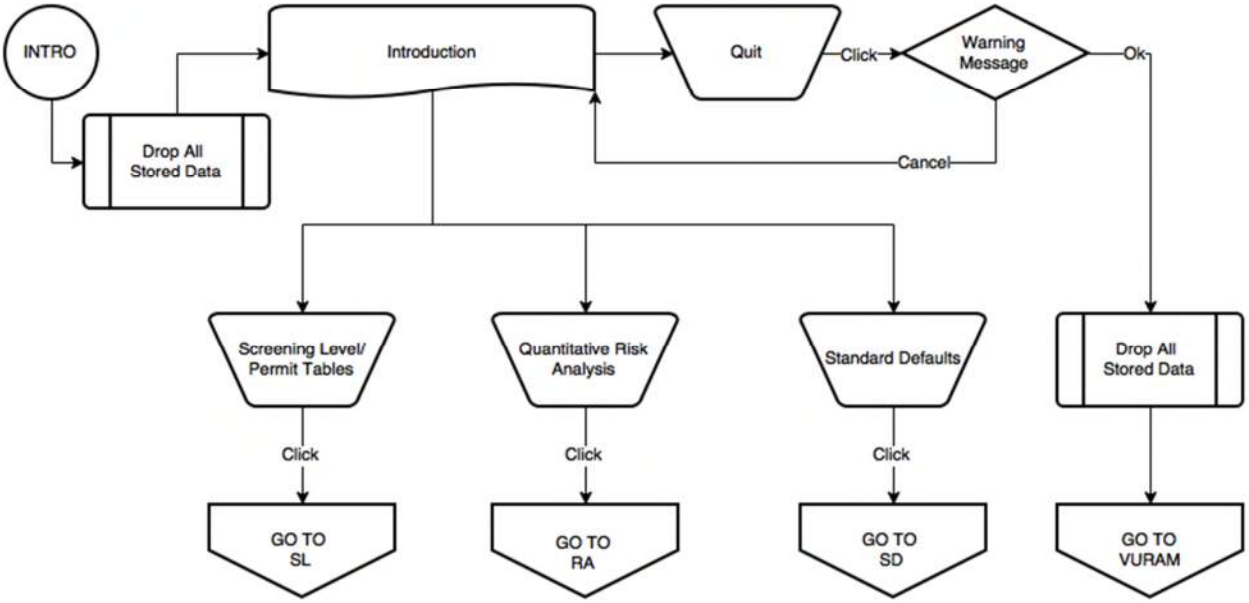


INTRO

Introduction Page

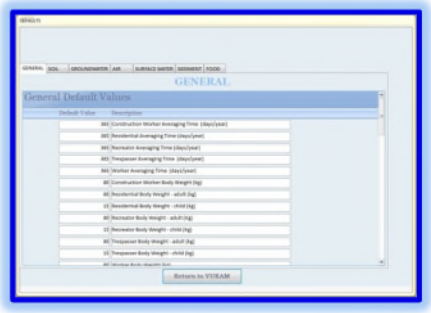
This page contains two options: SL and QRA. The SLs module (currently under development) is used for screening site-specific data to identify chemicals that need to advance to QRA.

The Risk Assessment module performs QRA using site specific chemicals and concentrations to provide a calculated hazard/risk.



SL RA SD VURAM

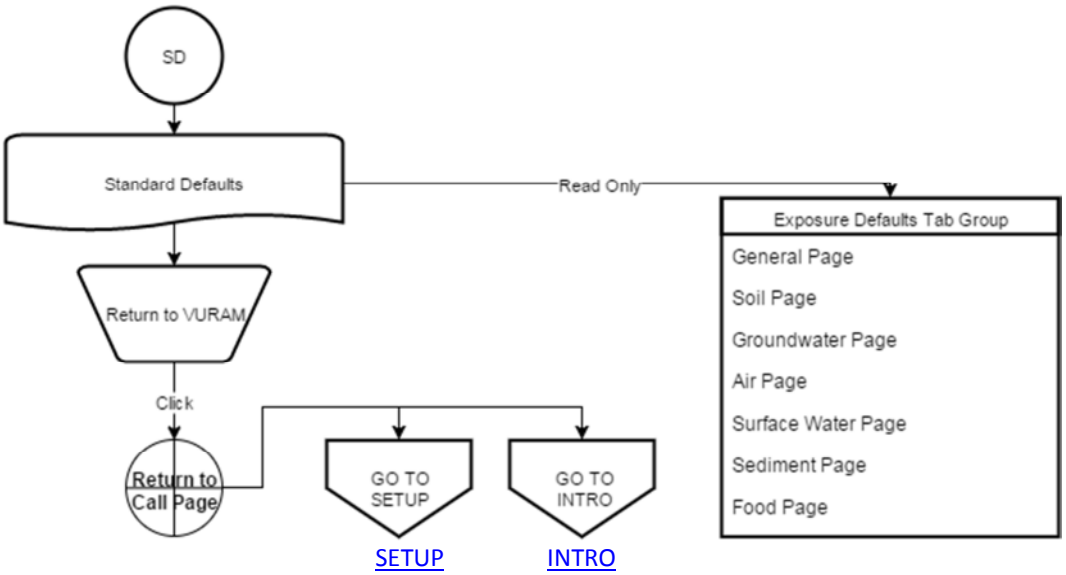
Standard Exposure Defaults Page



RSL exposure defaults and applicable VDEQ defaults are used where RSL values are not provided. VDEQ defaults are labeled as such.

There are 6 media specific tabs and a General tab, which includes exposure defaults applicable to most or all media. These defaults will also be displayed in the final report.

Note: Default values are displayed for reference only and not editable. VDEQ will update exposure defaults in line with EPA RSL when applicable.



SL Risk Assessment

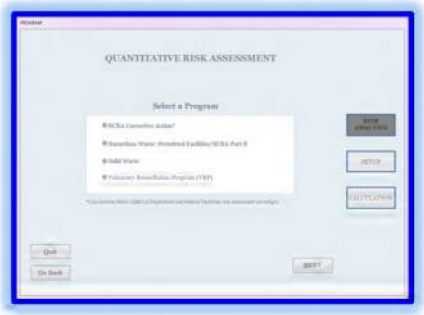
SCREENING LEVELS MODULE UNDER DEVELOPMENT

For QRAs performed under CERCLA, Federal Facilities, VRP, and RCRA Corrective Action, SL risk assessment is conducted to narrow down the list of site-specific constituents that need further evaluation.

VDEQ is developing interactive screening tables. This section will be updated once the SL Risk Assessment Module is incorporated into VURAM.

Note: Some of the SLs are determined by regulatory requirements and each program has its own set of screening values.

QRA Program Page



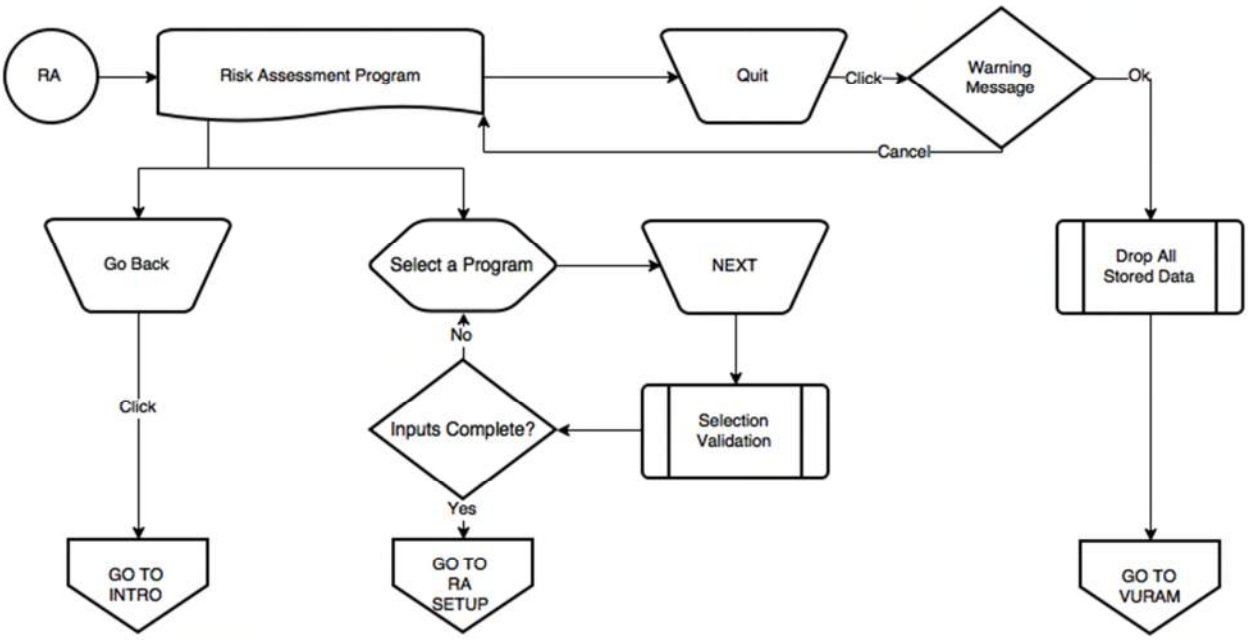
Selects regulatory program under which the QRA is being conducted: RCRA Corrective Action, Hazardous Waste: Permitted Facilities/RCRA Part B, Solid Waste, or Voluntary Remediation Program (VRP).

Only one regulatory program can be selected per each QRA calculation/report. This selection filters the chemicals available for risk analysis. Ensure the program selected reflects the appropriate regulatory program. If the regulatory program has not been determined contact VDEQ project manager for input. VRP may be selected for preliminary QRA if no regulatory program has been determined. Once a regulatory program has been established for a site/unit QRA may need to be re-evaluated under the assigned program.

Note: Only one program may be selected per QRA.

Note: The VRP construction scenario exposure defaults for soils differ from other programs. VRP exposure defaults are marked in the descriptions in both Appendix 4 and the Standard Defaults page.

Note: The Risk Analysis/Setup/Calculation boxes on the right side panel indicate the risk assessment steps. The current step is shown in a darker shade.



INTRO SETUP VURAM

QRA Setup Page

IMPROTANT! Site-specific COPCs and sample data should be collected and organized before beginning QRA.

Select **ONE** study area (Residential, Industiral/Commercial, Construction, Recreator, OR Trespasser). The selected regulatory program is displayed in orange at the top of this and subsequent pages.

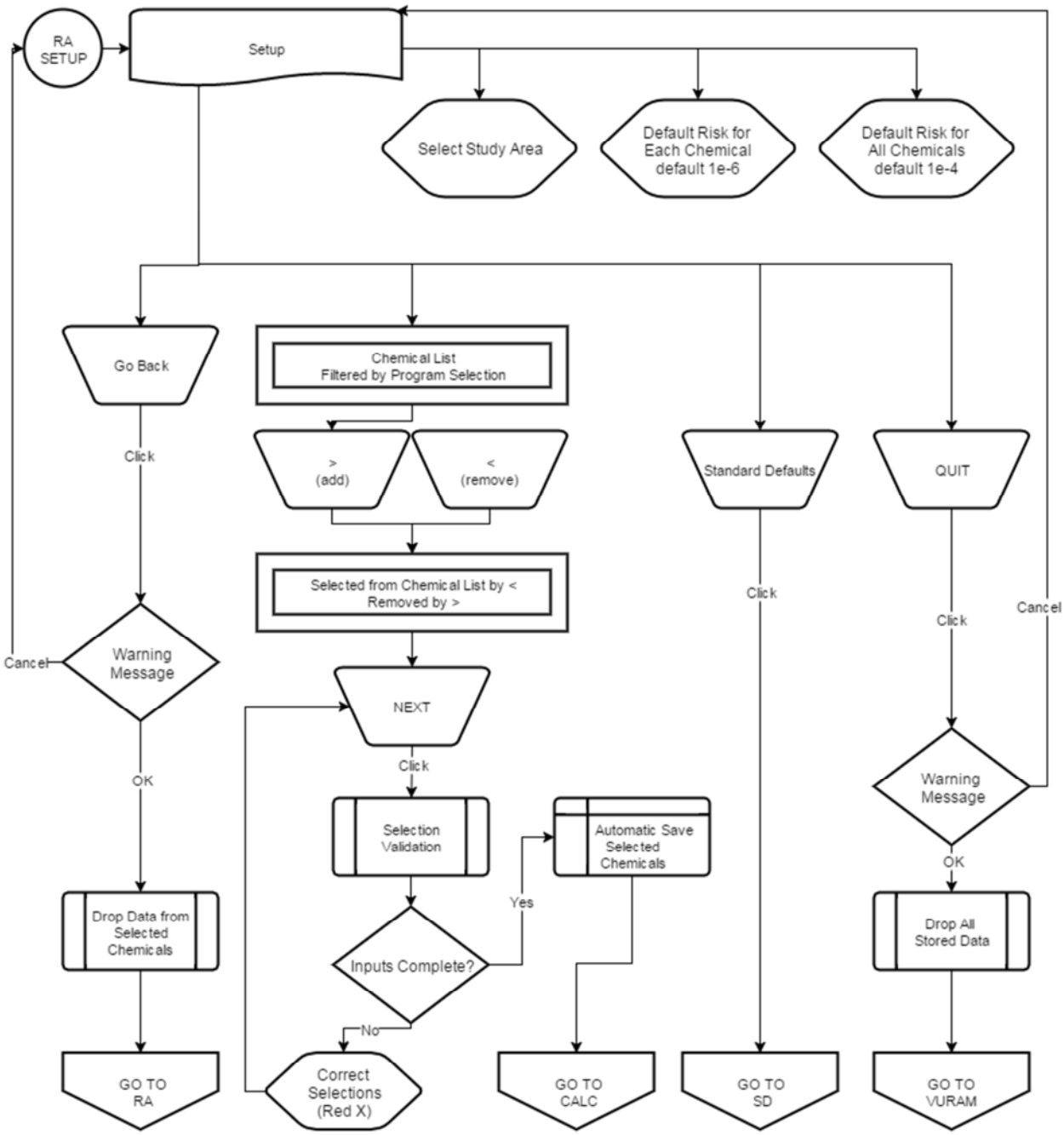
The **Chemicals List** provides chemical details for risk assessors and the interface to select site specific **COPCs** for **ALL** media identified in the CSM. The scroll bar on the bottom of the list can be used to view *Analyte* properties by scrolling right. Chemical names appear in VURAM as they are listed in the RSL table.

NOTE: The Contaminates of Potential Concern may show multiple entries of the same *Analyte* from the Chemical List. However, only one instance of each COPC will be stored for QRA computation.

NOTE: Only one study area can be selected per QRA. The study area selection and exposure pathway selection must reflect the CSM.

IMPORTANT! Select **ALL** chemicals for all the media that need to be included in site risk assessment. Returning to this page later in the VURAM process **WILL** cause all selections and entered data to be lost.

IMPORTANT! The selected risk level **must** be in consensus with VDEQ before it is entered in VURAM. If a risk level other than default is chosen without consulting with, and obtaining prior approval, from VDEQ, then the entered risk level may not be accepted as valid. See Acceptable Cancer Risk for more information.


RA SETUP
Setup
Select Study Area
Default Risk for Each Chemical default 1e-6
Default Risk for All Chemicals default 1e-4
Go Back
Click
Cancel
Warning Message
OK
Drop Data from Selected Chemicals
GO TO RA
Chemical List Filtered by Program Selection
> (add)
< (remove)
Selected from Chemical List by < Removed by >
NEXT
Click
Selection Validation
Inputs Complete?
Yes
No
Correct Selections (Red X)
Automatic Save Selected Chemicals
GO TO CALC
Standard Defaults
Click
GO TO SD
QUIT
Click
Cancel
Warning Message
OK
Drop All Stored Data
GO TO VURAM
RA
CALC
SD
VURAM

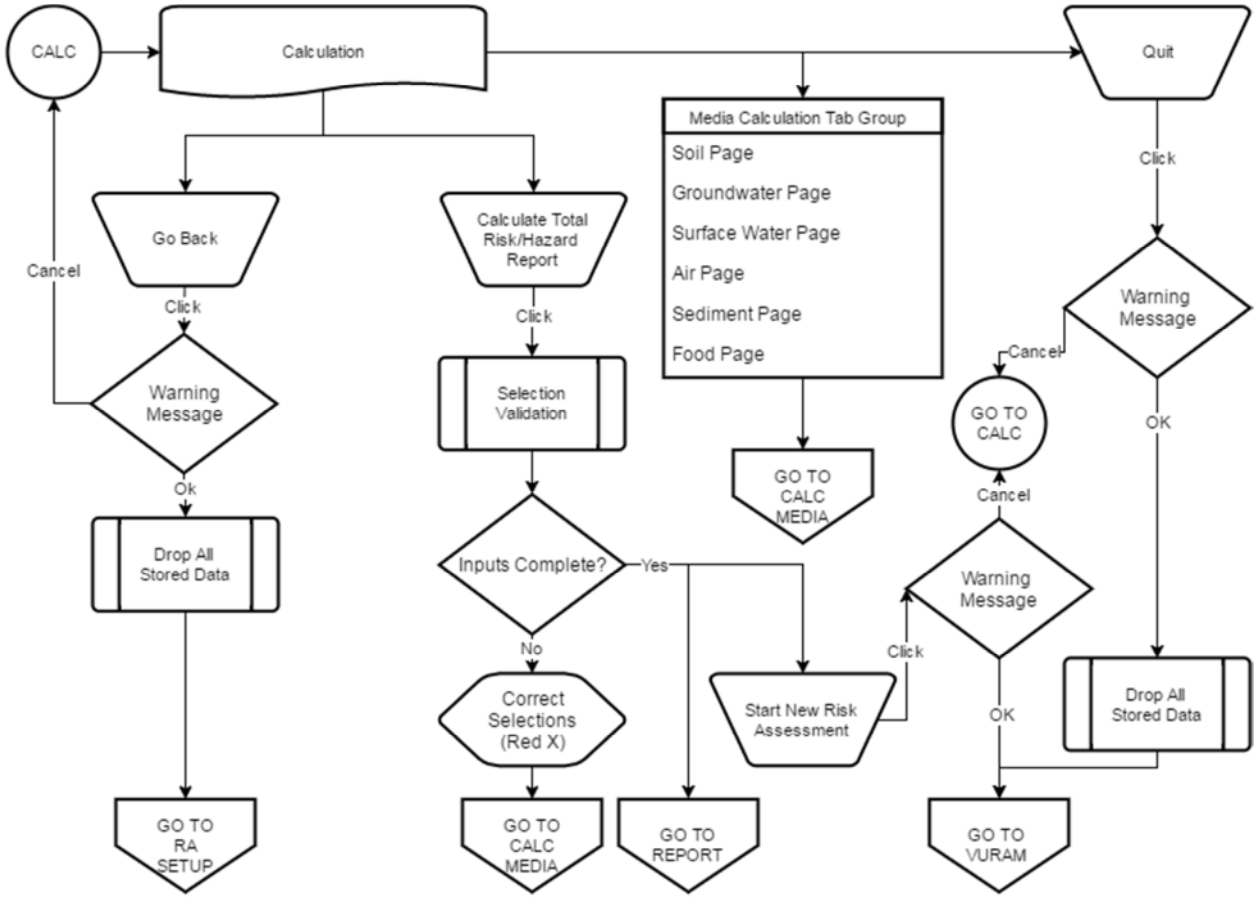
QRA Calculation Page

Before proceeding with QRA in VURAM data must be collected and the COPC concentrations must be entered/converted to the appropriate units as required and entered into the Concentrations page for each COPC selected in each media. Each media has a COPC list which may contain all or some of the site-specific COPCs. The table below provides a hypothetical example of media specific COPCs.

COPC	CAS	Soil EPC (mg/kg)	Groundwater EPC (ug/L)	Air EPC (ug/m3)
Aluminum	7429-90-5		220500	
Antimony (metallic)	7440-36-0	34.9	24.4	
Arsenic, Inorganic	7440-38-2	91.4	939	
Benzene	71-43-2	2.44		11.11
Benzo[a]pyrene	50-32-8	1.97		18.21
Mercury (elemental)	7439-97-6	2.8		9.98
Trichloroethylene	79-01-6	10.0		15.1

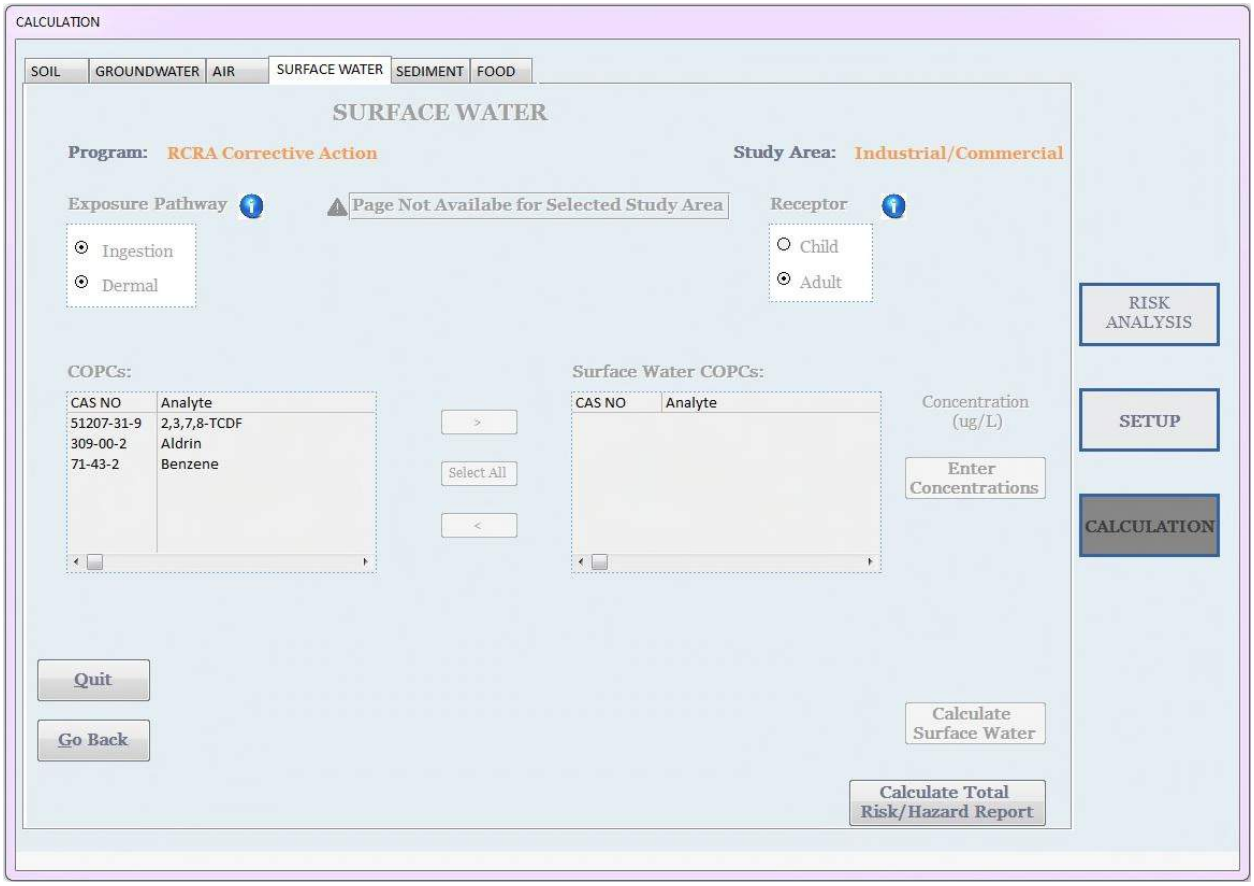
Six page tabs for Soil, Groundwater, Air, Surface Water, Sediment, and Food are available for QRA calculations based on Program and Setup selections. The appropriate exposure pathways and receptors are either preselected or available for selection. Use this page to select COPCs for each media to be included in the QRA based on the CSM.

FOR EACH media to be included in the QRA select media specific chemicals. Use the **Enter Concentrations** button to open the Concentrations page to enter EPCs for each COPC. Once concentrations have been entered and saved click the **Calculate Media** button to execute calculations for the media entered a green check mark will appear for each media calculated. Repeat these steps for each media. Once all media included in the CSM have been entered and calculated, click **Calculate Total Hazard/Risk Report** to generate the final QRA Report.


CALC
Calculation
Quit
Media Calculation Tab Group
Soil Page
Groundwater Page
Surface Water Page
Air Page
Sediment Page
Food Page
Click
Go Back
Cancel
Click
Warning Message
Ok
Drop All Stored Data
GO TO RA SETUP
Calculate Total Risk/Hazard Report
Click
Selection Validation
Inputs Complete?
Yes
No
Correct Selections (Red X)
GO TO CALC MEDIA
GO TO REPORT
GO TO CALC MEDIA
Start New Risk Assessment
Click
Warning Message
Cancel
OK
GO TO CALC
Cancel
Warning Message
OK
Drop All Stored Data
GO TO VURAM
SETUP
CALC MEDIA
REPORT
CALC MEDIA
VURAM

Calculation Media Specific Pages

Media options are restricted for calculation based on program and setup selections. If a media calculation page is not available refer to the Media Calculations Table lists availability of media based on the study area. Page availability in the table is marked as *No* and all exposure pathways and receptors are marked as *n/a*. The example below shows the Surface Water media as unavailable for the Industrial/Commercial study area, which reflects the table.

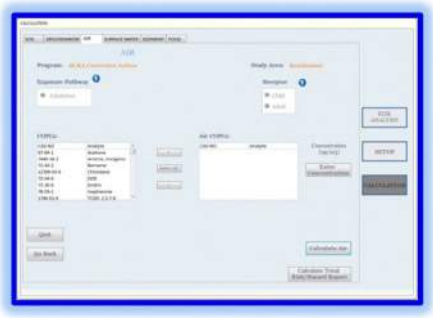


Each media tab has options for QRA calculations. Select COPCs for each media being calculated and click **Enter Concentrations**. Once concentrations have been entered and saved and **Calculate *Media*** run for **EACH** medium indicated by the CSM then click **Calculate Total Hazard/Risk Report**. If a required media tab is not available for the selected program and study area check that Setup and Program selections are correct. Both program and study area selections are displayed in orange at the top of the page for ease of reference.

IMPORTANT! At least one COPC must be selected and concentrations entered on a given media tab before clicking **Calculate *Media.***

NOTE: Construction Worker scenario uses subchronic toxicity values where available.

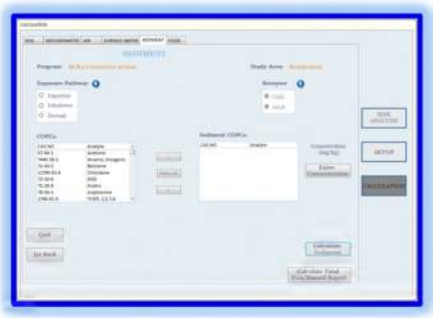
NOTE: Groundwater inhalation does NOT reflect the vapor intrusion pathway. Inhalation from groundwater refers to the inhalation of vapors during all uses of household water (e.g., showering, laundering, dish washing) and includes all possible exposures to volatilized air concentrations of contaminants that derive from contaminated tapwater in a residence.

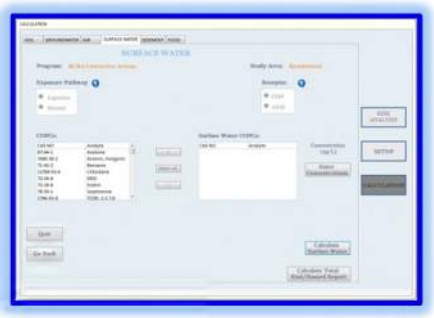


NOTE: Air concentrations –measured or calculated- in the air medium and can be used for evaluation inhalation hazard/risk from indoor (via vapor intrusion) or outdoor air exposure. The concentration input for this tab includes **ONLY ONE** of the following:

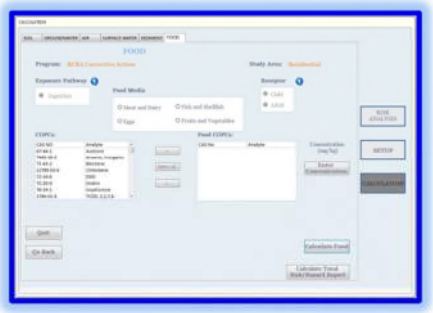
1. Measured concentration from one of the following data: sub-slab, shallow gas, deep soil gas, indoor air samples, or outdoor air samples.
2. Calculated air concentration from one of the following: groundwater to indoor air calculations, output from air dispersion model, or any model results used to generate fate-and-transport based air concentration.

For vapor intrusion evaluation where multiple lines of evidence are used, enter the media concentration that show **maximum** exceedance of screening levels (screening level module in VURAM is under development, please use VRP and RCRA CA websites to obtain the screening tables).



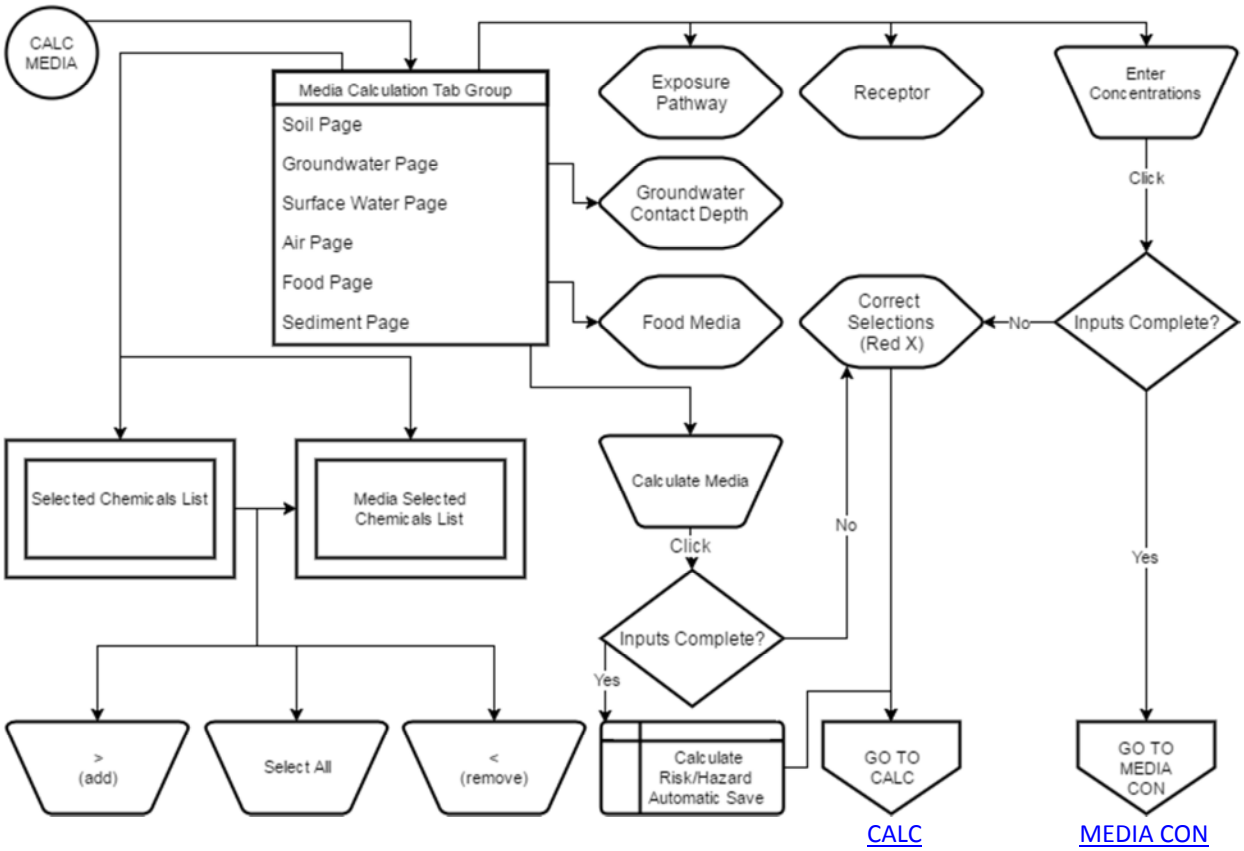


NOTE: Residential risk calculations for Surface Water and Sediment are run on recreator scenario values and exposure defaults. An information message is provided for these media tabs when the Residential study area is selected.



NOTE: The Food tab is available for the residential study area **ONLY**. Based on the CSM any combinations of Food Media may be selected. At least one Food Media option must be included if Food is included in QRA.

IMPORTANT! If QRA is non-residential and food risk is required then a separate VURAM session to calculate potential hazard/risk via food ingestion is necessary. In such case manually add food hazard/risk to report totals for final QRA results.


CALC MEDIA
Media Calculation Tab Group
Soil Page
Groundwater Page
Surface Water Page
Air Page
Food Page
Sediment Page
Exposure Pathway
Receptor
Enter Concentrations
Click
Groundwater Contact Depth
Food Media
Correct Selections (Red X)
No
Inputs Complete?
Selected Chemicals List
Media Selected Chemicals List
Calculate Media
Click
No
Yes
Inputs Complete?
Yes
> (add)
Select All
< (remove)
Calculate Risk/Hazard Automatic Save
GO TO CALC
GO TO MEDIA CON
CALC
MEDIA CON

Media Calculations Table

Media/Units	Study Area	Residential	Industrial /Commercial	Construction	Recreator	Trespasser
Soil (Composite) mg/kg	**Page Available†**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
	Exposure Pathway					
	Ingestion	Yes	Yes	Yes	Yes	Yes
	Inhalation	Yes	Yes	Yes	Yes	Yes
	Dermal	Yes	Yes	Yes	Yes	Yes
	Receptor					
	Child	Yes	No	No	Yes	Yes
	Adult	Yes	Yes	Yes	Yes	Yes
Groundwater µg/L	**Page Available**	**Yes**	**No**	**Yes**	**No**	**No**
	Exposure Pathway					
	Ingestion	Yes	n/a	*	n/a	n/a
	Inhalation	Yes	n/a	*	n/a	n/a
	Dermal	Yes	n/a	*	n/a	n/a
	Receptor					
	Child	Yes	n/a	No	n/a	n/a
	Adult	Yes	n/a	Yes	n/a	n/a
Air µg/m^3	**Page Available**	**Yes**	**Yes**	**No**	**No**	**No**
	Exposure Pathway					
	Inhalation	Yes	Yes	n/a	n/a	n/a
	Receptor					
	Child	Yes	No	n/a	n/a	n/a
	Adult	Yes	Yes	n/a	n/a	n/a
Surface Water µg/L	**Page Available**	**Yes**	**No**	**No**	**Yes**	**Yes**
	Exposure Pathway					
	Ingestion	Yes	n/a	n/a	Yes	Yes
	Dermal	Yes	n/a	n/a	Yes	Yes
	Receptor					
	Child	Yes	n/a	n/a	Yes	Yes
	Adult	Yes	n/a	n/a	Yes	Yes
Sediment mg/kg	**Page Available**	**Yes**	**No**	**No**	**Yes**	**Yes**
	Exposure Pathway					
	Ingestion	Yes	n/a	n/a	Yes	Yes
	Inhalation	Optional	n/a	n/a	Optional	Optional
	Dermal	Yes	n/a	n/a	Yes	Yes
	Receptor					
	Child	Yes	n/a	n/a	Yes	Yes
	Adult	Yes	n/a	n/a	Yes	Yes
Food mg/kg	**Page Available**	**Yes**	**No**	**No**	**No**	**No**
	Exposure Pathway					
	Ingestion	Yes	n/a	n/a	n/a	n/a
	Receptor**					
	Child	N/A	n/a	n/a	n/a	n/a
	Adult	N/A	n/a	n/a	n/a	n/a

† Soil Page NOT Available for Solid Waste Program Selection
*Exposure pathway for construction worker is dependent on depth to groundwater.
**Food calculations are not age specific. Hazard totals are reported under Non-Cancer Adult.

Media Concentrations

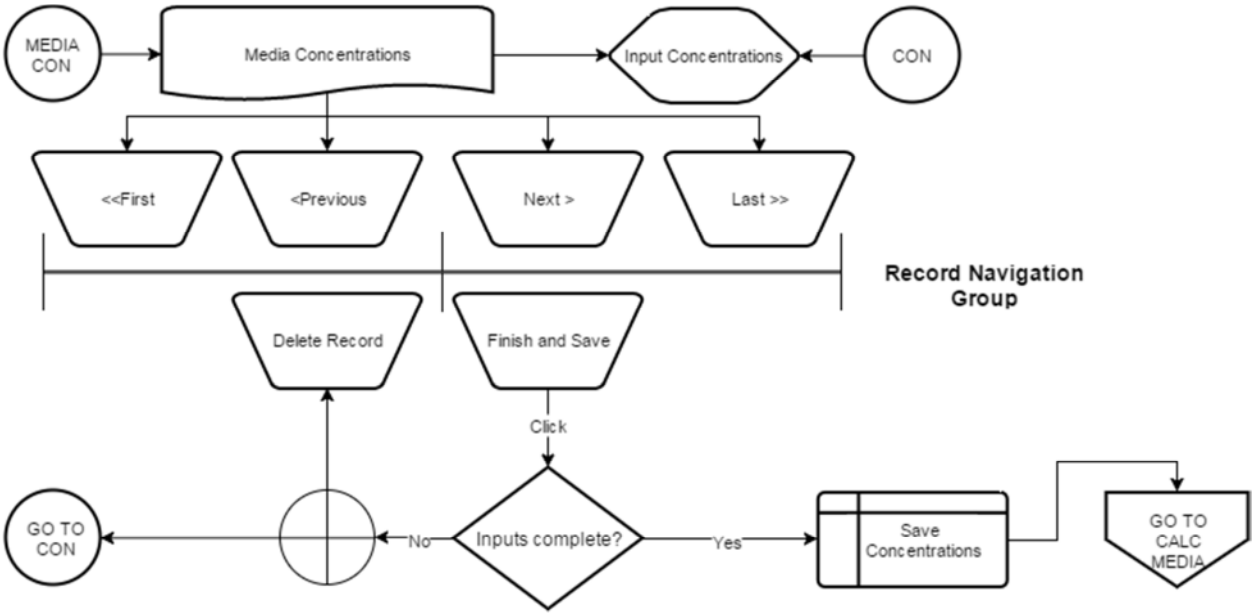
The table at the bottom of the page is not available for data entry and may be navigated by mouse or keyboard arrows. The record navigation buttons under the concentration box each contain an underlined letter used for Alt+{Key} (example Alt+N = Next >) navigation. Tab navigation is disabled for these controls. The Enter/Return key will proceed to the next record when entering concentration values.

Enter EPCs in the appropriate concentration field for each chemical selected. Concentrations entered must be greater than zero. Concentrations for **ALL** chemicals must be entered before proceeding. Close the page using the Red X/close button to return to the Calculations page if adding or removing chemicals. When the concentration for the last chemical is entered, click **Finish and Save** to return to the Calculations page.

NOTE: The last record will not display its value in table until saved or upon navigation to another record. The value is recorded in the underlying table once saved.

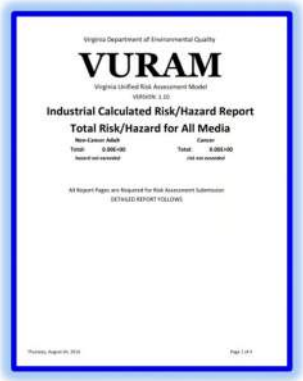
NOTE: Measured air concentration or calculated/modeled air concentrations may be used as input. Measured indoor air concentrations, calculated indoor air concentrations using measured sub-slab soil gas/shallow soil gas/deep soil gas/groundwater, or calculated groundwater to shower air concentrations can be used in QRA to estimate potential hazard/risk via air inhalation.

NOTE: Food media concentrations must be entered for **ALL** selected Food Media (Meat and Dairy, Eggs, Fish and Shellfish, and Fruits and Vegetables).



CALC MEDIA

Understanding the Report



The Total Hazard/Risk Report is broken down by selected media and by chemical. Individual hazard/risk levels are given for each selected chemical and each applicable exposure pathway where all values necessary for computation are available. Chemicals without computed hazard/risk values do not have associated values within VURAM and are reported as blank. VURAM does not compute uncertainty. However, blank values must be included in qualitative uncertainty discussion section of Risk Assessment report.

Media specific results for selected chemicals are displayed in the following order: Surface Water, Soil, Sediment, Groundwater, Food, and Air. If a media is not selected then it will not appear in the report.

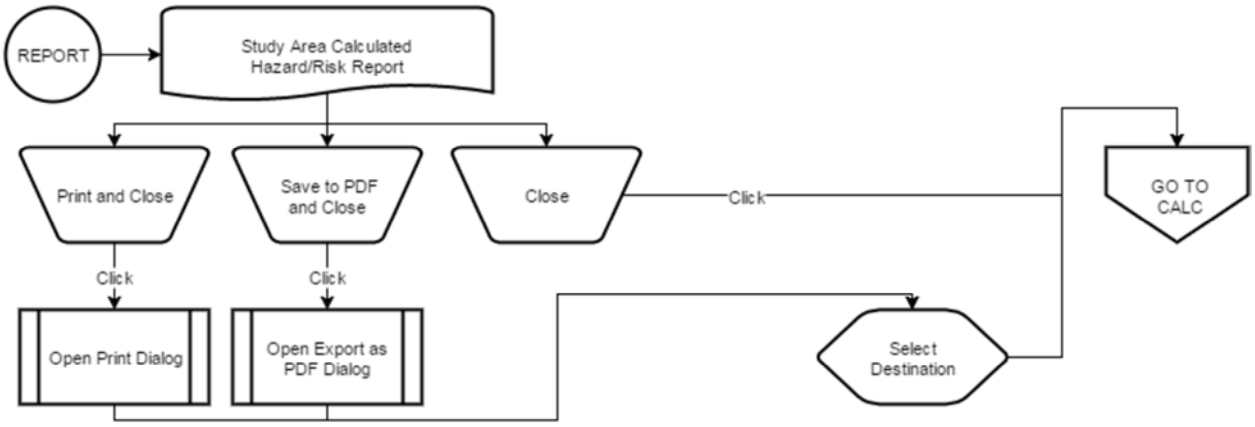
For chemicals with both carcinogenic and non-carcinogenic effects hazard and risk are calculated. Non-carcinogenic hazard quotients are calculated separately for adult and child where applicable. Carcinogenic risk is lifetime and not calculated separately for adult/child. See the Media Calculations Table for details.

Print and Close, **Save to PDF and Close**, and **Close** buttons are provided at the top of the report. The user command buttons on the report are displayed in the on screen Report View only and will **NOT** be visible or available in printed or PDF report outputs.

IMPORTANT! Once the report is closed changes can be made on the Calculation page as needed. Any changes will require re-calculation of the media affected and of the Total Hazard/Risk Report. Closing VURAM without saving/printing the report will result in the loss of **ALL** information entered. Ensure the report is saved/printed before closing VURAM or MS Access.

To run a new risk assessment under same or different regulatory program **Close** the report and select **Quit** from the Calculations page to return to the main VURAM page. Ensure the final report is saved with all updates. A report for each QRA must be included in the final Human Health Risk Assessment report submitted to VDEQ for review and approval. A PDF copy is recommended for records and for electronic submission.

Note: Due to unique media selection for Food a sub-report is displayed when food is included in QRA. Total hazard/risk for food appears in the main section of the report and is a sum of all selected food media calculated. As with all other media, if food is not selected it will not appear in the report.


REPORT
Study Area Calculated Hazard/Risk Report
Print and Close
Save to PDF and Close
Close
Click
GO TO CALC
Click
Click
Open Print Dialog
Open Export as PDF Dialog
Select Destination

CALC

Report Title Page

Virginia Department of Environmental Quality

VURAM

Virginia Unified Risk Assessment Model

VERSION: 1.10

1

Residential Calculated Hazard/Risk Report

Total Hazard/Risk for All Media

2

Non-Cancer Adult	Non-Cancer Child	Cancer
Total: 2.17E+01	**Total: 2.17E+01**	**Total: 1.10E-03**
Hazard Exceeded!	***Hazard Exceeded!***	***Risk Exceeded!***

3

All Report Pages are Required for Risk Assessment Submission

DETAILED REPORT FOLLOWS

Wednesday, October 05, 201 4

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Page 1 of 7

1. **Report Title:** Indicates version of VURAM and selected Study Area: Residential, Industrial (Composite for soil), Construction, Recreator, or Trespasser.
   NOTE: The version number is indicated in the report header. Check VDEQ website for the latest version of VURAM and ensure it is used for risk assessment. The newest available version of VURAM supersedes all previous versions.
   Return to Title Page
2. **Total Hazard/Risk:** Calculated by summing hazard/risk from all chemicals and all exposure pathways across all media for QRA. This represents site-wide QRA results to be used for risk based decision making.
   Note: Non-carcinogenic hazard quotients are calculated separately for adult and child where applicable. Carcinogenic risk is lifetime and **NOT** calculated separately for adult/child.
   Return to Title Page
3. **Hazard/Risk Exceeded:** Message highlights risk assessment totals that exceed site-wide risk based performance criteria. This message will be visible ONLY if the site-wide risk based criteria are exceeded.
   Return to Title Page
4. **Date Stamp:** Pulled automatically from system time settings.
   Return to Title Page
5. **Page Number:** Indicator automatically generated by VURAM.
   Return to Title Page

Detailed Report Main Section

Program: RCRA Corrective Action 6

Risk Based Performance Criteria

Default Hazard Index	Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

7

Soil 8

Analyte: Benzene 9
CAS: 71-43-2

		mg/kg 11	Calculated Hazard/Risk Values 12		
Concentration:	1.00E+01				
RfDo:	4.00E-03	**Non-Cancer Adult**	**Non-Cancer Child**	**Cancer**	
RfCi: 10	3.00E-02	Ingestion: 3.00E-03	Ingestion: 3.20E-02	Ingestion: 7.91E-07	
SFO:	5.50E-02	Dermal:	Dermal:	Dermal:	
IUR:	7.80E-06	Inhalation: 9.03E-02	Inhalation: 9.03E-02	Inhalation: 7.85E-06	
Mutagen:		**Total: 9.33E-02**	**Total: 1.22E-01**	**Total: 8.64E-06**	
		% Contribution to Media Hazard/Risk 47.28%	49.78%	95.32%	13

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Risk Exceeded! mg/kg	*Non-Cancer Adult*	*Non-Cancer Child*	*Cancer*
Recommended Acceptable Concentration	*N/A*	*N/A*	*1.16E+00*

Analyte: Tetrachloroethylene
CAS: 127-18-4

		mg/kg	Calculated Hazard/Risk Values		
Concentration:	1.00E+01				
RfDo:	6.00E-03	**Non-Cancer Adult**	**Non-Cancer Child**	**Cancer**	
RfCi:	4.00E-02	Ingestion: 2.00E-03	Ingestion: 2.13E-02	Ingestion: 3.02E-08	
SFO:	2.10E-03	Dermal:	Dermal:	Dermal:	
IUR:	2.60E-07	Inhalation: 1.02E-01	Inhalation: 1.02E-01	Inhalation: 3.94E-07	
Mutagen:		**Total: 1.04E-01**	**Total: 1.23E-01**	**Total: 4.24E-07**	
		% Contribution to Media Hazard/Risk 52.72%	50.22%	4.68%	

mg/kg	*Non-Cancer Adult*	*Non-Cancer Child*	*Cancer*
Recommended Acceptable Concentration	*N/A*	*N/A*	*N/A*

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Total Calculated Hazard/Risk For Media: Soil

Non-Cancer Adult		**Non-Cancer Child**		**Cancer**	
Ingestion:	4.99E-03	Ingestion:	5.33E-02	Ingestion:	8.21E-07
Dermal:	0.00E+00	Dermal:	0.00E+00	Dermal:	0.00E+00
Inhalation:	1.92E-01	Inhalation:	1.92E-01	Inhalation:	8.24E-06
Total:	**1.97E-01**	**Total:**	**2.46E-01**	**Total:**	**9.06E-06**

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Wednesday, October 05, 2016 Page 2 of 7

Program: **RCRA Corrective Action**

Default Hazard Index	Risk Based Performance Criteria: Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

Food

Analyte: **Benzene**
CAS: **71-43-2**

		mg/kg		Calculated Hazard/Risk Values			
Concentration:		**Non-Cancer Adult**		**Non-Cancer Child**		**Cancer**	
RfDo:	4.00E-03	Ingestion:	1.29E+01	Ingestion:	1.29E+01	Ingestion:	1.05E-03
RfCi:		Dermal:		Dermal:		Dermal:	
SFO:	5.50E-02	Inhalation:		Inhalation:		Inhalation:	
IUR:		**Total:**	**1.29E+01**	**Total:**	**1.29E+01**	**Total:**	**1.05E-03**
Mutagen:							
% Contribution to Media Hazard/Risk		60.00%		60.00%		96.32%	

17 18

	mg/kg	Non-Cancer Adult	Non-Cancer Child	Cancer
Hazard Exceeded Risk Exceeded!		*Non-Cancer Adult*	*Non-Cancer Child*	*Cancer*
Recommended Acceptable Concentration		*See Detailed Food Report*	*See Detailed Food Report*	*See Detailed Food Report*

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Analyte: **Tetrachloroethylene**
CAS: **127-18-4**

		mg/kg		Calculated Hazard/Risk Values			
Concentration:		**Non-Cancer Adult**		**Non-Cancer Child**		**Cancer**	
RfDo:	6.00E-03	Ingestion:	8.59E+00	Ingestion:	8.59E+00	Ingestion:	4.02E-05
RfCi:		Dermal:		Dermal:		Dermal:	
SFO:	2.10E-03	Inhalation:		Inhalation:		Inhalation:	
IUR:		**Total:**	**8.59E+00**	**Total:**	**8.59E+00**	**Total:**	**4.02E-05**
Mutagen:							
% Contribution to Media Hazard/Risk		40.00%		40.00%		3.68%	

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	mg/kg	Non-Cancer Adult	Non-Cancer Child	Cancer
Hazard Exceeded Risk Exceeded!		*Non-Cancer Adult*	*Non-Cancer Child*	*Cancer*
Recommended Acceptable Concentration		*See Detailed Food Report*	*See Detailed Food Report*	*See Detailed Food Report*

Total Calculated Hazard/Risk For Media: **Food**

Non-Cancer Adult		**Non-Cancer Child**		**Cancer**	
Ingestion:	2.15E+01	Ingestion:	2.15E+01	Ingestion:	1.09E-03
Dermal:	0.00E+00	Dermal:	0.00E+00	Dermal:	0.00E+00
Inhalation:	0.00E+00	Inhalation:	0.00E+00	Inhalation:	0.00E+00
Total:	**2.15E+01**	**Total:**	**2.15E+01**	**Total:**	**1.09E-03**

Wednesday, October 05, 2016 Page 3 of 7

Program: **RCRA Corrective Action**

Risk Based Performance Criteria

Default Hazard Index	Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

Total Hazard/Risk for All Media

Non-Cancer Adult		Non-Cancer Child		Cancer	
Ingestion:	2.15E+01	Ingestion::	2.15E+01	Ingestion::	1.09E-03
Dermal:	0.00E+00	Dermal:	0.00E+00	Dermal:	0.00E+00
Inhalation:	1.92E-01	Inhalation:	1.92E-01	Inhalation:	8.24E-06
Total:	**2.17E+01**	**Total:**	**2.17E+01**	**Total:**	**1.10E-03**
Hazard Exceeded!		***Hazard Exceeded!***		***Risk Exceeded!***	

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6. **Program:** Reflects selection from Program page.
   Return to Detailed Report
7. **Risk Based Performance Criteria:** Default Risk for Each Chemical and Default Risk for All Chemicals selected from Setup page. See Acceptable Noncancer Hazard and Cancer Risk for more information regarding selection options.
   Note: Default HI is always 1.
   Return to Detailed Report
8. **Media Header:** Found at the top of each group of chemicals analyzed. Media header is repeated on each page that contains analyzed chemicals.
   Return to Detailed Report
9. **CAS and Analyte:** Chemical CAS and chemical name.
   Return to Detailed Report
10. **Chemical Specific Values:** Concentrations entered on Media Concentrations pages. RfDo, RfCi, SFO, IUR, and Mutagen pull from chemical information tables in VURAM. Chemical specific values are displayed on the Setup page Chemical List.
    Return to Detailed Report
11. **Units:** Indicates the units in which EPCs are to be entered into VURAM. Units are media specific and hard coded.
    Return to Detailed Report
12. **Calculated Hazard/Risk Values Table:** Results are reported when all chemical values necessary for computation are available. Table totals are simple sums of columns.
    Return to Detailed Report
13. **% Contribution to Media Risk:** This represents percentage contribution of hazard/risk from a chemical to the overall media hazard/risk. This value helps identify hazard/risk driver(s) for each media and can guide management –based remediation/cleanup decisions.
    Return to Detailed Report
14. **Hazard/Risk Exceeded:** Messages displayed **ONLY** when individual risk for a chemical exceeds default acceptable risk (1E-6 or selected default) or when HQ exceeds default acceptable hazard quotient of 1. When individual risk/HQ is below threshold levels these messages will not show in the report.
    Return to Detailed Report
15. **Recommended Acceptable Concentrations:** These values are calculated for COPCs that exceed selected risk based performance criteria for individual risk OR HQ. These concentration levels that will meet HI/risk based performance criteria/goal for each chemical for the applicable media and may be considered as final clean-up goal for human health, direct contact, or for initiating site-specific project-management based decision making.
    These cleanup goals are strictly based on the use of available site specific data and do not reflect management option and/or decisions or regulatory program needs. These values are calculated for Residential and Industrial reports **ONLY.** If hazard/risk levels are not exceeding the risk based performance goals *N/A* will be displayed. If these concentrations are used as final remediation/cleanup goals and the facility demonstrates that the media has met these concentration levels then a follow-up/post-remediation QRA is not needed.
    Note: If different acceptable concentrations for carcinogenic and non-carcinogenic effect are provided, the lower of the two concentrations must be used as remediation/cleanup goal.
    Note: Groundwater cleanup goals are designed to protect human health risk via drinking water regardless of projected water use or MCLs. These goals must be evaluated, and modified if

needed, against fate and transport requirements.
Return to Detailed Report

16. **Media Totals:** Media-specific sum of hazard/risk for all chemicals and exposure pathways for specific media **ONLY**.
    Return to Detailed Report
17. **Food Concentrations:** Not shown on the main report section, displayed by food media on the Detailed Food Report subsection.
    Return to Detailed Report
18. **Food Recommended Acceptable Concentrations:** Sum of hazard/risk for all selected food media (fish and shellfish, eggs, meat and dairy, and/or fruits and vegetables) for each chemical. Food media details can be found in Detailed Food Report section of the report.
    NOTE: Non-carcinogen food calculations are not age specific. Non-Cancer hazard is reported to BOTH Child and Adult receptors.
    Return to Detailed Report
19. **Food Analyte Totals:** Not shown on main report section, values are calculated for selected food media (fish and shellfish, eggs, meat and dairy, and/or fruits and vegetables) for each chemical in Detailed Food Report section of the report.
    Return to Detailed Report
20. **Food Media Totals:** Sum of hazard/risk for all selected food media (fish and shellfish, eggs, meat and dairy, and/or fruits and vegetables) for all chemicals in Food media calculation.
    NOTE: Non-carcinogen food calculations are not age specific. Non-Cancer hazard is reported to BOTH Child and Adult receptors.
    Return to Detailed Report
21. **Total Hazard/Risk for All Media:** Site wide hazard/risk for all selected media. Calculated by summing hazard/risk from all chemicals and all exposure pathways across all media for QRA. These totals are also displayed on the report Title Page.
    Return to Detailed Report

Detailed Food Report Subsection

Program: **RCRA Corrective Action**

Risk Based Performance Criteria

Default Hazard Index	Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

Detailed Residential Food Report

Analyte: Benzene
CAS: 71-43-2

Concentrations	(mg/kg)
Meat/Dairy:	10
Eggs:	10
Fish/Shellfish:	
Fruits/Vegetables:	

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Calculated Hazard/Risk Values

23

Non-Cancer		Cancer	
Meat/Dairy:	8.39E+00	Meat/Dairy:	6.86E-04
Eggs:	4.49E+00	Eggs:	3.67E-04
Fish/Shellfish:		Fish/Shellfish:	
Fruits/Vegetables:		Fruits/Vegetables:	
Total:	**1.29E+01**	**Total:**	**1.05E-03**
% Contribution to Media Risk	*60.00%*		*96.32%*

24

25

26

Recommended Acceptable Concentrations		*Meat/Dairy*	*Eggs*	*Fish/Shellfish*	*Fruits/Vegetables*
Hazard Exceeded!	*Non-Cancer*	*1.19E+00*	*2.22E+00*	*N/A*	*N/A*
Risk Exceeded!	*Cancer*	*1.46E+04*	*2.72E+04*	*N/A*	*N/A*

Analyte: Tetrachloroethylene
CAS: 127-18-4

Concentrations	(mg/kg)
Meat/Dairy:	10
Eggs:	10
Fish/Shellfish:	
Fruits/Vegetables:	

Calculated Hazard/Risk Values

Non-Cancer		Cancer	
Meat/Dairy:	5.59E+00	Meat/Dairy:	2.62E-05
Eggs:	3.00E+00	Eggs:	1.40E-05
Fish/Shellfish:		Fish/Shellfish:	
Fruits/Vegetables:		Fruits/Vegetables:	
Total:	**8.59E+00**	**Total:**	**4.02E-05**
% Contribution to Media Risk	*40.00%*		*3.68%*

Recommended Acceptable Concentrations		*Meat/Dairy*	*Eggs*	*Fish/Shellfish*	*Fruits/Vegetables*
Hazard Exceeded!	*Non-Cancer*	*1.79E+00*	*3.34E+00*	*N/A*	*N/A*
Risk Exceeded!	*Cancer*	*3.82E+05*	*7.13E+05*	*N/A*	*N/A*

Total Hazard/Risk For Media: Detailed Food

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Non-Cancer		Cancer	
Meat and Dairy:	1.40E+01	Meat and Dairy:	7.12E-04
Eggs:	7.49E+00	Eggs:	3.81E-04
Fish and Shellfish:	0.00E+00	Fish and Shellfish:	0.00E+00
Fruits and Vegetables:	0.00E+00	Fruits and Vegetables:	0.00E+00
Total:	**2.15E+01**	**Total:**	**1.09E-03**

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22. **Food Media Concentrations:** Entered on Media Concentration pages. Displays only food group specific EPC. For chemical specific parameters see the Food Section of the Main Report.
    Return to Detailed Food Report
23. **Calculated Hazard/Risk Values Table:** Results are reported when all necessary for computation are available. Each column provides food-group specific hazard/ risk.
    Note: Concentrations **MUST** be entered for all food media selected. Therefore food media not selected will not have totals.
    Return to Detailed Food Report
24. **Total:** These are sum of hazard/risk from all food media for each chemical. This value is same as what is displayed on the Food section of the main Report.
    Return to Detailed Food Report
25. **% Contribution to Hazard/Risk:** This represents percentage contribution of hazard/risk from a chemical to the overall food hazard/risk. This value helps identify hazard/risk driver(s), which in turn can help make management-based remediation/cleanup decisions.
    Return to Detailed Food Report
26. **Recommended Acceptable Concentration:** Displays acceptable concentration for each food group. These calculated values are shown for chemicals that exceed risk based performance criteria/goal for individual hazard/risk. If multiple acceptable levels are provided the lowest value must be selected as remediation/cleanup goal or site specific management-based decision making. Where hazard/risk levels are not exceeding the risk based performance goals *N/A* is displayed.
    Return to Detailed Food Report
27. **Total Hazard/Risk Food:** Represent the sum of hazard/risk from all chemicals for each food media and total hazard/risk from all chemicals and all food media combined. This value is also reported in the Food section of the Main Report under **BOTH** Non-Cancer Child and Non-Cancer Adult.
    Return to Detailed Food Report

Report Exposure Defaults

Program: **RCRA Corrective Action**

Default Hazard Index	Risk Based Performance Criteria Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

Residential Exposure Default Values 28

Description	Value
Residential Soil Adherence Factor - adult (mg/cm2)	0.07
Residential Soil adherence Factor - child (mg/cm2)	0.2
Residential Averaging Time (days/yr)	365
Residential Body Weight - adult (kg)	80
Residential Body Weight - child (kg)	15
Residential Soil Mutagenic Dermal Contact Factor - age adjusted (mg/kg)	428260
Residential Soil Dermal Contact Factor - age adjusted (mg/kg)	103390
Residential Groundwater Mutagenic Dermal Contact Factor - age adjusted (cm2-event/kg)	8191633
Residential Groundwater Dermal Contact Factor - age adjusted (cm2-event/kg)	2610650
Residential Total Exposure Duration - child + adult (yr)	26
Residential Exposure Duration - adult (yr)	20
Residential Exposure Duration - child (yr)	6
Residential Exposure Frequency (days/yr)	350
Residential Exposure Frequency - adult (days/yr)	350
Residential Exposure Frequency - child (days/yr)	350
Residential Air Inhalation Exposure Time (hrs/day)	24
Residential Exposure Time - adult (hrs/day)	24
Residential Exposure Time - child (hrs/day)	24
Residential Groundwater Exposure Time -adult (hr/event)	0.71
Residential Groundwater Exposure Time -age adjusted (hr/event)	0.6708
Residential Groundwater Exposure Time - child (hr/event)	0.54
Residential Groundwater Inhalation Exposure Time (hrs/day)	24
Residential Soil Exposure Time (hrs/day)	24
Residential Groundwater Events (event/day)	1

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Program: RCRA Corrective Action

Default Hazard Index	Risk Based Performance Criteria Default Risk for Each Chemical	Default Risk for All Chemicals
1.00E+00	1.00E-06	1.00E-04

Residential Mutagenic Drinking Groundwater Ingestion Rate - age adjusted (L/kg)	1019.9
Residential Mutagenic Soil Ingestion Rate - age adjusted (mg-yr/kg-day)	166833.33
Residential Drinking Groundwater Ingestion Rate - age adjusted (L/kg)	327.95
Residential Soil Ingestion Rate - age adjusted (mg-yr/kg-day)	36750
Residential Air Inhalation Exposure Duration Mutagen Calculated - age adjusted (hr)	604800
Residential Groundwater Inhalation Exposure Duration Mutagen Calculated - age adjusted (d	25200
Residential Soil Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)	25200
Residential Food Eggs Ingestion Rate (mg/day)	150000
Residential Food Fish/Shellfish Ingestion Rate (mg/day)	54000
Residential Food Fruit/Vegetables Ingestion Rate (mg/day)	122000
Residential Food Meat/Dairy (mg/day)	280000
Residential Soil Ingestion Rate - adult (mg/day)	100
Residential Soil Ingestion Rate - child (mg/day)	200
Residential Drinking Groundwater Ingestion Rate - adult (L/day)	2.5
Residential Drinking Groundwater Ingestion Rate - child (L/day)	0.78
LifeTime Residential/Industrial/Construction/Recreator/Trespasser (yrs)	70
Residential Soil Surface Area - adult (cm2/day)	6032
Residential Soil Surface Area -child (cm2/day)	2373
Residential Water Surface Area - adult (cm2/day)	19652
Residential Water Surface Area -child (cm2/day)	6365

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28. **Exposure Defaults:** List of exposure defaults used for the calculations displayed for information purposes and for documenting input assumptions for QRA.
    Note: This list contains **ALL** defaults needed for study-area specific calculations and may include exposure defaults for media that were not selected in the QRA.
    Return to Report Exposure Defaults

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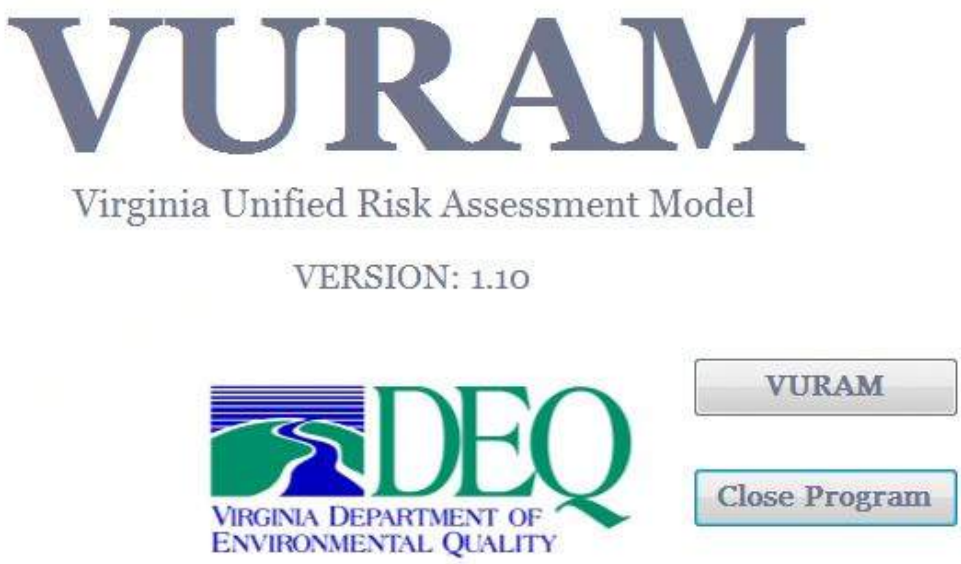
Appendices

Appendix 1. Full Size Page Images

All image option selections, chemicals, and concentration values are for demonstrative purposes **ONLY** and do not represent any actual site data or analysis. Individual model runs of VURAM will be site-specific. *Return to Detailed Page* links below each image will return to the corresponding page under the Using VURAM Software Model section of this manual.

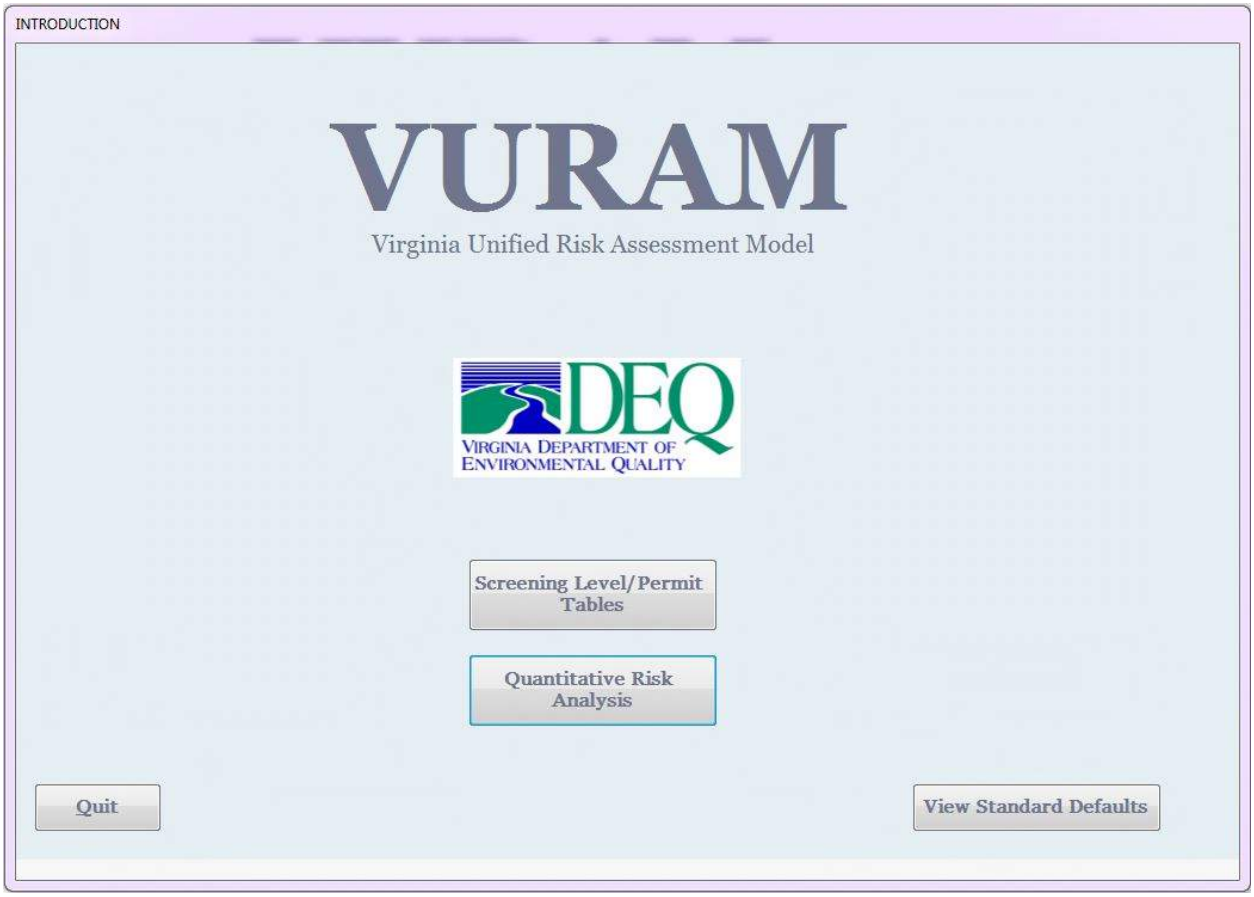
VURAM



Return to Hyperlink Example

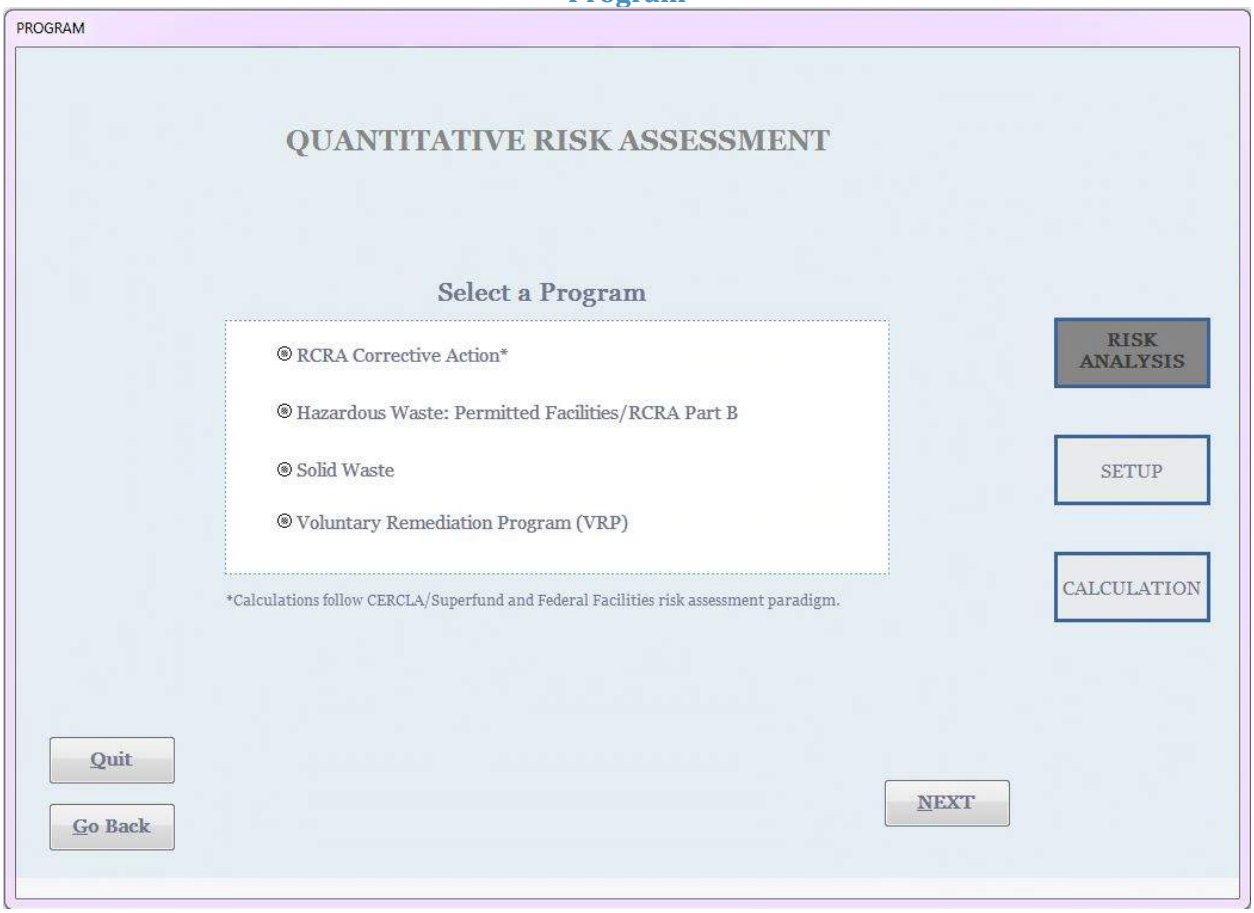
Return to Detailed Page

Introduction



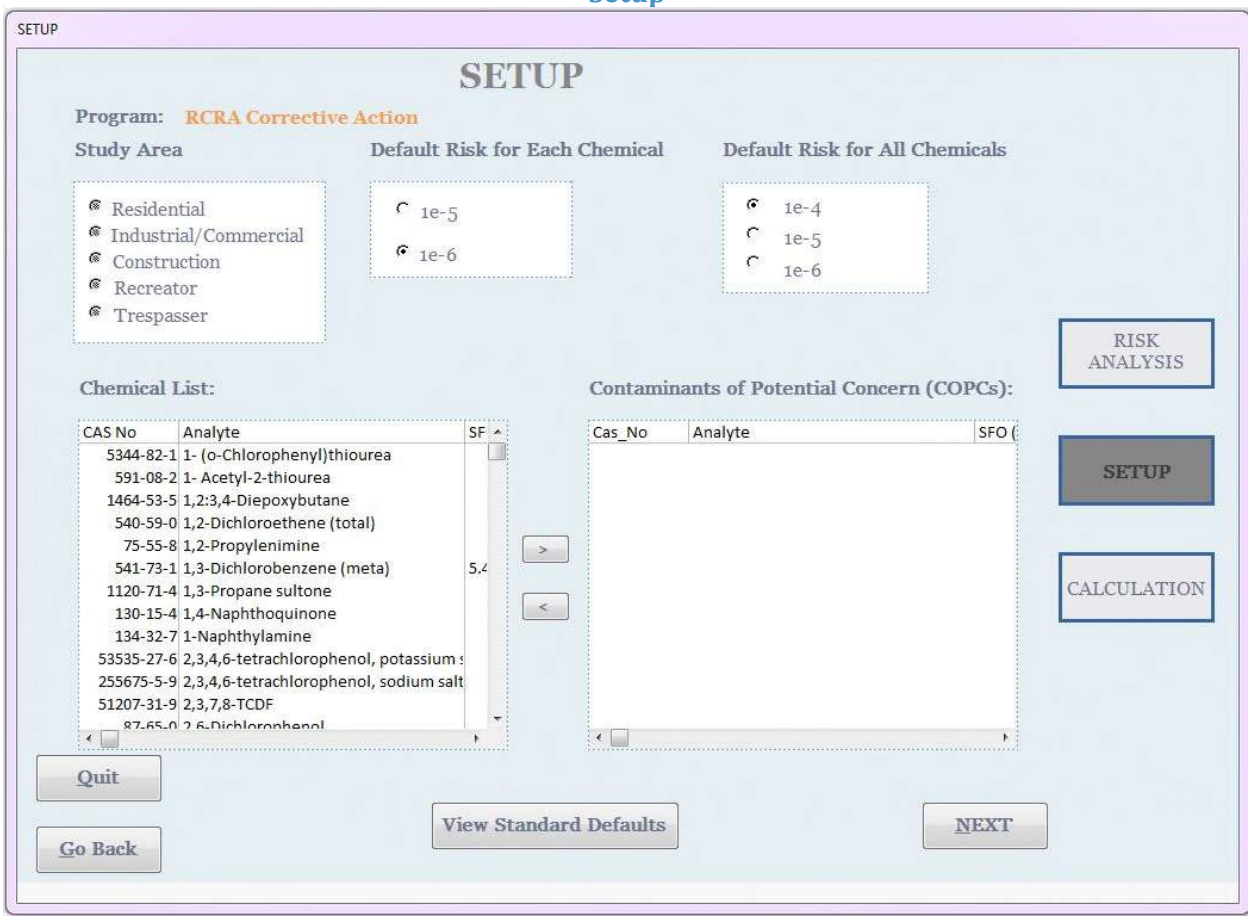
Return to Detailed Page

Program



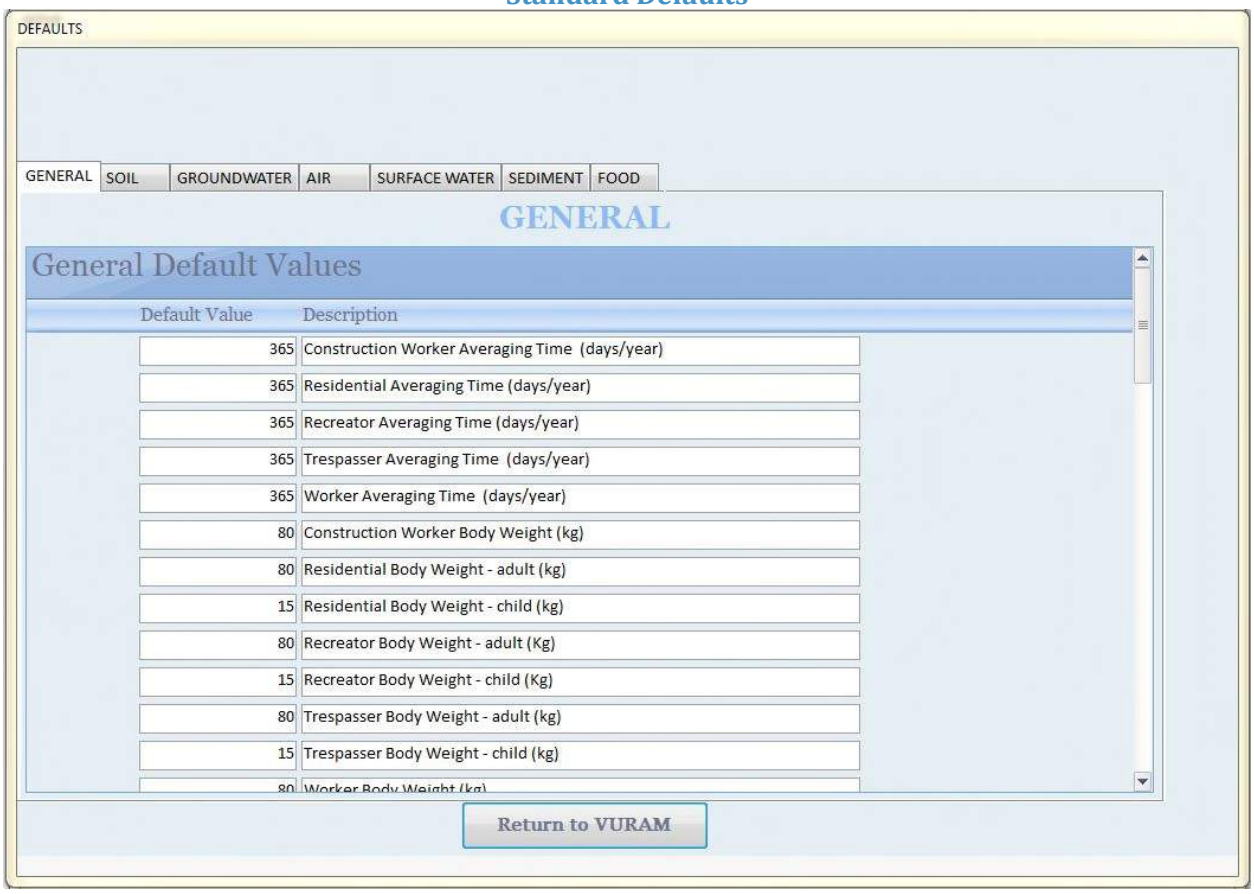
Return to Detailed Page

Setup



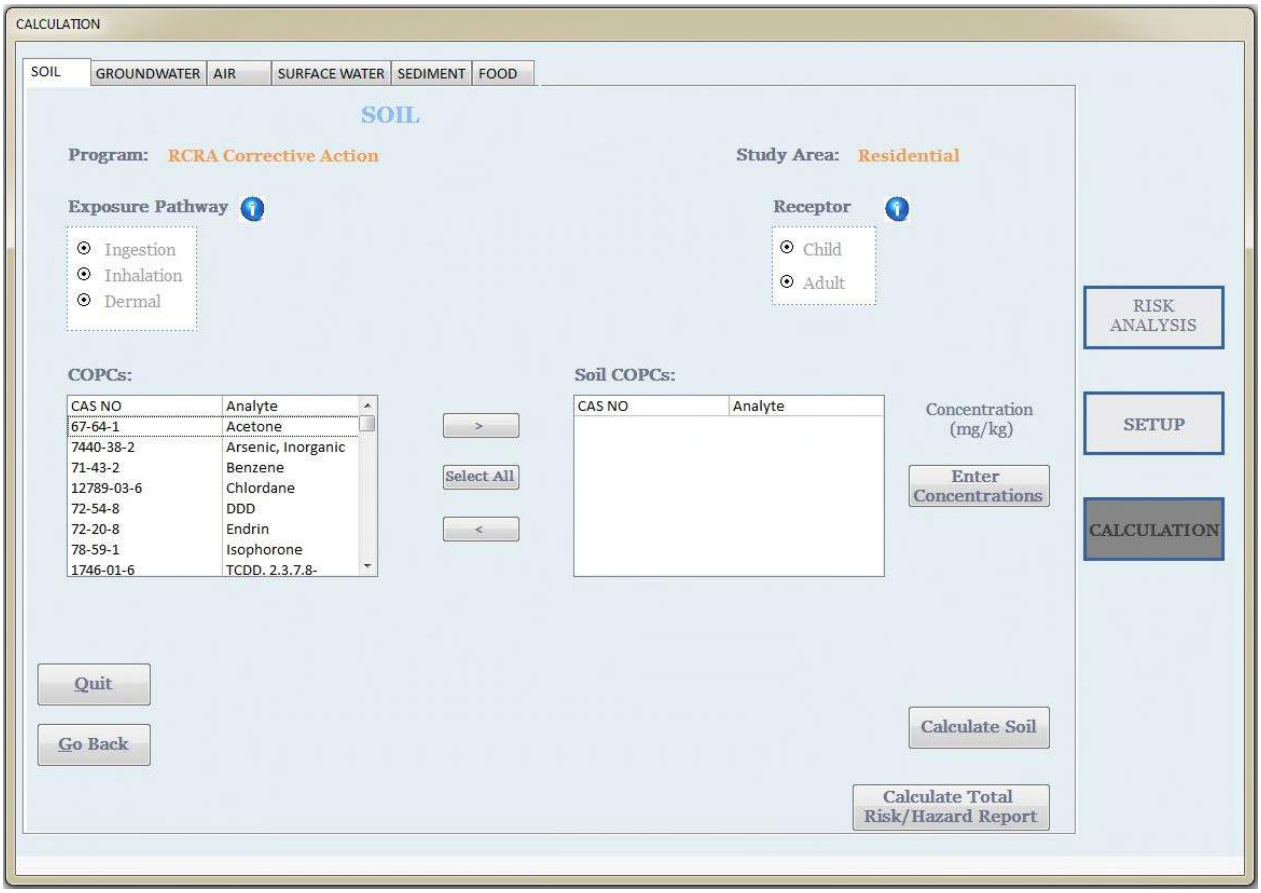
Return to Detailed Page

Standard Defaults



Return to Detailed Page

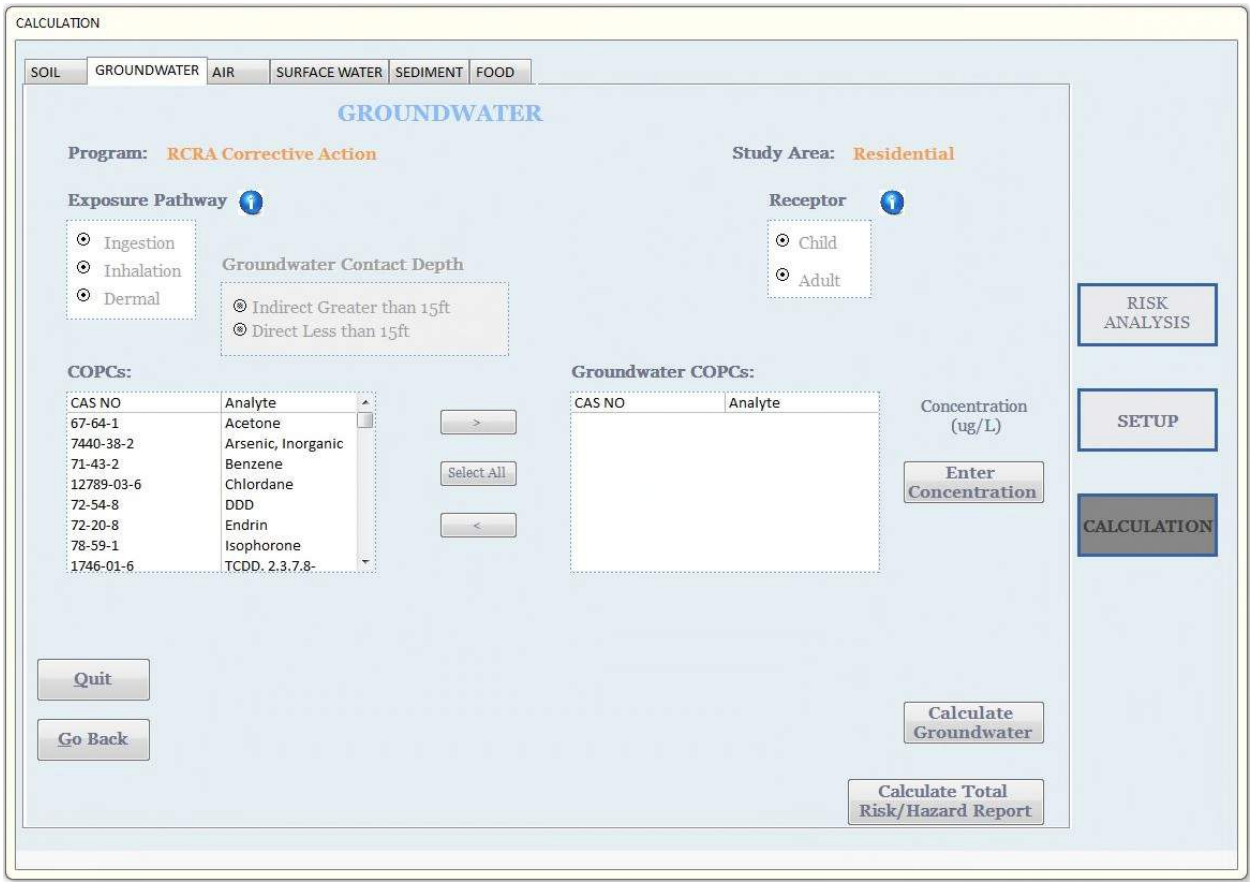
Soil Calculations



Return to Detailed Calculation Page

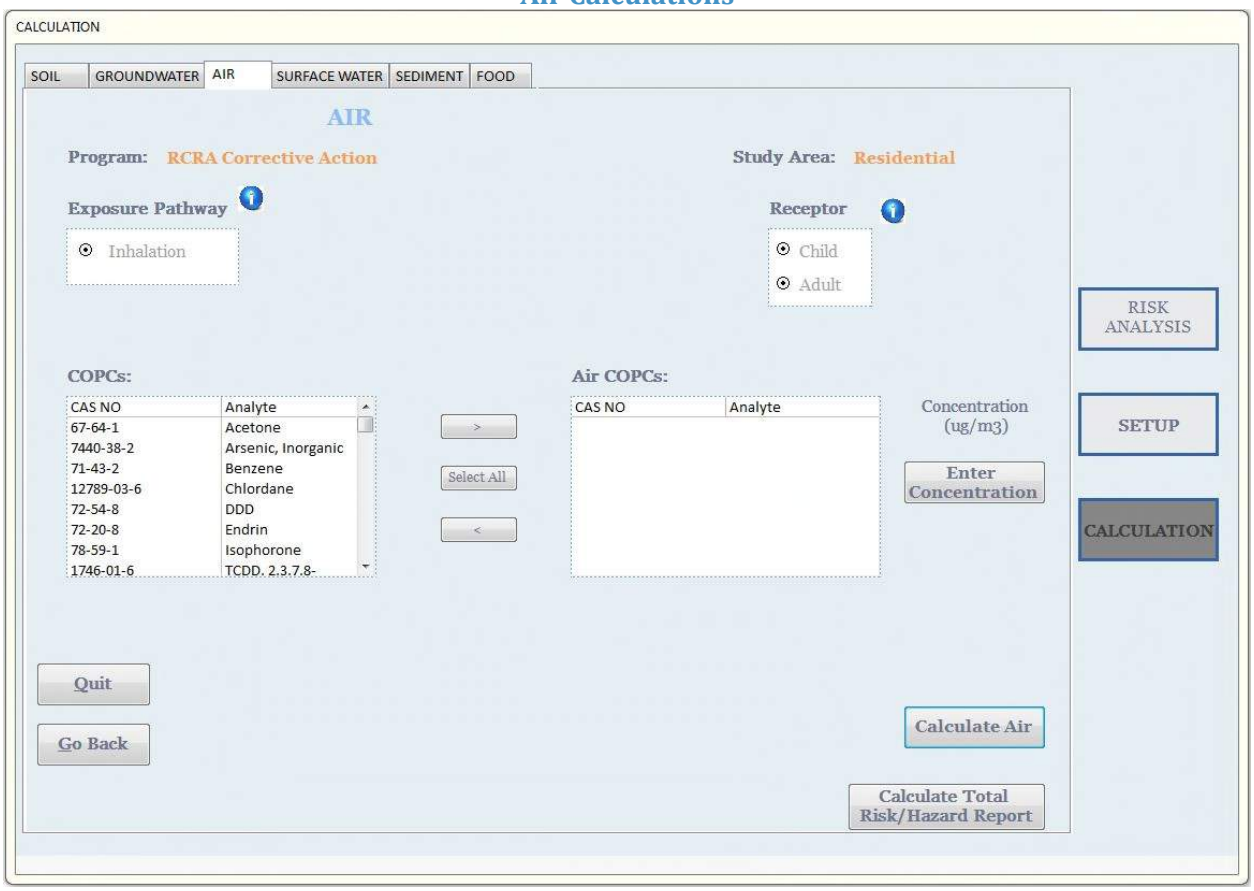
Return to Detailed Media Specific Calculation Page

Groundwater Calculations



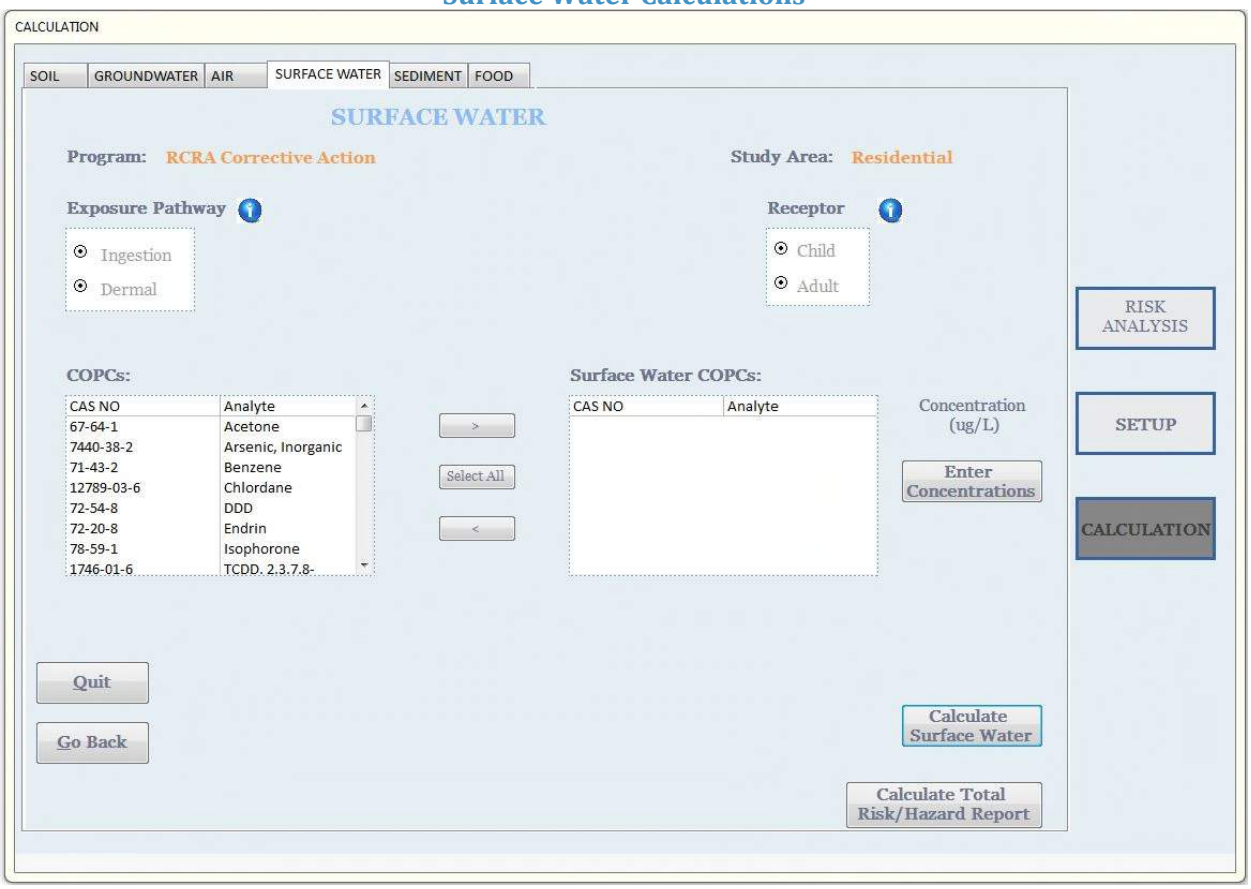
Return to Detailed Media Calculation Page

Air Calculations



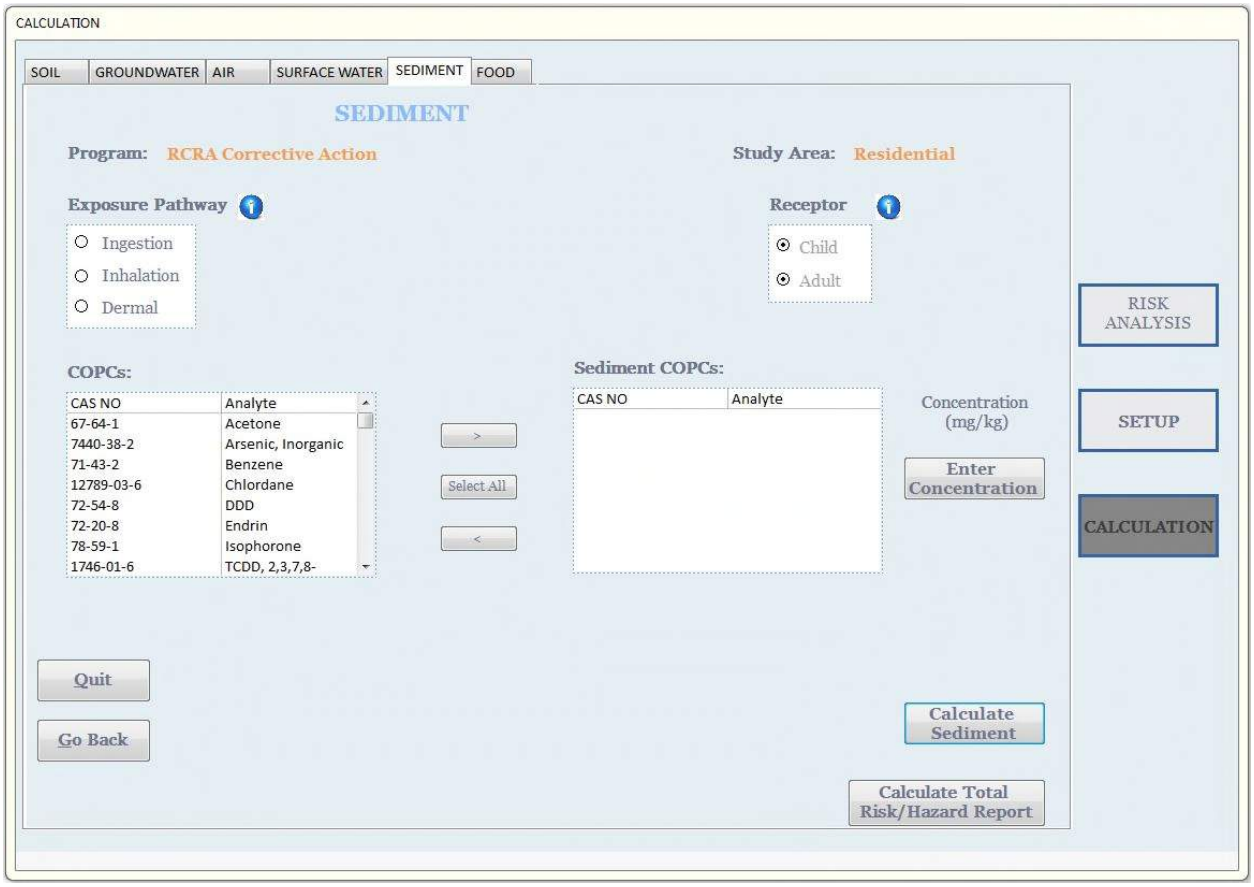
Return to Detailed Media Calculation Page

Surface Water Calculations



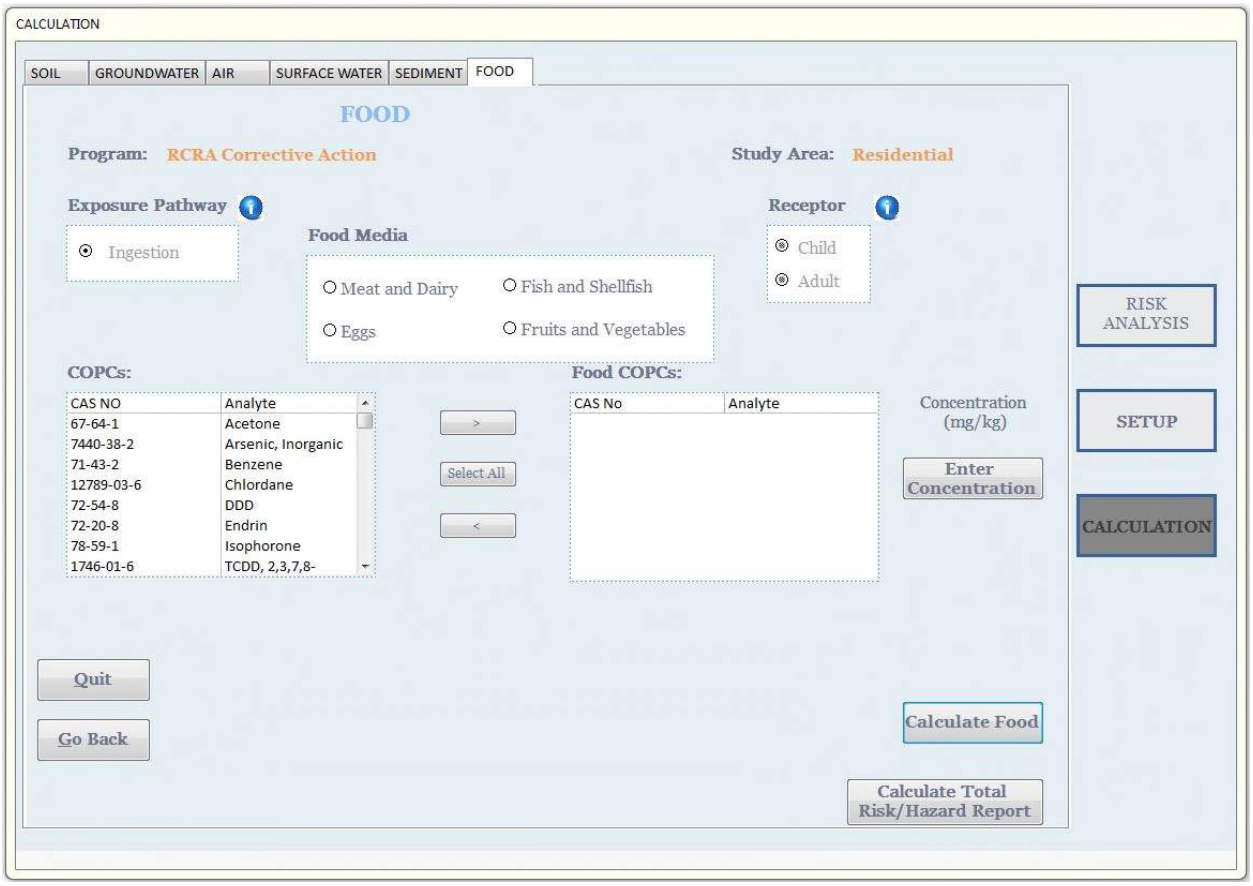
Return to Detailed Media Calculation Page

Sediment Calculations



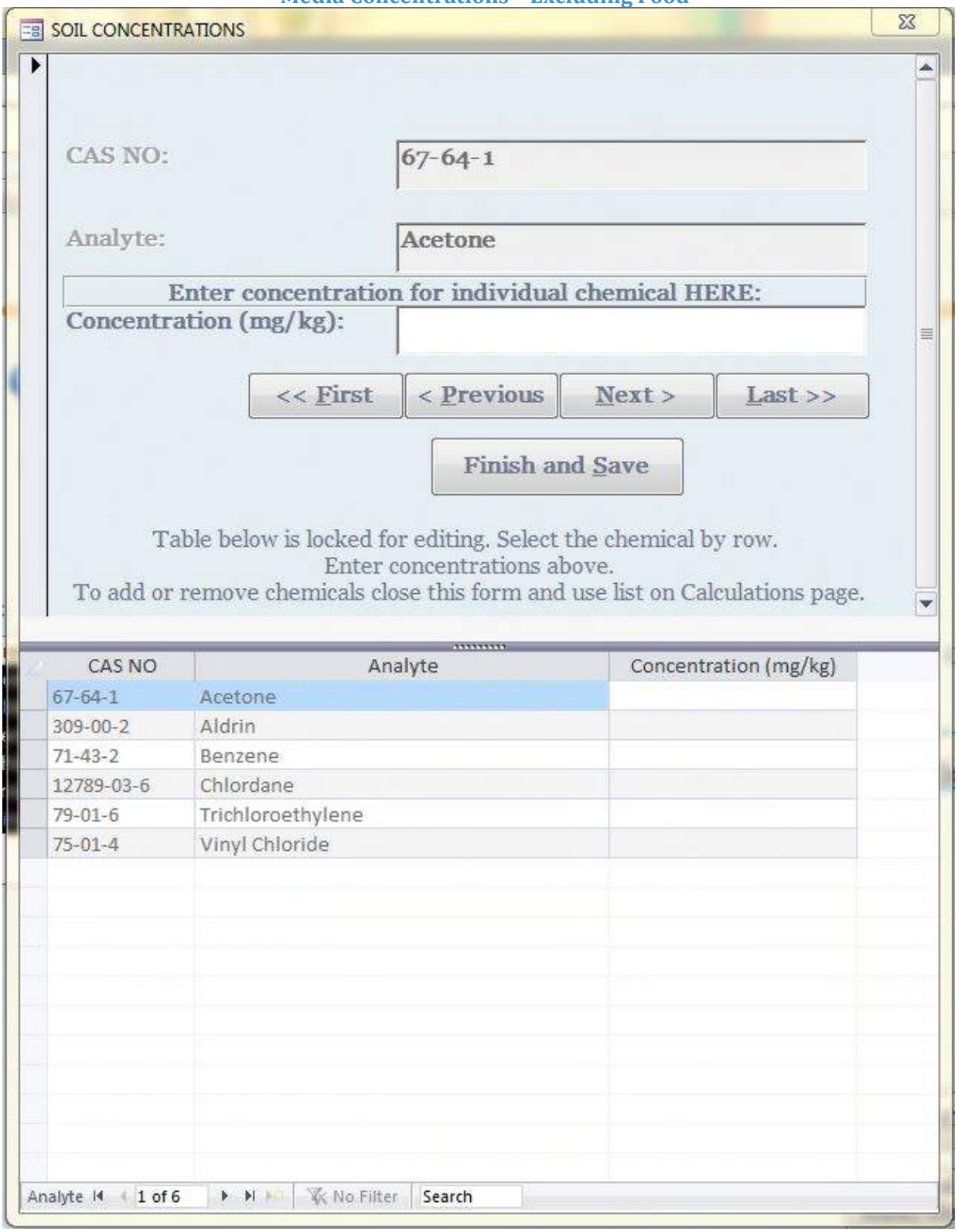
Return to Detailed Media Calculation Page

Food Calculations



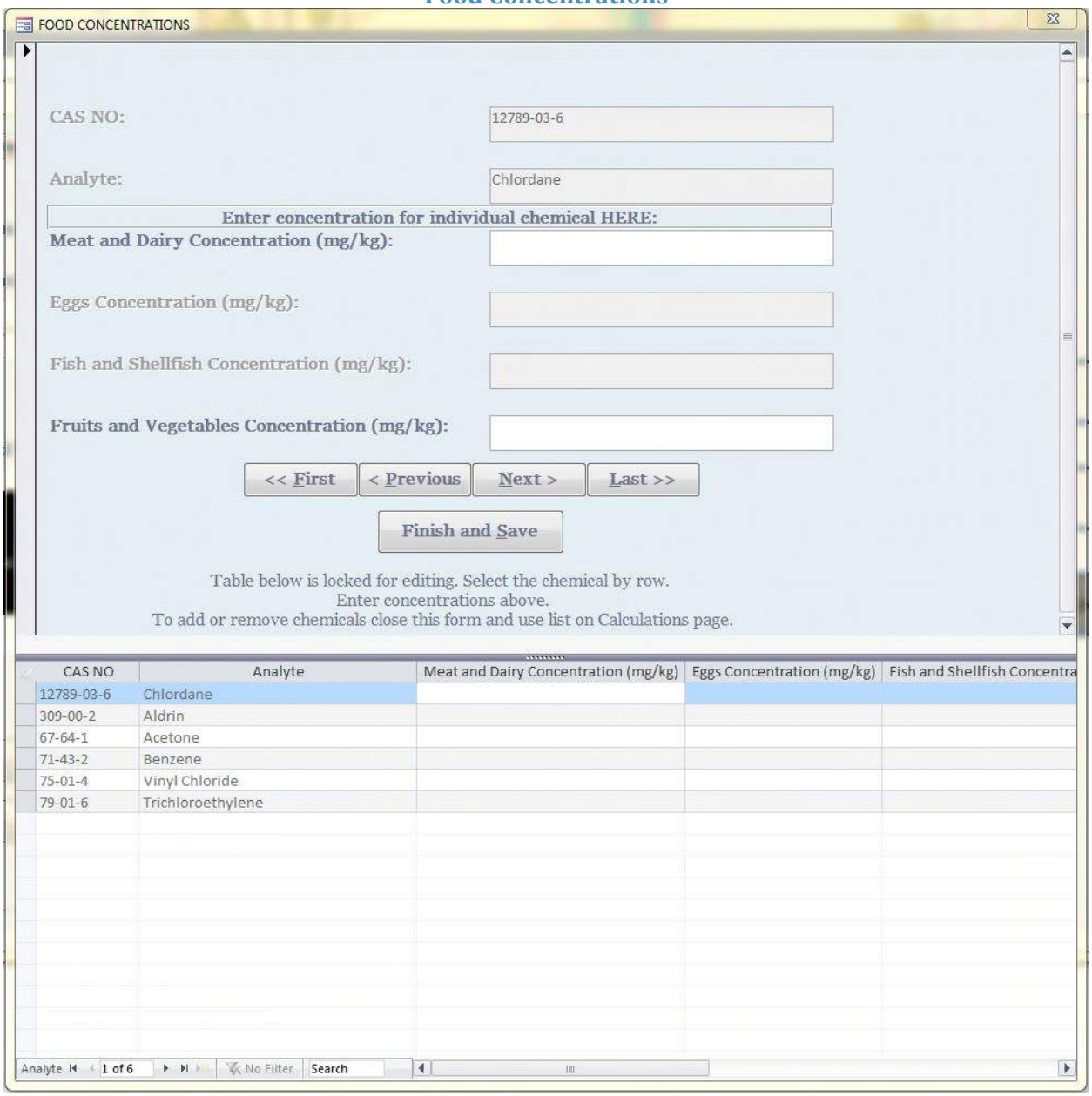
Return to Detailed Media Calculation Page

Media Concentrations – Excluding Food



Return to Detailed Page

Food Concentrations



Return to Detailed Page

Report View

Virginia Department of Environmental Quality

VURAM

Virginia Unified Risk Assessment Model

VERSION: 1.10

Construction Calculated Risk/Hazard Report

Total Risk/Hazard for All Media

Non-Cancer Adult		Cancer	
Total:	0.00E+00	Total:	0.00E+00
hazard not exceeded		*risk not exceeded*	

Print and Close | Save to PDF and Close | Close

All Report Pages are Required for Risk Assessment Submission

DETAILED REPORT FOLLOWS

Program: Hazardous Waste: Corrective Action (Federal Facilities; Superfund)

Risk Based Performance Criteria

Default Risk for Each Chemical	Default Risk for All Chemicals	Default Hazard Index
1.00E-06	1.00E-04	1.00E+00

Return to Detailed Page

Appendix 2. Risk Calculation Equations

Hazard/Risk values are done by calculations in VURAM based on the RSL equations provided by EPA RSL website. However, the computation within VURAM is done by solving for THQ/TR with a given concentration in place of SL. Therefore, the VURAM calculations are an algebraic rearrangement of the equations below. An example of the algebraic process follows for both THQ and TR using residential soil equations with an ingestion exposure pathway.

Site specific exposure defaults, documented and approved by VDEQ, may be used in the EPA hazard/risk calculation equations where appropriate. Such calculations must be manually added to the calculated hazard/risk for the media and total hazard/risk for the entire site.

Quick Reference Equations Table

Algebraic Process Example for Solving for VURAM computations	
EPA RSL Equation Abbreviations	
Residential Equation	
	Soil
	Groundwater
	Air
	Sediment
	Surface Water
	Food
Industrial Commercial Worker Equations	
	Soil Composite Worker
	Air
Construction	
	Soil
	Groundwater
Recreator	
	Soil or Sediment
	Surface Water
Trespasser	
	Soil or Sediment
	Surface Water

Algebraic Process Example for Solving for VURAM computations

Solving for Hazard Quotient for Residential Soil noncarcinogenic Ingestion Child
EPA provides equations for calculating in the following format:

$$SLres-soil-nc-ingc = \frac{THQ \times ATressc \times EDresc \times BWressc}{EFressc \times EDressc \times \frac{RBA}{RfDo} \times IRSressc \times 10^{-6}}$$

Where:

SLres-soil-nc-ingc = SL residential soil noncarcinogen ingestion child

THQ =Target Hazard Quotient

ATressc = Averaging Time residential soil child

EDresc = Exposure Duration residential child

BWressc = Body Weight residential soil child

EFressc = Exposure Frequency residential soil child

EDressc = Exposure Duration residential soil child

RBA = Relative Bioavailability

RfDo = Refernce Dose Oral

IRSressc =Ingestion Rate Soil residential Soil child

VURAM equations follow the following form by solving for THQ:

$$HQres-soil-nc-ingc = CON \times \frac{EFressc \times EDressc \times \frac{RBA}{RfD} \times IRSressc \times 10^{-6}}{ATressc \times EDressc \times BWressc}$$

Where:

HQres-soil-nc-ingc = Hazard Quotient residential soil noncarcinogen ingestion child

CON =Concentration

ATressc = Averaging Time residential soil child

EDresc = Exposure Duration residential child

BWressc = Body Weight residential soil child

EFressc = Exposure Frequency residential soil child

EDressc = Exposure Duration residential soil child

RBA = Relative Bioavailability

RfDo = Refernce Dose Oral

IRSressc =Ingestion Rate Soil residential Soil child

Solving for Risk for Residential Soil carcinogenic Ingestion
EPA provides equations for calculating in the following format:

$$SLres - soil - c - ing = \frac{TR \times ATress \times LT}{CSFo \times RBA \times IFSres - adj \times 10^{-6}}$$

Where:

SLres-soil-c-ing = SL residential soil carcinogen ingestion

TR =Target Risk

ATress = Averaging Time residential soil

LT = Life Time

CSFo = Cancer Slope Factor Oral

IFSres-adj = Ingestion Rate residential age adjusted

VURAM equations follow the following form by solving for Risk:

$$Riskres - soil - c - ing = CON \times \frac{CSFo \times RBA \times IFSres - adj \times 10^{-6}}{ATress \times LT}$$

Where:

Riskres-soil-c-ing = Risk residential soil carcinogen ingestion

CON =Concentration

ATress = Averaging Time residential soil

LT = Life Time

CSFo = Cancer Slope Factor Oral

RBA = Relative Bioavailability

IFSres-adj = Ingestion Rate residential age adjusted

EPA RSL equation give values within the equation layout for some exposure defaults. The format above reflects the Residential Soil equation for the case of noncarcinogenic-child and carcinogenic on the ingestion exposure route without these values for mathematical clarity. A complete list of exposure defaults used in VURAM can be found in Appendix 4.

Concentrations (CON) are site specific and entered into VURAM thought the media specific Concentration pages.

Return to Equations Table

EPA RSL Equation Abbreviations

This table is available from EPA RSL User's Guide and is only applicable to the equations in this appendix.

Symbol	Definition (units)
$SL_{res\text{-}air\text{-}ca}$	Resident Air Carcinogenic (µg/m^3)
$SL_{res\text{-}air\text{-}ca\text{-}vinyl\ chloride}$	Resident Air Carcinogenic Vinyl Chloride (µg/m^3)
$SL_{res\text{-}air\text{-}mu}$	Resident Air Mutagenic (µg/m^3)
$SL_{res\text{-}air\text{-}nc}$	Resident Air Noncarcinogenic (µg/m^3)
$SL_{res\text{-}fsh\text{-}ca\text{-}ing}$	Resident Fish Carcinogenic (mg/kg)
$SL_{res\text{-}fsh\text{-}nc\text{-}ing}$	Resident Fish Noncarcinogenic (mg/kg)
$SL_{water\text{-}ca\text{-}ing}$	Resident Tapwater Groundwater Carcinogenic Ingestion (µg/L)
$SL_{water\text{-}ca\text{-}der}$	Resident Tapwater Groundwater Carcinogenic Dermal (µg/L)
$SL_{water\text{-}ca\text{-}inh}$	Resident Tapwater Groundwater Carcinogenic Inhalation (µg/L)
$SL_{water\text{-}ca\text{-}tot}$	Resident Tapwater Groundwater Carcinogenic Total (µg/L)
$SL_{res\text{-}water\text{-}ca\text{-}vc\text{-}ing}$	Resident Tapwater Groundwater Carcinogenic Vinyl Chloride Ingestion (µg/L)
$SL_{res\text{-}water\text{-}ca\text{-}vc\text{-}der}$	Resident Tapwater Groundwater Carcinogenic Vinyl Chloride Dermal (µg/L)
$SL_{res\text{-}water\text{-}ca\text{-}vc\text{-}inh}$	Resident Tapwater Groundwater Carcinogenic Vinyl Chloride Inhalation (µg/L)
$SL_{res\text{-}water\text{-}ca\text{-}vc\text{-}tot}$	Resident Tapwater Groundwater Carcinogenic Vinyl Chloride Total (µg/L)
$SL_{water\text{-}mu\text{-}ing}$	Resident Tapwater Groundwater Mutagenic Ingestion (µg/L)
$SL_{water\text{-}mu\text{-}der}$	Resident Tapwater Groundwater Mutagenic Dermal (µg/L)
$SL_{water\text{-}mu\text{-}inh}$	Resident Tapwater Groundwater Mutagenic Inhalation (µg/L)
$SL_{water\text{-}mu\text{-}tot}$	Resident Tapwater Groundwater Mutagenic Total (µg/L)
$SL_{water\text{-}nc\text{-}ing}$	Resident Tapwater Groundwater Noncarcinogenic Ingestion (µg/L)
$SL_{water\text{-}nc\text{-}der}$	Resident Tapwater Groundwater Noncarcinogenic Dermal (µg/L)
$SL_{water\text{-}nc\text{-}inh}$	Resident Tapwater Groundwater Noncarcinogenic Inhalation (µg/L)
$SL_{water\text{-}nc\text{-}tot}$	Resident Tapwater Groundwater Noncarcinogenic Total (µg/L)
$SL_{res\text{-}sol\text{-}ca\text{-}ing}$	Resident Soil Carcinogenic Ingestion (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}der}$	Resident Soil Carcinogenic Dermal (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}inh}$	Resident Soil Carcinogenic Inhalation (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}tot}$	Resident Soil Carcinogenic Total (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}vc\text{-}ing}$	Resident Soil Carcinogenic Vinyl Chloride Ingestion (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}vc\text{-}der}$	Resident Soil Carcinogenic Vinyl Chloride Dermal (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}vc\text{-}inh}$	Resident Soil Carcinogenic Vinyl Chloride Inhalation (mg/kg)
$SL_{res\text{-}sol\text{-}ca\text{-}vc\text{-}tot}$	Resident Soil Carcinogenic Vinyl Chloride Total (mg/kg)
$SL_{res\text{-}sol\text{-}mu\text{-}ing}$	Resident Soil Mutagenic Ingestion (mg/kg)
$SL_{res\text{-}sol\text{-}mu\text{-}der}$	Resident Soil Mutagenic Dermal (mg/kg)
$SL_{res\text{-}sol\text{-}mu\text{-}inh}$	Resident Soil Mutagenic Inhalation (mg/kg)

$SL_{res\text{-}sol\text{-}mu\text{-}tot}$	Resident Soil Mutagenic Total (mg/kg)
$SL_{res\text{-}sol\text{-}nc\text{-}ing}$	Resident Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{res\text{-}sol\text{-}nc\text{-}der}$	Resident Soil Noncarcinogenic Dermal (mg/kg)
$SL_{res\text{-}sol\text{-}nc\text{-}inh}$	Resident Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{res\text{-}sol\text{-}nc\text{-}tot}$	Resident Soil Noncarcinogenic Total (mg/kg)
$SL_{w\text{-}sol\text{-}ca\text{-}ing}$	Composite Worker Soil Carcinogenic Ingestion (mg/kg)
$SL_{w\text{-}sol\text{-}ca\text{-}der}$	Composite Worker Soil Carcinogenic Dermal (mg/kg)
$SL_{w\text{-}sol\text{-}ca\text{-}inh}$	Composite Worker Soil Carcinogenic Inhalation (mg/kg)
$SL_{w\text{-}sol\text{-}ca\text{-}tot}$	Composite Worker Soil Carcinogenic Total (mg/kg)
$SL_{w\text{-}sol\text{-}nc\text{-}ing}$	Composite Worker Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{w\text{-}sol\text{-}nc\text{-}der}$	Composite Worker Soil Noncarcinogenic Dermal (mg/kg)
$SL_{w\text{-}sol\text{-}nc\text{-}inh}$	Composite Worker Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{w\text{-}sol\text{-}nc\text{-}tot}$	Composite Worker Soil Noncarcinogenic Total (mg/kg)
$SL_{iw\text{-}sol\text{-}ca\text{-}ing}$	Indoor Worker Soil Carcinogenic Ingestion (mg/kg)
$SL_{iw\text{-}sol\text{-}ca\text{-}der}$	Indoor Worker Soil Carcinogenic Dermal (mg/kg)
$SL_{iw\text{-}sol\text{-}ca\text{-}inh}$	Indoor Worker Soil Carcinogenic Inhalation (mg/kg)
$SL_{iw\text{-}sol\text{-}ca\text{-}tot}$	Indoor Worker Soil Carcinogenic Total (mg/kg)
$SL_{iw\text{-}sol\text{-}nc\text{-}ing}$	Indoor Worker Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{iw\text{-}sol\text{-}nc\text{-}der}$	Indoor Worker Soil Noncarcinogenic Dermal (mg/kg)
$SL_{iw\text{-}sol\text{-}nc\text{-}inh}$	Indoor Worker Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{iw\text{-}sol\text{-}nc\text{-}tot}$	Indoor Worker Soil Noncarcinogenic Total (mg/kg)
$SL_{ow\text{-}sol\text{-}ca\text{-}ing}$	Outdoor Worker Soil Carcinogenic Ingestion (mg/kg)
$SL_{ow\text{-}sol\text{-}ca\text{-}der}$	Outdoor Worker Soil Carcinogenic Dermal (mg/kg)
$SL_{ow\text{-}sol\text{-}ca\text{-}inh}$	Outdoor Worker Soil Carcinogenic Inhalation (mg/kg)
$SL_{ow\text{-}sol\text{-}ca\text{-}tot}$	Outdoor Worker Soil Carcinogenic Total (mg/kg)
$SL^{ow\text{-}sol\text{-}nc\text{-}ing}$	Outdoor Worker Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{ow\text{-}sol\text{-}nc\text{-}der}$	Outdoor Worker Soil Noncarcinogenic Dermal (mg/kg)
$SL_{ow\text{-}sol\text{-}nc\text{-}inh}$	Outdoor Worker Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{ow\text{-}sol\text{-}nc\text{-}tot}$	Outdoor Worker Soil Noncarcinogenic Total (mg/kg)
$SL_{cw\text{-}sol\text{-}ca\text{-}ing}$	Construction Worker Soil Carcinogenic Ingestion (mg/kg)
$SL_{cw\text{-}sol\text{-}ca\text{-}der}$	Construction Worker Soil Carcinogenic Dermal (mg/kg)
$SL_{cw\text{-}sol\text{-}ca\text{-}inh}$	Construction Worker Soil Carcinogenic Inhalation (mg/kg)
$SL_{cw\text{-}sol\text{-}ca\text{-}tot}$	Construction Worker Soil Carcinogenic Total (mg/kg)
$SL_{cw\text{-}sol\text{-}nc\text{-}ing}$	Construction Worker Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{cw\text{-}sol\text{-}nc\text{-}der}$	Construction Worker Soil Noncarcinogenic Dermal (mg/kg)

$SL_{cw\text{-}sol\text{-}nc\text{-}inh}$	Construction Worker Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{cw\text{-}sol\text{-}nc\text{-}tot}$	Construction Worker Soil Noncarcinogenic Total (mg/kg)
$SL_{rec\text{-}sol\text{-}ca\text{-}ing}$	Recreator Soil Carcinogenic Ingestion (mg/kg)
$SL_{rec\text{-}sol\text{-}ca\text{-}der}$	Recreator Soil Carcinogenic Dermal (mg/kg)
$SL_{rec\text{-}sol\text{-}ca\text{-}inh}$	Recreator Soil Carcinogenic Inhalation (mg/kg)
$SL_{rec\text{-}sol\text{-}ca\text{-}tot}$	Recreator Soil Carcinogenic Total (mg/kg)
$SL_{rec\text{-}sol\text{-}nc\text{-}ing}$	Recreator Soil Noncarcinogenic Ingestion (mg/kg)
$SL_{rec\text{-}sol\text{-}nc\text{-}der}$	Recreator Soil Noncarcinogenic Dermal (mg/kg)
$SL_{rec\text{-}sol\text{-}nc\text{-}inh}$	Recreator Soil Noncarcinogenic Inhalation (mg/kg)
$SL_{rec\text{-}sol\text{-}nc\text{-}tot}$	Recreator Soil Noncarcinogenic Total (mg/kg)
$SL_{rec\text{-}water\text{-}ca\text{-}der}$	Recreator Surface Water Carcinogenic Dermal (µg/L)
$SL_{rec\text{-}water\text{-}ca\text{-}ing}$	Recreator Surface Water Carcinogenic Ingestion (µg/L)
$SL_{rec\text{-}water\text{-}ca\text{-}tot}$	Recreator Surface Water Carcinogenic Total (µg/L)
$S_{Lrec\text{-}water\text{-}vc\text{-}der}$	Recreator Surface Water Carcinogenic Vinyl Chloride Dermal (µg/L)
$SL_{rec\text{-}water\text{-}vc\text{-}ing}$	Recreator Surface Water Carcinogenic Vinyl Chloride Ingestion (µg/L)
$SL_{rec\text{-}water\text{-}vc\text{-}tot}$	Recreator Surface Water Carcinogenic Vinyl Chloride Total (µg/L)
$SL_{rec\text{-}water\text{-}nc\text{-}der}$	Recreator Surface Water Non-Carcinogenic Dermal (µg/L)
$SL_{rec\text{-}water\text{-}nc\text{-}ing}$	Recreator Surface Water Non-Carcinogenic Ingestion (µg/L)
$SL_{rec\text{-}water\text{-}nc\text{-}tot}$	Recreator Surface Water Non-Carcinogenic Total (µg/L)
RfD_o	Chronic Oral Reference Dose (mg/kg-day)
RfC	Chronic Inhalation Reference Concentration (mg/m3)
CSF_o	Chronic oral Slope Factor $(mg/kg\text{-}day)^{-1}$
IUR	Chronic Inhalation Unit Risk $(\mu g/m3)^{-1}$
TR	target risk
THQ	target hazard quotient
THI	target hazard index
K	Andelman Volatilization Factor (L/m3)
K_p	Dermal Permeability Constant (cm/hour)
$AT_{res\text{-}c}$	Averaging time - resident soil child (days)
$AT_{res\text{-}a}$	Averaging time - resident soil adult (days)
AT_{res}	Averaging time - resident soil age adjusted (days)
$AT_{w\text{-}a}$	Averaging time - composite worker (days)
AT_w	Averaging time - composite worker (days)
$AT_{iw\text{-}a}$	Averaging time - composite worker (days)
AT_{iw}	Averaging time - indoor worker soil (days)

AT_{ow-a}	Averaging time - composite worker (days)
AT_{ow}	Averaging time - outdoor worker soil (days)
AT_{cw-a}	Averaging time - composite worker (days)
AT_{cw}	Averaging time - construction worker soil (days)
AT_{rec-c}	Averaging time - recreator soil child (days)
AT_{rec-a}	Averaging time - recreator soil adult (days)
AT_{rec}	Averaging time - recreator soil (days)
LT	Lifetime (years)
IRW_{res-c}	Resident Drinking Water Ingestion Rate - Child (L/day)
IRW_{res-a}	Resident Drinking Water Ingestion Rate - Adult (L/day)
$IFW_{res-adj}$	Resident Drinking Water Ingestion Rate - Age-adjusted (L/kg)
$IFWM_{res-adj}$	Resident Mutagenic Drinking Water Ingestion Rate - Age-adjusted (L/kg)
IRS_{res-c}	Resident Soil Ingestion Rate - Child (mg/day)
IRS_{res-a}	Resident Soil Ingestion Rate - Adult (mg/day)
$IFS_{res-adj}$	Resident Soil Ingestion Rate - Age-adjusted (mg/kg)
$IFSM_{res-adj}$	Resident Mutagenic Soil Ingestion Rate - Age-adjusted (mg/kg)
IR_{iw}	Indoor Worker Soil Ingestion Rate (mg/day)
IR_{ow}	Outdoor Worker Soil Ingestion Rate (mg/day)
IR_{cw}	Construction Worker Soil Ingestion Rate (mg/day)
IR_{w}	Composite Worker Soil Ingestion Rate (mg/day)
IRW_{rec-c}	Recreator Surface Water Ingestion Rate - Child (L/hour)
IRW_{rec-a}	Recreator Surface Water Ingestion Rate - Adult (L/hour)
$IFW_{rec-adj}$	Recreator Surface Water Ingestion Rate - Age-adjusted (L/kg)
IRW_{0-2}	Surface Water Ingestion Rate - Age Segment 0-2 (L/hour)
IRW_{2-6}	Surface Water Ingestion Rate - Age Segment 2-6 (L/hour)
IRW_{6-16}	Surface Water Ingestion Rate - Age Segment 6-16 (L/hour)
IRW_{16-26}	Surface Water Ingestion Rate - Age Segment 16-26 (L/hour)
$IFWM_{rec-adj}$	Recreator Mutagenic Surface Water Ingestion Rate - Age-adjusted (L/kg)
IRS_{rec-c}	Recreator Soil Ingestion Rate - Child (mg/day)
IRS_{rec-a}	Recreator Soil Ingestion Rate - Adult (mg/day)
$IFS_{rec-adj}$	Recreator Soil Ingestion Rate - Age-adjusted (mg/kg)
IRS_{0-2}	Soil Ingestion Rate - Age-segment 0-2 (mg/day)
IRS_{2-6}	Soil Ingestion Rate - Age-segment 2-6 (mg/day)
IRS_{6-16}	Soil Ingestion Rate - Age-segment 6-16 (mg/day)
IRS_{16-26}	Soil Ingestion Rate - Age-segment 16-26 (mg/day)

$IFSM_{rec-adj}$	Recreator Mutagenic Soil Ingestion Rate - Age-adjusted (mg/kg)
$DFS_{res-adj}$	Resident soil dermal contact factor- age-adjusted (mg/kg)
$DFSM_{res-adj}$	Resident Mutagenic soil dermal contact factor- age-adjusted (mg/kg)
$DFS_{rec-adj}$	Recreator soil dermal contact factor- age-adjusted (mg/kg)
$DFSM_{rec-adj}$	Recreator Mutagenic soil dermal contact factor- age-adjusted (mg/kg)
$DFW_{res-adj}$	Resident water dermal contact factor- age-adjusted (cm2 - event/kg)
$DFWM_{res-adj}$	Resident Mutagenic water dermal contact factor- age-adjusted (cm^2 - event/kg)
$DFW_{rec-adj}$	Recreator water dermal contact factor- age-adjusted (cm^2 - event/kg)
$DFWM_{rec-adj}$	Recreator Mutagenic water dermal contact factor- age-adjusted (cm^2 - event/kg)
IRF_{res-a}	Fish Ingestion Rate (mg/day)
SA_{res-c}	Resident surface area soil - child (cm^2/day)
SA_{res-a}	Resident surface area soil - adult (cm^2/day)
SA_{res-c}	Resident surface area water - child (cm^2)
SA_{res-a}	Resident surface area water - adult (cm^2)
SA_{ow}	Outdoor Worker soil surface area - adult (cm^2/day)
SA_{cw}	Construction Worker soil surface area - adult (cm^2/day)
SA_{w}	Composite Worker soil surface area - adult (cm^2/day)
SA_{rec-c}	Recreator surface area soil - child (cm^2/day)
SA_{rec-a}	Recreator surface area soil - adult (cm^2/day)
SA_{rec-c}	Recreator surface area water - child (cm^2)
SA_{rec-a}	Recreator surface area water - adult (cm^2)
SA_{0-2}	Resident/Recreator surface area soil - age segment 0-2 (cm^2/day)
SA_{2-6}	Resident/Recreator surface area soil - age segment 2-6 (cm^2/day)
SA_{6-16}	Resident/Recreator surface area soil - age segment 6-16 (cm^2/day)
SA_{16-26}	Resident/Recreator surface area soil - age segment 16-26 (cm^2/day)
SA_{0-2}	Resident/Recreator surface area water - age segment 0-2 (cm^2)
SA_{2-6}	Resident/Recreator surface area water - age segment 2-6 (cm^2)
SA_{6-16}	Resident/Recreator surface area water - age segment 6-16 (cm^2)
SA_{16-26}	Resident/Recreator surface area water - age segment 16-26 (cm^2)
AF_{res-c}	Resident soil adherence factor - child (mg/cm^2)
AF_{res-a}	Resident soil adherence factor - adult (mg/cm^2)
AF_{ow}	Outdoor Worker soil adherence factor (mg/cm^2)
AF_{w}	Composite Worker soil adherence factor (mg/cm^2)
AF_{cw}	Construction Worker soil adherence factor (mg/cm^2)
AF_{rec-c}	Recreator soil adherence factor - child (mg/cm^2)

AF_{rec-a}	Recreator soil adherence factor - adult (mg/cm^2)
AF_{0-2}	Resident/Recreator soil adherence factor - age segment 0-2 (mg/cm^2)
AF_{2-6}	Resident/Recreator soil adherence factor - age segment 2-6 (mg/cm^2)
AF_{6-16}	Resident/Recreator soil adherence factor - age segment 6-16 (mg/cm^2)
AF_{16-26}	Resident/Recreator soil adherence factor - age segment 16-26 (mg/cm2)
BW_{res-c}	Resident Body Weight - child (kg)
BW_{res-a}	Resident Body Weight - adult (kg)
BW_{rec-c}	Recreator Body Weight - child (kg)
BW_{rec-a}	Recreator Body Weight - adult (kg)
BW_{0-2}	Resident/Recreator Body Weight - age segment 0-2 (kg)
BW_{2-6}	Resident/Recreator Body Weight - age segment 2-6 (kg)
BW_{6-16}	Resident/Recreator Body Weight - age segment 6-16 (kg)
BW_{16-26}	Resident/Recreator Body Weight - age segment 16-26 (kg)
BW_{ow}	Outdoor Worker Body Weight (kg)
BW_{cw}	Construction Worker Body Weight (kg)
BW_{iw}	Indoor Worker Body Weight (kg)
BW_{w}	Composite Worker Body Weight (kg)
ABS_{d}	Fraction of contaminant absorbed dermally from soil (unitless)
GIABS	Fraction of contaminant absorbed in gastrointestinal tract (unitless) Note: if the GIABS is >50% then it is set to 100% for the calculation of dermal toxicity values.
DA_{event}	Absorbed dose per event (µg/cm2 - event)
EF_{res}	Resident Exposure Frequency (days/year)
EF_{res-a}	Resident Exposure Frequency - adult (days/year)
EF_{res-c}	Resident Exposure Frequency - child (days/year)
EF_{w}	Composite Worker Exposure Frequency (days/year)
EF_{iw}	Indoor Worker Exposure Frequency (days/year)
EF_{ow}	Outdoor Worker Exposure Frequency (days/year)
EF_{cw}	Construction Worker Exposure Frequency (days/year)
EF_{rec}	Recreator Exposure Frequency (days/year)
EF_{rec-c}	Recreator Exposure Frequency - child (days/year)
EF_{rec-a}	Recreator Exposure Frequency - adult (days/year)
EF_{0-2}	Exposure Frequency - age segment 0-2 (days/year)
EF_{2-6}	Exposure Frequency - age segment 2-6 (days/year)
EF_{6-16}	Exposure Frequency - age segment 6-16 (days/year)
EF_{16-26}	Exposure Frequency - age segment 16-26 (days/year)

ED_{res}	Resident Exposure Duration (years)
ED_{res-c}	Resident Exposure Duration - child (years)
ED_{res-a}	Resident Exposure Duration - adult (years)
ED_{w}	Composite Worker Exposure Duration - (years)
ED_{iw}	Indoor Worker Exposure Duration - (years)
ED_{ow}	Outdoor Worker Exposure Duration (years)
ED_{cw}	Construction Worker Exposure Duration (years)
ED_{rec}	Recreator Exposure Duration (years)
ED_{rec-c}	Recreator Exposure Duration - child (years)
ED_{rec-a}	Recreator Exposure Duration - adult (years)
ED_{0-2}	Resident/Recreator Exposure Duration - age segment 0-2 (years)
ED_{2-6}	Resident/Recreator Exposure Duration - age segment 2-6 (years)
ED_{6-16}	Resident/Recreator Exposure Duration - age segment 6-16 (years)
ED_{16-26}	Resident/Recreator Exposure Duration - age segment 16-26 (years)
ET_{res-a}	Resident Exposure Time (hours/day)
ET_{res-c}	Resident Exposure Time (hours/day)
ET_{res}	Resident Exposure Time (hours/day)
ET_{w}	Composite Worker Exposure Time (hours/day)
ET_{iw}	Indoor Worker Exposure Time (hours/day)
ET_{ow}	Outdoor Worker Exposure Time (hours/day)
ET_{cw}	Construction Worker Exposure Time (hours/day)
ET_{rec}	Recreator Exposure Time (hours/day)
ET_{rec-c}	Recreator Exposure Time - child (hours/day)
ET_{rec-a}	Recreator Exposure Time - adult (hours/day)
$ET_{event-res-c}$	Resident Water Exposure Time - child (hours/event)
$ET_{event-res-a}$	Resident Water Exposure Time - adult (hours/event)
$ET_{event-res-adj}$	Resident Water Exposure Time - age-adjusted (hours/event)
$ET_{event-res-madj}$	Resident Exposure Time - age-adjusted (hours/event)
$ET_{event-rec-c}$	Recreator Surface Water Exposure Time - child (hours/event)
$ET_{event-rec-a}$	Recreator Surface Water Exposure Time - adult (hours/event)
ET_{0-2}	Exposure Time - age segment 0-2 (hours/day)
ET_{2-6}	Exposure Time - age segment 2-6 (hours/day)
ET_{6-16}	Exposure Time - age segment 6-16 (hours/day)
ET_{16-26}	Exposure Time - age segment 16-26 (hours/day)
$ET_{event-rec-adj}$	Recreator Exposure Time - age-adjusted (hours/event)

$ET_{event\text{-}rec(0\text{-}2)}$	Exposure Time - age segment 0-2 (hours/event)
$ET_{event\text{-}rec(2\text{-}6)}$	Exposure Time - age segment 2-6 (hours/event)
$ET_{event\text{-}rec(6\text{-}16)}$	Exposure Time - age segment 6-16 (hours/event)
$ET_{event\text{-}rec(16\text{-}26)}$	Exposure Time - age segment 16-26 (hours/event)
$ET_{event\text{-}res(0\text{-}2)}$	Exposure Time - age segment 0-2 (hours/event)
$ET_{event\text{-}res(2\text{-}6)}$	Exposure Time - age segment 2-6 (hours/event)
$ET_{event\text{-}res(6\text{-}16)}$	Exposure Time - age segment 6-16 (hours/event)
$ET_{event\text{-}res(16\text{-}26)}$	Exposure Time - age segment 16-26 (hours/event)
$ET_{event\text{-}rec\text{-}madj}$	Recreator Exposure Time - age-adjusted (hours/event)
$EV_{rec\text{-}c}$	Recreator Events - child (events/day)
$EV_{rec\text{-}a}$	Recreator Events - adult (events/day)
$EV_{res\text{-}c}$	Resident Events - child (events/day)
$EV_{res\text{-}a}$	Resident Events - adult (events/day)
$EV_{0\text{-}2}$	Events - age segment 0-2 (events/day)
$EV_{2\text{-}6}$	Events - age segment 2-6 (events/day)
$EV_{6\text{-}16}$	Events - age segment 6-16 (events/day)
$EV_{16\text{-}26}$	Events - age segment 16-26 (events/day)
C_w	Target soil leachate concentration (mg/L)
DAF	Dilution attenuation factor (unitless)
ED	Exposure duration
I	Infiltration Rate (m/year)
L	source length parallel to ground water flow (m)
i	hydraulic gradient (m/m)
K	aquifer hydraulic conductivity (m/year)
θ_w	water-filled soil porosity (L_{water}/L_{soil})
θ_a	air-filled soil porosity (L_{air}/L_{soil})
n	total soil porosity(L_{pore}/L_{soil})
ρ_s	soil particle density (Kg/L)
ρ_b	dry soil bulk density (kg/L)
H'	Dimensionless Henry Law Constant (unitless)
K_d	soil-water partition coefficient (L/kg)
K_{oc}	soil organic carbon/water partition coefficient (L/kg)
f_{oc}	fraction organic carbon in soil (g/g)
d_a	aquifer thickness (m)
d_s	depth of source (m)

d	mixing zone depth (m)
PEF_w	Particulate Emission Factor - Minneapolis (m^3/kg)
Q/C_{wind}	Inverse of the Mean Concentration at the Center of a 0.5-Acre-Square Source (g/m^2-s per kg/m^3)
V	Fraction of Vegetative Cover (unitless)
U_m	Mean Annual Wind Speed (m/s)
U_t	Equivalent Threshold Value of Wind Speed at 7m (m/s)
F(x)	Function Dependent on U_m /U_t (unitless)
A	Dispersion constant unitless
A_s	Areal extent of the site or contamination (acres)
B	Dispersion constant unitless
C	Dispersion constant unitless
PEF_{sc}	Particulate Emission Factor - subchronic (m^3/kg)
Q/C_{sr}	Inverse of the ratio of the 1-h geometric mean concentration to the emission flux along a straight road segment bisecting a square site (g/m^2-s per kg/m^3)
F_D	Dispersion correction factor (unitless)
T	Total time over which construction occurs (s)
A_R	Surface area of contaminated road segment (m2)
L_R	Length of road segment (ft)
W_R	Width of road segment (ft)
W	Mean vehicle weight (tons)
p	Number of days with at least 0.01 inches of precipitation (days/year)
∑VKT	Sum of fleet vehicle kilometers traveled during the exposure duration (km)
A	Dispersion constant unitless
A_s	Areal extent of site surface soil contamination (acres)
B	Dispersion constant unitless
C	Dispersion constant unitless
PEF'_{sc}	Particulate Emission Factor - subchronic (m^3/kg)
Q/C_{sa}	Inverse of the ratio of the 1-h. geometric mean air concentration and the emission flux at the center of the square emission source (g/m^2-s per kg/m^3)
F_D	Dispersion correction factor (unitless)
A	Dispersion constant unitless
B	Dispersion constant unitless
C	Dispersion constant unitless
A_s	Areal extent of site surface soil contamination (acres)
J'_T	Total time-averaged PM_{10} unit emission flux for construction activities other than traffic on unpaved roads (g/m^2-s)

M^{PC}_{wind}	Unit mass emitted from wind erosion (g)
V	Fraction of Vegetative Cover (unitless)
U_m	Mean Annual Wind Speed (m/s)
U_t	Equivalent Threshold Value of Wind Speed at 7m (m/s)
F(x)	Function Dependent on U_m /U_t (unitless)
A_{surf}	Areal extent of site surface soil contamination (m^2)
ED	Exposure duration (years)
M_{excav}	Unit mass emitted from excavation soil dumping (g)
0.35	PM_{10} particle size multiplier (unitless)
U_m	Mean annual wind speed during construction (m/s)
$M_{m\text{-}excav}$	Gravimetric soil moisture content (%)
ρ_{soil}	In situ soil density (includes water) (Mg/m3)
A_{excav}	Areal extent of excavation (m2)
d_{excav}	Average depth of excavation (m)
$N_{A\text{-}dump}$	Number of times soil is dumped (unitless)
M_{doz}	Unit mass emitted from dozing operations (g)
0.75	PM_{10} scaling factor (unitless)
s_{doz}	Soil silt content (%)
$M_{m\text{-}doz}$	Gravimetric soil moisture content (%)
$\sum VKT_{doz}$	Sum of dozing kilometers traveled (km)
S_{doz}	Average dozing speed (kph)
$N_{A\text{-}doz}$	Number of times site is dozed (unitless)
B_d	Dozer blade length (m)
M_{grade}	Unit mass emitted from grading operations (g)
0.60	PM10 scaling factor (unitless)
$\sum VKT_{grade}$	Sum of grading kilometers traveled (km)
S_{grade}	Average grading speed (kph)
$N_{A\text{-}grade}$	Number of times site is graded (unitless)
B_g	Grader blade length (m)
M_{till}	Unit mass emitted from tilling operations (g)
s_{till}	Soil silt content (%)
$A_{c\text{-}till}$	Areal extent of tilling (acres)
$A_{c\text{-}grade}$	Areal extent of grading (acres)
$A_{c\text{-}doz}$	Areal extent of dozinging (acres)
$N_{A\text{-}till}$	Number of times soil is tilled (unitless)

VF_s	Volatilization Factor - Los Angeles (m^3/kg)
C_{sat}	Soil saturation concentration (mg/kg)
Q/C_{vol}	Inverse of the Mean Concentration at the Center of a 0.5-Acre-Square Source (g/m^2-s per kg/m^3)
A	Dispersion constant unitless
A_s	Areal extent of the site contamination (acres)
B	Dispersion constant unitless
C	Dispersion constant unitless
D_A	Apparent Diffusivity (cm^2/s)
T	Exposure interval (s)
T	Exposure interval (years)
ρ_b	Dry soil bulk density (g/cm^3)
θ_a	Air-filled soil porosity (L_{air}/L_{soil}) ($n-\theta_w$)
n	Total soil porosity (L_{pore}/L_{soi}l) (1-(ρ_b/ρ_s)
θ_w	Water-filled soil porosity (L_{water}/L_{soil})
ρ_s	Soil particle density (g/cm^3)
S	Water Solubility Limit (mg/L)
D_{ia}	Diffusivity in air (cm^2/s)
H'	Dimensionless Henry's Law Constant
D_{iw}	Diffusivity in water (cm^2/s)
K_d	Soil-water partition coefficient (L/Kg) ($K_{oc}\times f_{oc}$)
K_{oc}	Soil organic carbon-water partition coefficient (L/Kg)
f_{oc}	Organic carbon content of soil (g/g)
ds	Average source depth (m)
VFsc	Subchronic Volatilization Factor (m^3/kg)
Q/C_{sa}	Inverse of the ratio of the 1-h geometric mean air concentration to the volatilization flux at the center of a square source (g/m^2-s per kg/m^3)
A	Dispersion constant unitless
A_c	Areal extent of the site soil contamination (acres)
B	Dispersion constant unitless
C	Dispersion constant unitless
D_A	Apparent Diffusivity (cm^2/s)
T	Total time over which construction occurs (s)
ρ_b	Dry soil bulk density (g/cm^3)
F_D	Dispersion correction factor (unitless)
θ_a	Air-filled soil porosity (L_{air}/L_{soil}) ($n-\theta_w$)

n	Total soil porosity (L_{pore}/L_{soil}) (1-(ρ_b/ρ_s)
θ_w	Water-filled soil porosity (L_{water}/L_{soil})
ρ_s	Soil particle density (g/cm^3)
D_{ia}	Diffusivity in air (cm^2/s)
H'	Dimensionless Henry's Law Constant
D_{iw}	Diffusivity in water (cm^2/s)
K_d	Soil-water partition coefficient (L/Kg) (K_{oc}×f_{oc})
K_{oc}	Soil organic carbon-water partition coefficient (L/Kg)
f_{oc}	Organic carbon content of soil (g/g)
T	Total time over which construction occurs (year)
d_s	Average source depth (m)

Return to Equations Table

Residential Equations

Soil

Noncarcinogenic-child
Ingestion

$$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right) \times BW_{res\text{-}c}\,(15\ kg)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Dermal

$$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right) \times BW_{res\text{-}c}\,(15\ kg)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

Inhalation

$$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times ET_{res\text{-}c}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Noncarcinogenic-adult
Ingestion

$$SL_{res\text{-}soil\text{-}nc\text{-}ing\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\,(26\ years)\right) \times BW_{res\text{-}a}\,(80\ kg)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Dermal

$$SL_{res\text{-}soil\text{-}nc\text{-}der\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\,(26\ years)\right) \times BW_{res\text{-}a}\,(80\ kg)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

Inhalation

$$SL_{res\text{-}soil\text{-}nc\text{-}inh\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{res\text{-}a}\left(\frac{365\ days}{year} \times ED_{res}\,(26\ years)\right)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times ET_{res\text{-}a}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Carcinogenic
Ingestion

$$SL_{res\text{-}soil\text{-}ca\text{-}ing}\left(mg/kg\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

Dermal

$$SL_{res\text{-}soil\text{-}ca\text{-}der}\left(mg/kg\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\left(6\ years\right) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

Inhalation

$$SL_{res\text{-}soil\text{-}ca\text{-}inh}\left(mg/kg\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{res}\left(\frac{350\ days}{year}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times ED_{res}\left(26\ years\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right)}$$

Mutagenic
Ingestion

$$SL_{res\text{-}soil\text{-}mu\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\,(2\ years) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\,(4\ years) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\,(10\ years) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\,(10\ years) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)} \end{array}\right)$$

Dermal

$$SL_{res\text{-}soil\text{-}mu\text{-}der}\,(mg/kg) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{\left(\frac{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\,(2\ years) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\,(4\ years) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\,(10\ years) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\,(10\ years) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)} \end{array}\right)$$

Inhalation

$$SL_{res\text{-}soil\text{-}mu\text{-}inh}(mg/kg) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\begin{array}{l} \left(ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}(2\ years) \times 10\right) + \\ \left(ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}(4\ years) \times 3\right) + \\ \left(ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}(10\ years) \times 3\right) + \\ \left(ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}(10\ years) \times 1\right) \end{array}\right)}$$

Vinyl Chloride

Ingestion

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}ing}(mg/kg) = \frac{TR}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) \times \frac{10^{-6} kg}{1\ mg}}{AT_{res}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6} kg}{1\ mg}}{BW_{res\text{-}c}(15\ kg)}\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}(6\ years) \times IRS_{res\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{res\text{-}c}(15\ kg)} + \\ \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}(26\ years) - ED_{res\text{-}c}(6\ years)\right) \times IRS_{res\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{res\text{-}a}(80\ kg)} \end{array}\right)$$

Dermal

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}der}(mg/kg) = \frac{TR}{\left(\frac{\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d \times \frac{10^{-6} kg}{1\ mg}}{AT_{res}\left(\frac{365\ days}{year} \times LT(70\ years)\right)}\right) + \left(\frac{\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS \times \frac{10^{-6} kg}{1\ mg}}{BW_{res\text{-}c}(15\ kg)}\right)}$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\begin{array}{l} \frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}(6\ years) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}(15\ kg)} + \\ \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times \left(ED_{res}(26\ years) - ED_{res\text{-}c}(6\ years)\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}(80\ kg)} \end{array}\right)$$

Inhalation

$$SL_{res\text{-}soil\text{-}ca\text{-}vc\text{-}inh}\,(mg/kg) = \frac{TR}{\left(\dfrac{IUR\left(\mu g/m^3\right)^{-1} \times EF_{res}\left(\dfrac{350\ days}{year}\right) \times ED_{res}\,(26\ years) \times ET_{res}\left(\dfrac{24\ hours}{day}\right) \times \left(\dfrac{1\ day}{24\ hours}\right) \times \left(\dfrac{1000\ \mu g}{mg}\right)}{AT_{res}\left(\dfrac{365\ days}{year} \times LT\,(70\ years)\right) \times VF_s\left(\dfrac{m^3}{kg}\right)}\right) + \left(\dfrac{IUR\left(\mu g/m^3\right)^{-1}}{VF_s\left(\dfrac{m^3}{kg}\right)} \times \left(\dfrac{1000\ \mu g}{mg}\right)\right)}$$

Trichloroethylene

Ingestion

$$SL_{res\text{-}soil\text{-}tce\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{res}\left(\dfrac{365\ days}{year} \times LT\,(70\ years)\right)}{CSF_o\left(\dfrac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times \left(\dfrac{10^{-6}\,kg}{mg}\right) \times \left(\left(CAF_o\,(0.804) \times IFS_{res\text{-}adj}\left(\dfrac{37{,}650\ mg}{kg}\right)\right) + \left(MAF_o\,(0.202) \times IFSM_{res\text{-}adj}\left(\dfrac{166{,}833\ mg}{kg}\right)\right)\right)}$$

where:

$$IFS_{res\text{-}adj}\left(\frac{36{,}750\ mg}{kg}\right) = \left(\frac{ED_{res\text{-}c}\,(6\ years) \times EF_{res\text{-}c}\left(\dfrac{350\ days}{year}\right) \times IRS_{res\text{-}c}\left(\dfrac{200\ mg}{day}\right)}{BW_{res\text{-}c}\,(15\ kg)} + \frac{\left(ED_{res}\,(26\ years) - ED_{res\text{-}c}\,(6\ years)\right) \times EF_{res\text{-}a}\left(\dfrac{350\ days}{year}\right) \times IRS_{res\text{-}a}\left(\dfrac{100\ mg}{day}\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

where:

$$IFSM_{res\text{-}adj}\left(\frac{166{,}833\ mg}{kg}\right) = \left(\frac{ED_{0\text{-}2}\,(2\ years) \times EF_{0\text{-}2}\left(\dfrac{350\ days}{year}\right) \times IRS_{0\text{-}2}\left(\dfrac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \frac{ED_{2\text{-}6}\,(4\ years) \times EF_{2\text{-}6}\left(\dfrac{350\ days}{year}\right) \times IRS_{2\text{-}6}\left(\dfrac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \frac{ED_{6\text{-}16}\,(10\ years) \times EF_{6\text{-}16}\left(\dfrac{350\ days}{year}\right) \times IRS_{6\text{-}16}\left(\dfrac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \frac{ED_{16\text{-}26}\,(10\ years) \times EF_{16\text{-}26}\left(\dfrac{350\ days}{year}\right) \times IRS_{16\text{-}26}\left(\dfrac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)}\right)$$

Dermal

$$SL_{res\text{-}soil\text{-}tce\text{-}der}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times \left(\frac{10^{-6}kg}{mg}\right) \times \left(\left(CAF_o\left(0.804\right) \times DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) \times ABS_d\right) + \left(MAF_o\left(0.202\right) \times DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) \times ABS_d\right)\right)}$$

where:

$$DFS_{res\text{-}adj}\left(\frac{103{,}390\ mg}{kg}\right) = \left(\frac{ED_{res\text{-}c}\left(6\ years\right) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times SA_{res\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{res\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{\left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times SA_{res\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{res\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$DFSM_{res\text{-}adj}\left(\frac{428{,}260\ mg}{kg}\right) = \left(\frac{ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \frac{ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \frac{ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \frac{ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)}\right)$$

Inhalation

$$SL_{res\text{-}soil\text{-}tce\text{-}inh}\left(\frac{mg}{kg}\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\left(CAF_i\left(0.756\right) \times EF_{res}\left(\frac{350\ days}{year}\right) \times ED_{res}\left(26\ years\right) \times ET_{res}\left(\frac{24\ hours}{day}\right)\right) + \left(\left(ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 10\right) + \left(ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times MAF_i\left(0.244\right) \times 1\right)\right)\right)}$$

Supporting Equations
Child

$$ED_{res\text{-}c}(6\text{ years}) = ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})$$

$$BW_{res\text{-}c}(15\text{ kg}) = \frac{BW_{0\text{-}2}(15\text{ kg}) \times ED_{0\text{-}2}(2\text{ years}) + BW_{2\text{-}6}(15\text{ kg}) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

$$EF_{res\text{-}c}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{EF_{0\text{-}2}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{0\text{-}2}(2\text{ years}) + EF_{2\text{-}6}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

$$ET_{res\text{-}c}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{ET_{0\text{-}2}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{0\text{-}2}(2\text{ years}) + ET_{2\text{-}6}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

$$AF_{res\text{-}c}\left(\frac{0.2\text{ mg}}{\text{cm}^2}\right) = \frac{AF_{0\text{-}2}\left(\frac{0.2\text{ mg}}{\text{cm}^2}\right) \times ED_{0\text{-}2}(2\text{ years}) + AF_{2\text{-}6}\left(\frac{0.2\text{ mg}}{\text{cm}^2}\right) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

$$SA_{res\text{-}c}\left(\frac{2373\text{ cm}^2}{\text{day}}\right) = \frac{SA_{0\text{-}2}\left(\frac{2373\text{ cm}^2}{\text{day}}\right) \times ED_{0\text{-}2}(2\text{ years}) + SA_{2\text{-}6}\left(\frac{2373\text{ cm}^2}{\text{day}}\right) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

$$IRS_{res\text{-}c}\left(\frac{200\text{ mg}}{\text{day}}\right) = \frac{IRS_{0\text{-}2}\left(\frac{200\text{ mg}}{\text{day}}\right) \times ED_{0\text{-}2}(2\text{ years}) + IRS_{2\text{-}6}\left(\frac{200\text{ mg}}{\text{day}}\right) \times ED_{2\text{-}6}(4\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years})}$$

Adult

$$ED_{res\text{-}a}\,(20\text{ years}) = ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})$$

$$BW_{res\text{-}a}\,(80\text{ kg}) = \frac{BW_{6\text{-}16}\,(80\text{ kg}) \times ED_{6\text{-}16}\,(10\text{ years}) + BW_{16\text{-}26}\,(80\text{ kg}) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$EF_{res\text{-}a}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{EF_{6\text{-}16}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + EF_{16\text{-}26}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$ET_{res\text{-}a}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{ET_{6\text{-}16}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{6\text{-}16}\,(2\text{ years}) + ET_{16\text{-}26}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{16\text{-}26}\,(4\text{ years})}{ED_{6\text{-}16}\,(2\text{ years}) + ED_{16\text{-}26}\,(4\text{ years})}$$

$$AF_{res\text{-}a}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) = \frac{AF_{6\text{-}16}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + AF_{16\text{-}26}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$SA_{res\text{-}a}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) = \frac{SA_{6\text{-}16}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + SA_{16\text{-}26}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$IRS_{res\text{-}a}\left(\frac{100\text{ mg}}{\text{day}}\right) = \frac{IRS_{6\text{-}16}\left(\frac{100\text{ mg}}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + IRS_{16\text{-}26}\left(\frac{100\text{ mg}}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$ED_{res\text{-}a}(20\text{ years}) = ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})$$

$$BW_{res\text{-}a}(80\text{ kg}) = \frac{BW_{6\text{-}16}(80\text{ kg}) \times ED_{6\text{-}16}(10\text{ years}) + BW_{16\text{-}26}(80\text{ kg}) \times ED_{16\text{-}26}(10\text{ years})}{ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

$$EF_{res\text{-}a}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{EF_{6\text{-}16}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{6\text{-}16}(10\text{ years}) + EF_{16\text{-}26}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{16\text{-}26}(10\text{ years})}{ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

$$ET_{res\text{-}a}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{ET_{6\text{-}16}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{6\text{-}16}(2\text{ years}) + ET_{16\text{-}26}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{16\text{-}26}(4\text{ years})}{ED_{6\text{-}16}(2\text{ years}) + ED_{16\text{-}26}(4\text{ years})}$$

$$AF_{res\text{-}a}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) = \frac{AF_{6\text{-}16}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) \times ED_{6\text{-}16}(10\text{ years}) + AF_{16\text{-}26}\left(\frac{0.07\text{ mg}}{\text{cm}^2}\right) \times ED_{16\text{-}26}(10\text{ years})}{ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

$$SA_{res\text{-}a}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) = \frac{SA_{6\text{-}16}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) \times ED_{6\text{-}16}(10\text{ years}) + SA_{16\text{-}26}\left(\frac{6032\text{ cm}^2}{\text{day}}\right) \times ED_{16\text{-}26}(10\text{ years})}{ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

$$IRS_{res\text{-}a}\left(\frac{100\text{ mg}}{\text{day}}\right) = \frac{IRS_{6\text{-}16}\left(\frac{100\text{ mg}}{\text{day}}\right) \times ED_{6\text{-}16}(10\text{ years}) + IRS_{16\text{-}26}\left(\frac{100\text{ mg}}{\text{day}}\right) \times ED_{16\text{-}26}(10\text{ years})}{ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

Age-adjusted

$$ED_{res}(26\text{ years}) = ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years}) + ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})$$

$$EF_{res}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{EF_{0\text{-}2}\left(\frac{350\text{ days}}{\text{year}}\right)\times ED_{0\text{-}2}(2\text{ years}) + EF_{2\text{-}6}\left(\frac{350\text{ days}}{\text{year}}\right)\times ED_{2\text{-}6}(4\text{ years}) + EF_{6\text{-}16}\left(\frac{350\text{ days}}{\text{year}}\right)\times ED_{6\text{-}16}(10\text{ years}) + EF_{16\text{-}26}\left(\frac{350\text{ days}}{\text{year}}\right)\times ED_{16\text{-}26}(10\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years}) + ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

$$ET_{res}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{ET_{0\text{-}2}\left(\frac{24\text{ hours}}{\text{day}}\right)\times ED_{0\text{-}2}(2\text{ years}) + ET_{2\text{-}6}\left(\frac{24\text{ hours}}{\text{day}}\right)\times ED_{2\text{-}6}(4\text{ years}) + ET_{6\text{-}16}\left(\frac{24\text{ hours}}{\text{day}}\right)\times ED_{6\text{-}16}(10\text{ years}) + ET_{16\text{-}26}\left(\frac{24\text{ hours}}{\text{day}}\right)\times ED_{16\text{-}26}(10\text{ years})}{ED_{0\text{-}2}(2\text{ years}) + ED_{2\text{-}6}(4\text{ years}) + ED_{6\text{-}16}(10\text{ years}) + ED_{16\text{-}26}(10\text{ years})}$$

Return to Equations Table

Groundwater/RSL Tap Water

Noncarcinogenic-child
Ingestion

$$SL_{water\text{-}nc\text{-}ing\text{-}c}\,(\mu g/L) = \frac{THQ \times AT_{reswc}\left(\frac{365\ days}{year} \times ED_{reswc}\,(6\ years)\right) \times BW_{reswc}\,(15\ kg) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{reswc}\left(350\ \frac{days}{year}\right) \times ED_{reswc}\,(6\ years) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{reswc}\left(\frac{0.78\ L}{day}\right)}$$

Dermal

FOR INORGANICS:

$$SL_{water\text{-}nc\text{-}der\text{-}c}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right) \times ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hour}\right) \times \left[\frac{ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times BW_{res\text{-}c}\,(15\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS}\right) \times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right) \times ED_{res\text{-}c}\,(6\ years) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times SA_{res\text{-}c}\,(6365\ cm^2)}$$

Inhalation

$$SL_{water\text{-}nc\text{-}inh\text{-}c}\,(\mu g/L) = \frac{THQ \times AT_{res\text{-}c}\left(\frac{365\ days}{year} \times ED_{res\text{-}c}\,(6\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times ED_{res\text{-}c}\,(6\ years) \times ET_{res\text{-}c}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times K\left(\frac{0.5\ L}{m^3}\right)}$$

Noncarcinogenic-adult
Ingestion

$$SL_{water\text{-}nc\text{-}ing\text{-}a}\,(\mu g/L) = \frac{THQ \times AT_{reswa}\left(\frac{365\ days}{year} \times ED_{resw}\,(26\ years)\right) \times BW_{reswa}\,(80\ kg) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{reswa}\left(350\ \frac{days}{year}\right) \times ED_{resw}\,(26\ years) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{reswa}\left(\frac{2.5\ L}{day}\right)}$$

Dermal

FOR INORGANICS:

$$SL_{water\text{-}nc\text{-}der\text{-}a}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) = \frac{THQ\times AT_{res\text{-}a}\left(\frac{365\ days}{year}\times ED_{res}\,(26\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{res\text{-}a}\,(80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times ED_{res}\,(26\ years)\times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times SA_{res\text{-}a}\,(19652\ cm^2)}$$

Inhalation

$$SL_{water\text{-}nc\text{-}inh\text{-}a}\,(\mu g/L) = \frac{THQ\times AT_{res\text{-}a}\left(\frac{365\ days}{year}\times ED_{res}\,(26\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times ED_{res}\,(26\ years)\times ET_{res\text{-}a}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(mg/m^3\right)}\times K\left(\frac{0.5\ L}{m^3}\right)}$$

Carcinogenic

Ingestion

$$SL_{water\text{-}ca\text{-}ing}\,(\mu g/L) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times\left(IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{res\text{-}c}\,(6\ years)\times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\,(15\ kg)}+\frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times\left(ED_{res}\,(26\ years)-ED_{res\text{-}c}\,(6\ years)\right)\times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

Dermal

FOR INORGANICS:

$$SL_{water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right)}$$

where:

$$DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\,(6\ years)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{reswc}\,(15\ kg)}+\frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times\left(ED_{res}\,(26\ years)-ED_{res\text{-}c}\,(6\ years)\right)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}{BW_{res\text{-}a}\,(80\ kg)}\right)$$

and:

$$ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)\times ED_{res\text{-}c}\,(6\ years)+ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)\times\left(ED_{res}\,(26\ years)-ED_{res\text{-}c}\,(6\ years)\right)\right)}{ED_{res}\,(26\ years)}\right)$$

Inhalation

$$SL_{water\text{-}ca\text{-}inh}\,(\mu g/L) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)}{EF_{res}\left(\frac{350\ days}{year}\right)\times ED_{res}\,(26\ years)\times ET_{res}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times IUR\left(\mu g/m^3\right)^{-1}\times K\left(\frac{0.5\ L}{m^3}\right)}$$

Mutagenic
Ingestion

$$SL_{water\text{-}mu\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right)}$$

where:

$$IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right) = \left(\begin{array}{l} \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\left(years\right) \times IRW_{0\text{-}2}\left(\frac{0.78\ L}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\left(years\right) \times IRW_{2\text{-}6}\left(\frac{0.78\ L}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ED_{6\text{-}16}\left(years\right) \times IRW_{6\text{-}16}\left(\frac{2.5\ L}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ED_{16\text{-}26}\left(years\right) \times IRW_{16\text{-}26}\left(\frac{2.5\ L}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

Dermal

FOR INORGANICS:

$$SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) \le t^*\ (hours), \text{then } SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}madj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) > t^*\ (hours), \text{then } SL_{water\text{-}mu\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}madj}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right)}$$

where:

$$DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l}\left(\frac{EV_{0\text{-}2}\left(\frac{1\ events}{day}\right)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ED_{0\text{-}2}\ (years)\times SA_{0\text{-}2}\left(6365\ cm^2\right)\times 10}{BW_{0\text{-}2}\ (15\ kg)}\right)+\\ \left(\frac{EV_{2\text{-}6}\left(\frac{1\ events}{day}\right)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ED_{2\text{-}6}\ (years)\times SA_{2\text{-}6}\left(6365\ cm^2\right)\times 3}{BW_{2\text{-}6}\ (15\ kg)}\right)+\\ \left(\frac{EV_{6\text{-}16}\left(\frac{1\ events}{day}\right)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ED_{6\text{-}16}\ (years)\times SA_{6\text{-}16}\left(19652\ cm^2\right)\times 3}{BW_{6\text{-}16}\ (80\ kg)}\right)+\\ \left(\frac{EV_{16\text{-}26}\left(\frac{1\ events}{day}\right)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ED_{16\text{-}26}\ (years)\times SA_{16\text{-}26}\left(19652\ cm^2\right)\times 1}{BW_{16\text{-}26}\ (80\ kg)}\right)\end{array}\right]$$

and:

$$ET_{event\text{-}res\text{-}madj}\left(\frac{0.6708\ hours}{event}\right) = \frac{\left(\begin{array}{l}ET_{event\text{-}res\ (0\text{-}2)}\left(\frac{0.54\ hours}{event}\right)\times ED_{0\text{-}2}\ (2\ years)+ET_{event\text{-}res\ (2\text{-}6)}\left(\frac{0.54\ hours}{event}\right)\times ED_{2\text{-}6}\ (4\ years)+\\ ET_{event\text{-}res\ (6\text{-}16)}\left(\frac{0.71\ hours}{event}\right)\times ED_{6\text{-}16}\ (10\ years)+ET_{event\text{-}res\ (16\text{-}26)}\left(\frac{0.71\ hours}{event}\right)\times ED_{16\text{-}26}\ (10\ years)\end{array}\right)}{ED_{0\text{-}2}\ (2\ years)+ED_{2\text{-}6}\ (4\ years)+ED_{6\text{-}16}\ (10\ years)+ED_{16\text{-}26}\ (10\ years)}$$

Inhalation

$$SL_{water\text{-}mu\text{-}inh}\left(\mu g/L\right)=\frac{TR\times AT_{resw}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{IUR\left(\mu g/m^{3}\right)^{-1}\times K\left(\frac{0.5\ L}{m^{3}}\right)\times\left(\begin{array}{l}\left(EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ET^{inh}_{0\text{-}2}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times ED_{0\text{-}2}\left(years\right)\times 10\right)+\\ \left(EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ET^{inh}_{2\text{-}6}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times ED_{2\text{-}6}\left(years\right)\times 3\right)+\\ \left(EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ET^{inh}_{6\text{-}16}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times ED_{6\text{-}16}\left(years\right)\times 3\right)+\\ \left(EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ET^{inh}_{16\text{-}26}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times ED_{16\text{-}26}\left(years\right)\times 1\right)\end{array}\right)}$$

Vinyl Chloride
Ingestion

$$SL_{water\text{-}ca\text{-}vc\text{-}ing}\left(\mu g/L\right)=\frac{TR}{\left(\frac{CSF_{o}\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)\times\left(\frac{mg}{1000\ \mu g}\right)}{AT_{res}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}\right)+\left(\frac{CSF_{o}\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)\times\left(\frac{mg}{1000\ \mu g}\right)}{BW_{res\text{-}c}\left(15\ kg\right)}\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)=\left(\begin{array}{l}\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times ED_{res\text{-}c}\left(6\ years\right)\times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)}+\\ \frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times\left(ED_{res}\left(26\ years\right)-ED_{res\text{-}c}\left(6\ years\right)\right)\times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\end{array}\right)$$

Dermal

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) \le t^{*}\ (hours), \text{then } SL_{water\text{-}vc\text{-}der}\ (\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) > t^{*}\ (hours), \text{then } SL_{water\text{-}vc\text{-}der}\ (\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR}{\left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right)}{AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}\right)+\left(\frac{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{res\text{-}c}\ (15\ kg)\times\left(\frac{1000\ \mu g}{mg}\right)}\right)}$$

where:

$$DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right) = \left(\frac{EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\ (6\ years)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{res\text{-}c}\ (15\ kg)}+\frac{EF_{res\text{-}a}\left(\frac{350\ days}{year}\right)\times EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}a}\ (20\ years)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}{BW_{res\text{-}a}\ (80\ kg)}\right)$$

and:

$$ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right)\times ED_{res\text{-}c}\ (6\ years)+ET_{event\text{-}res\text{-}a}\left(\frac{0.71\ hours}{event}\right)\times\left(ED_{res}\ (26\ years)-ED_{res\text{-}c}\ (6\ years)\right)\right)}{ED_{res}\ (26\ years)}\right)$$

Inhalation

$$SL_{water\text{-}ca\text{-}vc\text{-}inh}\ (\mu g/L) = \frac{TR}{\left(\frac{IUR\left(\mu g/m^3\right)^{-1}\times EF_{res}\left(\frac{350\ days}{year}\right)\times ED_{res}\ (26\ years)\times ET_{res}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times K\left(\frac{0.5\ L}{m^3}\right)}{AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}\right)+\left(IUR\left(\mu g/m^3\right)^{-1}\times K\left(\frac{0.5\ L}{m^3}\right)\right)}$$

Trichloroethylene
Ingestion

$$SL_{water\text{-}tce\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times \left(\left(CAF_o\left(0.804\right) \times IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right)\right)\right) + \left(MAF_o\left(0.202\right) \times IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right)\right)}$$

where:

$$IFW_{res\text{-}adj}\left(\frac{327.95\ L}{kg}\right) = \left(\frac{ED_{res\text{-}c}\left(6\ years\right) \times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) \times IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right)}{BW_{res\text{-}c}\left(15\ kg\right)} + \frac{\left(ED_{res}\left(26\ years\right) - ED_{res\text{-}c}\left(6\ years\right)\right) \times EF_{res\text{-}a}\left(\frac{350\ days}{year}\right) \times IRW_{res\text{-}a}\left(\frac{2.5\ L}{day}\right)}{BW_{res\text{-}a}\left(80\ kg\right)}\right)$$

where:

$$IFWM_{res\text{-}adj}\left(\frac{1019.9\ L}{kg}\right) = \left(\frac{ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.78\ L}{day}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \frac{ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.78\ L}{day}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \frac{ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{2.5\ L}{day}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \frac{ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{2.5\ L}{day}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)}\right)$$

Dermal

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) \le t^{*}\ (hours), \text{then } SL_{water\text{-}tce\text{-}der}\ (\mu g/L) = \frac{DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times \tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}res\text{-}adj}\left(\frac{hours}{event}\right) > t^{*}\ (hours), \text{then } SL_{water\text{-}tce\text{-}der}\ (\mu g/L) = \frac{DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR\times AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\times\left(\left(CAF_o\ (0.804)\ \times DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right)\right)+\left(MAF_o\ (0.202)\ \times DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right)\right)\right)}$$

where:

$$DFW_{res\text{-}adj}\left(\frac{2{,}610{,}650\ events\text{-}cm^2}{kg}\right) = \left(\frac{EV_{res\text{-}c}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}c}\ (6\ years)\times EF_{res\text{-}c}\left(\frac{350\ days}{year}\right)\times SA_{res\text{-}c}\left(6365\ cm^2\right)}{BW_{res\text{-}c}\ (15\ kg)}+\frac{EV_{res\text{-}a}\left(\frac{1\ events}{day}\right)\times ED_{res\text{-}a}\ (20\ years)\times EF_{resw\text{-}a}\left(\frac{350\ days}{year}\right)\times SA_{res\text{-}a}\left(19652\ cm^2\right)}{BW_{res\text{-}a}\ (80\ kg)}\right)$$

where:

$$DFWM_{res\text{-}adj}\left(\frac{8{,}191{,}633\ events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l}\left(\frac{EV_{0\text{-}2}\left(\frac{1\ events}{day}\right)\times ED_{0\text{-}2}\ (2\ years)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times SA_{0\text{-}2}\left(6365\ cm^2\right)\times 10}{BW_{0\text{-}2}\ (15\ kg)}\right)+\\ \left(\frac{EV_{2\text{-}6}\left(\frac{1\ events}{day}\right)\times ED_{2\text{-}6}\ (4\ years)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times SA_{2\text{-}6}\left(6365\ cm^2\right)\times 3}{BW_{2\text{-}6}\ (15\ kg)}\right)+\\ \left(\frac{EV_{6\text{-}16}\left(\frac{1\ events}{day}\right)\times ED_{6\text{-}16}\ (10\ years)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times SA_{6\text{-}16}\left(19652\ cm^2\right)\times 3}{BW_{6\text{-}16}\ (80\ kg)}\right)+\\ \left(\frac{EV_{16\text{-}26}\left(\frac{1\ events}{day}\right)\times ED_{16\text{-}26}\ (10\ years)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times SA_{16\text{-}26}\left(19652\ cm^2\right)\times 1}{BW_{16\text{-}26}\ (80\ kg)}\right)\end{array}\right]$$

and:

$$ET_{event\text{-}res\text{-}adj}\left(\frac{0.6708\ hours}{event}\right) = \frac{\left(\begin{array}{l}ET_{event\text{-}res(0\text{-}2)}\left(\frac{0.54\ hours}{event}\right)\times ED_{0\text{-}2}\ (2\ years)+ET_{event\text{-}res(2\text{-}6)}\left(\frac{0.54\ hours}{event}\right)\times ED_{2\text{-}6}\ (4\ years)+\\ ET_{event\text{-}res(6\text{-}16)}\left(\frac{0.71\ hours}{event}\right)\times ED_{6\text{-}16}\ (10\ years)+ET_{event\text{-}res(16\text{-}26)}\left(\frac{0.71\ hours}{event}\right)\times ED_{16\text{-}26}\ (10\ years)\end{array}\right)}{ED_{0\text{-}2}\ (2\ years)+ED_{2\text{-}6}\ (4\ years)+ED_{6\text{-}16}\ (10\ years)+ED_{16\text{-}26}\ (10\ years)}$$

Inhalation

$$SL_{water\text{-}tce\text{-}inh}\left(\mu g/L\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\frac{\mu g}{m^3}\right)^{-1} \times K\left(\frac{0.5\ L}{m^3}\right) \times \left(\left(EF_{res}\left(\frac{350\ days}{year}\right) \times ED_{res}\left(26\ years\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times CAF_i\left(0.756\right)\right) + \left(\left(\left(ED_{0\text{-}2}\left(2\ years\right) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 10\right) + \left(ED_{2\text{-}6}\left(4\ years\right) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{6\text{-}16}\left(10\ years\right) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 3\right) + \left(ED_{16\text{-}26}\left(10\ years\right) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times MAF_i\left(0.244\right) \times 1\right)\right)\right)\right)}$$

Supporting Equations
Child

$$ED_{res\text{-}c}\left(6\ years\right) = ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)$$

$$BW_{res\text{-}c}\left(15\ kg\right) = \frac{BW_{0\text{-}2}\left(15\ kg\right) \times ED_{0\text{-}2}\left(2\ years\right) + BW_{2\text{-}6}\left(15\ kg\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$EV_{res\text{-}c}\left(\frac{1\ event}{day}\right) = \frac{EV_{0\text{-}2}\left(\frac{1\ event}{day}\right) \times ED_{0\text{-}2}\left(2\ years\right) + EV_{2\text{-}6}\left(\frac{1\ event}{day}\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$EF_{res\text{-}c}\left(\frac{350\ days}{year}\right) = \frac{EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ED_{0\text{-}2}\left(2\ years\right) + EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$ET_{event\text{-}res\text{-}c}\left(\frac{0.54\ hours}{event}\right) = \frac{ET_{event\left(0\text{-}2\right)}\left(\frac{0.54\ hours}{event}\right) \times ED_{0\text{-}2}\left(2\ years\right) + ET_{event\left(2\text{-}4\right)}\left(\frac{0.54\ hours}{event}\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$ET_{res\text{-}c}\left(\frac{24\ hours}{day}\right) = \frac{ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times ED_{0\text{-}2}\left(2\ years\right) + ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$SA_{res\text{-}c}\left(6365\ cm^2\right) = \frac{SA_{0\text{-}2}\left(6365\ cm^2\right) \times ED_{0\text{-}2}\left(2\ years\right) + SA_{2\text{-}6}\left(6365\ cm^2\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

$$IRW_{res\text{-}c}\left(\frac{0.78\ L}{day}\right) = \frac{IRW_{0\text{-}2}\left(\frac{0.78\ L}{day}\right) \times ED_{0\text{-}2}\left(2\ years\right) + IRW_{2\text{-}6}\left(\frac{0.78\ L}{day}\right) \times ED_{2\text{-}6}\left(4\ years\right)}{ED_{0\text{-}2}\left(2\ years\right) + ED_{2\text{-}6}\left(4\ years\right)}$$

Adult

$$ED_{res\text{-}a}\,(20\text{ years}) = ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})$$

$$BW_{res\text{-}a}\,(80\text{ kg}) = \frac{BW_{6\text{-}16}\,(80\text{ kg}) \times ED_{6\text{-}16}\,(10\text{ years}) + BW_{16\text{-}26}\,(80\text{ kg}) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$EV_{res\text{-}a}\left(\frac{1\text{ event}}{\text{day}}\right) = \frac{EV_{6\text{-}16}\left(\frac{1\text{ event}}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + EV_{16\text{-}26}\left(\frac{1\text{ event}}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$EF_{res\text{-}a}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{EF_{6\text{-}16}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + EF_{16\text{-}26}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$ET_{event\text{-}res\text{-}a}\left(\frac{0.71\text{ hours}}{\text{event}}\right) = \frac{ET_{event\,(6\text{-}16)}\left(\frac{0.71\text{ hours}}{\text{event}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + ET_{event\,(16\text{-}26)}\left(\frac{0.71\text{ hours}}{\text{event}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$ET_{res\text{-}a}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{ET_{6\text{-}16}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + ET_{16\text{-}26}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$SA_{res\text{-}a}\left(19652\text{ cm}^2\right) = \frac{SA_{6\text{-}16}\left(19652\text{ cm}^2\right) \times ED_{6\text{-}16}\,(10\text{ years}) + SA_{16\text{-}26}\left(19652\text{ cm}^2\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$IRW_{res\text{-}a}\left(\frac{2.5\text{ L}}{\text{day}}\right) = \frac{IRW_{6\text{-}16}\left(\frac{2.5\text{ L}}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + IRW_{16\text{-}26}\left(\frac{2.5\text{ L}}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years})}{ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

Age-adjusted

$$ED_{res}\,(26\text{ years}) = ED_{0\text{-}2}\,(2\text{ years}) + ED_{2\text{-}6}\,(4\text{ years}) + ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})$$

$$EF_{res}\left(\frac{350\text{ days}}{\text{year}}\right) = \frac{\begin{array}{l} EF_{0\text{-}2}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{0\text{-}2}\,(2\text{ years}) + EF_{2\text{-}6}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{2\text{-}6}\,(4\text{ years}) + \\ EF_{6\text{-}16}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + EF_{16\text{-}26}\left(\frac{350\text{ days}}{\text{year}}\right) \times ED_{16\text{-}26}\,(10\text{ years}) \end{array}}{ED_{0\text{-}2}\,(2\text{ years}) + ED_{2\text{-}6}\,(4\text{ years}) + ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

$$ET_{res}\left(\frac{24\text{ hours}}{\text{day}}\right) = \frac{\begin{array}{l} ET_{0\text{-}2}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{0\text{-}2}\,(2\text{ years}) + ET_{2\text{-}6}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{2\text{-}6}\,(4\text{ years}) + \\ ET_{6\text{-}16}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{6\text{-}16}\,(10\text{ years}) + ET_{16\text{-}26}\left(\frac{24\text{ hours}}{\text{day}}\right) \times ED_{16\text{-}26}\,(10\text{ years}) \end{array}}{ED_{0\text{-}2}\,(2\text{ years}) + ED_{2\text{-}6}\,(4\text{ years}) + ED_{6\text{-}16}\,(10\text{ years}) + ED_{16\text{-}26}\,(10\text{ years})}$$

Return to Equations Table

Air

Noncarcinogenic
Inhalation

$$SL_{res\text{-}air\text{-}nc}\left(\mu g/m^3\right)=\frac{THQ\times AT_r\left(\frac{365\ days}{year}\times ED_r\ (26\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_r\ (26\ years)\times ET_{ra}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times\frac{1}{RfC\left(\frac{mg}{m^3}\right)}}$$

Carcinogenic
Inhalation

$$SL_{res\text{-}air\text{-}ca}\left(\mu g/m^3\right)=\frac{TR\times AT_r\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{EF_r\left(\frac{350\ days}{year}\right)\times ED_r\ (26\ years)\times ET_{ra}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}}$$

Mutagenic
Inhalation

$$SL_{res\text{-}air\text{-}mu}\left(\mu g/m^3\right)=\frac{TR\times AT_r\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{\left(\frac{1\ day}{24\ hours}\right)\times\left(\begin{array}{l}\left(ED_{0\text{-}2}\ (yrs)\times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right)\times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times 10\right)+\\ \left(ED_{2\text{-}6}\ (yrs)\times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right)\times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times 3\right)+\\ \left(ED_{6\text{-}16}\ (yrs)\times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right)\times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times 3\right)+\\ \left(ED_{16\text{-}26}\ (yrs)\times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right)\times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right)\times IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times 1\right)\end{array}\right)}$$

Vinyl Chloride
Inhalation

$$SL_{res\text{-}air\text{-}ca\text{-}vinyl\ chloride}\left(\mu g/m^3\right)=\frac{TR}{IUR\left(\frac{\mu g}{m^3}\right)^{-1}+\left(\frac{IUR\left(\frac{\mu g}{m^3}\right)^{-1}\times EF_{res}\left(\frac{350\ days}{year}\right)\times ED_{res}\ (26\ years)\times ET_{res}\left(\frac{24\ hours}{day}\right)\times\left(\frac{1\ day}{24\ hours}\right)}{AT_{res}\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}\right)}$$

Trichloroethylene
Inhalation

$$SL_{res\text{-}air\text{-}tce}\left(\mu g/m^3\right) = \frac{TR \times AT_{res}\left(\frac{365\ days}{year} \times LT\ (70\ years)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\begin{array}{l} \left(ED_{res}\ (26\ years) \times EF_{res}\left(\frac{350\ days}{year}\right) \times ET_{res}\left(\frac{24\ hours}{day}\right) \times CAF_i\ (0.756)\right) + \\ \left(\begin{array}{l} \left(ED_{0\text{-}2}\ (2\ years) \times EF_{0\text{-}2}\left(\frac{350\ days}{year}\right) \times ET_{0\text{-}2}\left(\frac{24\ hours}{day}\right) \times MAF_i\ (0.244) \times 10\right) + \\ \left(ED_{2\text{-}6}\ (4\ years) \times EF_{2\text{-}6}\left(\frac{350\ days}{year}\right) \times ET_{2\text{-}6}\left(\frac{24\ hours}{day}\right) \times MAF_i\ (0.244) \times 3\right) + \\ \left(ED_{6\text{-}16}\ (10\ years) \times EF_{6\text{-}16}\left(\frac{350\ days}{year}\right) \times ET_{6\text{-}16}\left(\frac{24\ hours}{day}\right) \times MAF_i\ (0.244) \times 3\right) + \\ \left(ED_{16\text{-}26}\ (10\ years) \times EF_{16\text{-}26}\left(\frac{350\ days}{year}\right) \times ET_{16\text{-}26}\left(\frac{24\ hours}{day}\right) \times MAF_i\ (0.244) \times 1\right) \end{array}\right) \end{array}\right)}$$

Return to Equations Table

Sediment

Calculates on Recreator Exposure Defaults and Recreator Sediment Equations
Return to Equations Table

Surface Water

Calculates on Recreator Exposure Defaults and Recreator Surface Water Equations
Return to Equations Table

Food

Noncarcinogenic

$$SL_{res\text{-}fsh\text{-}nc\text{-}ing}\ (mg/kg) = \frac{THQ \times AT_r\left(\frac{365\ days}{year} \times ED_r\ (26\ years)\right) \times BW_a\ (80\ Kg)}{EF_r\left(\frac{350\ days}{year}\right) \times ED_r\ (26\ year) \times \frac{1}{RfD_o\left(\frac{mg}{Kg\text{-}day}\right)} \times IRF_a\left(\frac{mg}{day}\right) \times \frac{10^{-6} Kg}{1 mg}}$$

Carcinogenic

$$SL_{res\text{-}fsh\text{-}ca\text{-}ing}\ (mg/kg) = \frac{TR \times AT_r\left(\frac{365\ days}{year} \times LT\ (70\ years)\right) \times BW_a\ (80\ Kg)}{EF_r\left(\frac{350\ days}{year}\right) \times ED_r\ (26\ year) \times CSF_o\left(\frac{mg}{Kg\text{-}day}\right)^{-1} \times IRF_a\left(\frac{mg}{day}\right) \times \frac{10^{-6} Kg}{1\ mg}}$$

Return to Equations Table

Industrial Commercial Worker RSL Composite Worker Equations

Soil (Composite Worker)

Noncarcinogenic
Ingestion

$$SL_{w\text{-}soil\text{-}nc\text{-}ing}\,(mg/kg) = \frac{THQ \times AT_{w\text{-}a}\left(\frac{365\ days}{year} \times ED_w\,(25\ years)\right) \times BW_w\,(80\ kg)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IR_w\left(100\ \frac{mg}{day}\right) \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

Dermal

$$SL_{w\text{-}soil\text{-}nc\text{-}der}\,(mg/kg) = \frac{THQ \times AT_{w\text{-}a}\left(\frac{365\ days}{year} \times ED_w\,(25\ years)\right) \times BW_w\,(80\ kg)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times \left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS}\right) \times SA_w\left(\frac{3527\ cm^2}{day}\right) \times AF_w\left(\frac{0.12\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

Inhalation

$$SL_{w\text{-}soil\text{-}nc\text{-}inh}\,(mg/kg) = \frac{THQ \times AT_{w\text{-}a}\left(\frac{365\ days}{year} \times ED_w\,(25\ years)\right)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times ET_w\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Carcinogenic
Ingestion

$$SL_{w\text{-}soil\text{-}ca\text{-}ing}\,(mg/kg) = \frac{TR \times AT_w\left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \times BW_w\,(80\ kg)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IR_w\left(100\ \frac{mg}{day}\right) \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

Dermal

$$SL_{w\text{-}soil\text{-}ca\text{-}der}\,(mg/kg) = \frac{TR \times AT_w\left(\frac{365\ days}{year} \times LT\,(70\ years)\right) \times BW_w\,(80\ kg)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times SA_w\left(\frac{3527\ cm^2}{day}\right) \times AF_w\left(\frac{0.12\ mg}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\ kg}{1\ mg}\right)}$$

Inhalation

$$SL_{w\text{-}soil\text{-}ca\text{-}inh}\,(mg/kg) = \frac{TR \times AT_w\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{EF_w\left(250\ \frac{days}{year}\right) \times ED_w\,(25\ years) \times ET_w\left(\frac{8\ hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Return to Equations Table

Air

Noncarcinogenic
Inhalation

$$SL_{w\text{-}air\text{-}nc}\left(\mu g/m^3\right)=\frac{THQ\times AT_w\left(\frac{365\ days}{year}\times ED_w\ (25\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{EF_w\left(\frac{250\ days}{year}\right)\times ED_w\ (25\ years)\times ET_w\left(\frac{8\ hr}{24\ hr}\right)\times\frac{1}{RfC\left(mg/m^3\right)}}$$

Carcinogenic
Inhalation

$$SL_{w\text{-}air\text{-}ca}\left(\mu g/m^3\right)=\frac{TR\times AT_w\left(\frac{365\ days}{year}\times LT\ (70\ years)\right)}{EF_w\left(\frac{250\ days}{year}\right)\times ED_w\ (25\ years)\times ET_w\left(\frac{8\ hr}{24\ hr}\right)\times IUR\left(\mu g/m^3\right)^{-1}}$$

Return to Equations Table

Construction Worker RSL Standard Vehicle Traffic Equations

Soil

NOTE: VURAM uses Subchronic toxicity values where available for construction worker scenario.

Noncarcinogenic
Ingestion

$$SL_{cw\text{-}soil\text{-}nc\text{-}ing}\,(mg/kg) = \frac{THQ \times AT_{cw\text{-}a}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times \frac{7\text{ days}}{week} \times ED_{cw}\,(1\text{ year})\right) \times BW_{cw}\,(80\text{ kg})}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IR_{cw}\left(330\,\frac{mg}{day}\right) \times \left(\frac{10^{-6}\text{ kg}}{1\text{ mg}}\right)}$$

Dermal

$$SL_{cw\text{-}soil\text{-}nc\text{-}der}\,(mg/kg) = \frac{THQ \times AT_{cw\text{-}a}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times \frac{7\text{ days}}{week} \times ED_{cw}\,(1\text{ year})\right) \times BW_{cw}\,(80\text{ kg})}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times \left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS}\right) \times SA_{cw}\left(\frac{3527\text{ cm}^2}{day}\right) \times AF_{cw}\left(\frac{0.3\text{ mg}}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\text{ kg}}{1\text{ mg}}\right)}$$

Inhalation

$$SL_{cw\text{-}soil\text{-}nc\text{-}inh}\,(mg/kg) = \frac{THQ \times AT_{cw\text{-}a}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times \frac{7\text{ days}}{week} \times ED_{cw}\,(1\text{ year})\right)}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times ET_{cw}\left(\frac{8\text{ hours}}{day}\right) \times \left(\frac{1\text{ day}}{24\text{ hours}}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_{sc}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

Carcinogenic
Ingestion

$$SL_{cw\text{-}soil\text{-}ca\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\text{ days}}{year} \times LT\,(70\text{ years})\right) \times BW_{cw}\,(80\text{ kg})}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IR_{cw}\left(330\,\frac{mg}{day}\right) \times \left(\frac{10^{-6}\text{ kg}}{1\text{ mg}}\right)}$$

Dermal

$$SL_{cw\text{-}soil\text{-}ca\text{-}der}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\text{ days}}{year} \times LT\,(70\text{ years})\right) \times BW_{cw}\,(80\text{ kg})}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times \left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times SA_{cw}\left(\frac{3527\text{ cm}^2}{day}\right) \times AF_{cw}\left(\frac{0.3\text{ mg}}{cm^2}\right) \times ABS_d \times \left(\frac{10^{-6}\text{ kg}}{1\text{ mg}}\right)}$$

Inhalation

$$SL_{cw\text{-}soil\text{-}ca\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{cw}\left(\frac{365\text{ days}}{year} \times LT\,(70\text{ years})\right)}{EF_{cw}\left(EW_{cw}\,\frac{50\text{ weeks}}{year} \times DW_{cw}\,\frac{5\text{ days}}{week}\right) \times ED_{cw}\,(1\text{ year}) \times ET_{cw}\left(\frac{8\text{ hours}}{day}\right) \times \left(\frac{1\text{ day}}{24\text{ hours}}\right) \times IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1}{VF_{sc}\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_{sc}\left(\frac{m^3}{kg}\right)}\right)}$$

Return to Equations Table

Groundwater

See Construction Groundwater Trench Model in Appendix 3.
NOTE: VURAM uses Subchronic toxicity values where available for construction worker scenario.
Return to Equations Table

Recreator

Soil or Sediment

Noncarcinogenic Child
Ingestion

$$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\,(years)\right) \times BW_{rec\text{-}c}\,(15\ kg)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Dermal

$$SL_{rec\text{-}soil\text{-}nc\text{-}der\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\,(years)\right) \times BW_{rec\text{-}c}\,(15\ kg)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

Inhalation

$$SL_{rec\text{-}soil\text{-}nc\text{-}inh\text{-}c}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\,(years)\right)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\,(years) \times ET_{rec\text{-}c}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Noncarcinogenic Adult
Ingestion

$$SL_{rec\text{-}soil\text{-}nc\text{-}ing\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\,(years)\right) \times BW_{rec\text{-}a}\,(80\ kg)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times \frac{RBA}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)} \times IRS_{rec\text{-}a}\left(\frac{100\ mg}{day}\right) \times \frac{10^{-6}kg}{1mg}}$$

Dermal

$$SL_{rec\text{-}soil\text{-}nc\text{-}der\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\,(years)\right) \times BW_{rec\text{-}a}\,(80\ kg)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times \frac{1}{\left(RfD_o\left(\frac{mg}{kg\text{-}day}\right) \times GIABS\right)} \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right) \times ABS_d \times \frac{10^{-6}kg}{1mg}}$$

Inhalation

$$SL_{rec\text{-}soil\text{-}nc\text{-}inh\text{-}a}\,(mg/kg) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\,(years)\right)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\,(years) \times ET_{rec\text{-}a}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \frac{1}{RfC\left(mg/m^3\right)} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right)}$$

Carcinogenic
Ingestion

$$SL_{rec\text{-}soil\text{-}ca\text{-}ing}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}c}\left(\frac{200\ mg}{day}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times IRS_{rec\text{-}a}\left(\frac{100\ mg}{day}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

Dermal

$$SL_{rec\text{-}soil\text{-}ca\text{-}der}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFS_{rec\text{-}adj}\left(\frac{mg}{Kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2mg}{cm^2}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

Inhalation

$$SL_{rec\text{-}soil\text{-}ca\text{-}inh}\left(mg/kg\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1000\ \mu g}{mg}\right) \times EF_{rec}\left(\frac{days}{year}\right) \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times ED_{rec}\left(years\right) \times ET_{rec}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right)}$$

Mutagenic
Ingestion

$$SL_{rec\text{-}soil\text{-}mu\text{-}ing}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \\ \frac{ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \\ \frac{ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \\ \frac{ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)} \end{array}\right)$$

Dermal

$$SL_{rec\text{-}soil\text{-}mu\text{-}der}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d \times \left(\frac{10^{-6}kg}{mg}\right)}$$

where:

$$DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \\ \frac{ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \\ \frac{ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \\ \frac{ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)} \end{array}\right)$$

Inhalation

$$SL_{rec\text{-}soil\text{-}mu\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{recs}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\begin{array}{l} \left(ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times ET_{0\text{-}2}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 10\right) + \\ \left(ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times ET_{2\text{-}6}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \\ \left(ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times ET_{6\text{-}16}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 3\right) + \\ \left(ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times ET_{16\text{-}26}\left(\frac{hours}{day}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times 1\right) \end{array}\right)}$$

Vinyl Chloride
Ingestion

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}ing}\,(mg/kg) = \frac{TR}{\left(\dfrac{CSF_o\left(\dfrac{mg}{kg\text{-}day}\right)^{-1} \times IFS_{rec\text{-}adj}\left(\dfrac{mg}{kg}\right) \times \dfrac{10^{-6}kg}{1\ mg}}{AT_{recs}\left(\dfrac{365\ days}{year} \times LT\ (70\ years)\right)}\right) + \left(\dfrac{CSF_o\left(\dfrac{mg}{kg\text{-}day}\right)^{-1} \times IRS_{recsc}\left(\dfrac{200\ mg}{day}\right) \times \dfrac{10^{-6}kg}{1\ mg}}{BW_{recsc}\,(15\ kg)}\right)}$$

Dermal

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}der}\,(mg/kg) = \frac{TR}{\left(\dfrac{\dfrac{CSF_o\left(\dfrac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times DFS_{rec\text{-}adj}\left(\dfrac{mg}{kg}\right) \times ABS_d \times \dfrac{10^{-6}kg}{1\ mg}}{AT_{rec}\left(\dfrac{365\ days}{year} \times LT\,(70\ years)\right)}\right) + \left(\dfrac{\dfrac{CSF_o\left(\dfrac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times SA_{rec\text{-}c}\left(\dfrac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\dfrac{0.2\ mg}{cm^2}\right) \times ABS \times \dfrac{10^{-6}kg}{1\ mg}}{BW_{rec\text{-}c}\,(15\ kg)}\right)}$$

Inhalation

$$SL_{rec\text{-}soil\text{-}ca\text{-}vc\text{-}inh}\,(mg/kg) = \frac{TR}{\left(\dfrac{IUR\left(\mu g/m^3\right)^{-1} \times EF_{rec}\left(\dfrac{days}{year}\right) \times ED_{rec}\,(years) \times ET_{rec}\left(\dfrac{hours}{day}\right) \times \left(\dfrac{1\ day}{24\ hours}\right) \times \left(\dfrac{1000\ \mu g}{mg}\right)}{AT_{rec}\left(\dfrac{365\ days}{year} \times LT\,(70\ years)\right) \times VF_s\left(\dfrac{m^3}{kg}\right)}\right) + \left(\dfrac{IUR\left(\mu g/m^3\right)^{-1}}{VF_s\left(\dfrac{m^3}{kg}\right)} \times \left(\dfrac{1000\ \mu g}{mg}\right)\right)}$$

Trichloroethylene
Ingestion

$$SL_{rec\text{-}soil\text{-}tce\text{-}ing}\left(mg/kg\right)=\frac{TR\times AT_{recs}\left(\frac{365\ days}{year}\times LT\left(70\ years\right)\right)}{CSF_{o}\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times\left(\frac{10^{-6}\ kg}{mg}\right)\times\left(\left(CAF_{o}\left(0.804\right)\times IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right)\right)+\left(MAF_{o}\left(0.202\right)\times IFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right)\right)\right)}$$

where:

$$IFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right)=\left(\frac{ED_{recsc}\left(years\right)\times EF_{recsc}\left(\frac{days}{year}\right)\times IRS_{recsc}\left(\frac{200\ mg}{day}\right)}{BW_{recsc}\left(15\ kg\right)}+\frac{\left(ED_{recs}\left(years\right)-ED_{recsc}\left(years\right)\right)\times EF_{recsa}\left(\frac{days}{year}\right)\times IRS_{recsa}\left(\frac{100\ mg}{day}\right)}{BW_{recsa}\left(80\ kg\right)}\right)$$

where:

$$IFSM_{rec\text{-}adj\text{-}}\left(\frac{mg}{kg}\right)=\left(\frac{ED_{0\text{-}2}\left(years\right)\times EF_{0\text{-}2}\left(\frac{days}{year}\right)\times IRS_{0\text{-}2}\left(\frac{200\ mg}{day}\right)\times 10}{BW_{0\text{-}2}\left(15\ kg\right)}+\frac{ED_{2\text{-}6}\left(years\right)\times EF_{2\text{-}6}\left(\frac{days}{year}\right)\times IRS_{2\text{-}6}\left(\frac{200\ mg}{day}\right)\times 3}{BW_{2\text{-}6}\left(15\ kg\right)}+\frac{ED_{6\text{-}16}\left(years\right)\times EF_{6\text{-}16}\left(\frac{days}{year}\right)\times IRS_{6\text{-}16}\left(\frac{100\ mg}{day}\right)\times 3}{BW_{6\text{-}16}\left(80\ kg\right)}+\frac{ED_{16\text{-}26}\left(years\right)\times EF_{16\text{-}26}\left(\frac{days}{year}\right)\times IRS_{16\text{-}26}\left(\frac{100\ mg}{day}\right)\times 1}{BW_{16\text{-}26}\left(80\ kg\right)}\right)$$

Dermal

$$SL_{rec\text{-}soil\text{-}tce\text{-}der}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times \left(\frac{10^{-6}kg}{mg}\right) \times \left(\left(CAF_o\,(0.804) \times DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d\right) + \left(MAF_o\,(0.202) \times DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) \times ABS_d\right)\right)}$$

where:

$$DFS_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{rec\text{-}c}\,(years) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(\frac{2373\ cm^2}{day}\right) \times AF_{rec\text{-}c}\left(\frac{0.2\ mg}{cm^2}\right)}{BW_{rec\text{-}c}\,(15\ kg)} + \frac{\left(ED_{rec}\,(years) - ED_{rec\text{-}c}\,(years)\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(\frac{6032\ cm^2}{day}\right) \times AF_{rec\text{-}a}\left(\frac{0.07\ mg}{cm^2}\right)}{BW_{rec\text{-}a}\,(80\ kg)}\right)$$

where:

$$DFSM_{rec\text{-}adj}\left(\frac{mg}{kg}\right) = \left(\frac{ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times AF_{0\text{-}2}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{0\text{-}2}\left(\frac{2373\ cm^2}{day}\right) \times 10}{BW_{0\text{-}2}\,(15\ kg)} + \frac{ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times AF_{2\text{-}6}\left(\frac{0.2\ mg}{cm^2}\right) \times SA_{2\text{-}6}\left(\frac{2373\ cm^2}{day}\right) \times 3}{BW_{2\text{-}6}\,(15\ kg)} + \frac{ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times AF_{6\text{-}16}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{6\text{-}16}\left(\frac{6032\ cm^2}{day}\right) \times 3}{BW_{6\text{-}16}\,(80\ kg)} + \frac{ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times AF_{16\text{-}26}\left(\frac{0.07\ mg}{cm^2}\right) \times SA_{16\text{-}26}\left(\frac{6032\ cm^2}{day}\right) \times 1}{BW_{16\text{-}26}\,(80\ kg)}\right)$$

Inhalation

$$SL_{rec\text{-}soil\text{-}tce\text{-}inh}\,(mg/kg) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\,(70\ years)\right)}{IUR\left(\mu g/m^3\right)^{-1} \times \left(\frac{1}{VF_s\left(\frac{m^3}{kg}\right)} + \frac{1}{PEF_w\left(\frac{m^3}{kg}\right)}\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times \left(\frac{1\ day}{24\ hours}\right) \times \left(\left(CAF_i\,(0.756) \times EF_{rec}\left(\frac{days}{year}\right) \times ED_{rec}\,(years) \times ET_{rec}\left(\frac{hours}{day}\right)\right) + \left(\left(ED_{0\text{-}2}\,(years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times ET_{0\text{-}2}\left(\frac{hours}{day}\right) \times MAF_i\,(0.244) \times 10\right) + \left(ED_{2\text{-}6}\,(years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times ET_{2\text{-}6}\left(\frac{hours}{day}\right) \times MAF_i\,(0.244) \times 3\right) + \left(ED_{6\text{-}16}\,(years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times ET_{6\text{-}16}\left(\frac{hours}{day}\right) \times MAF_i\,(0.244) \times 3\right) + \left(ED_{16\text{-}26}\,(years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times ET_{16\text{-}26}\left(\frac{hours}{day}\right) \times MAF_i\,(0.244) \times 1\right)\right)}$$

Supporting Equations
Child

$$ED_{rec\text{-}c}\,(\text{years}) = ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})$$

$$BW_{rec\text{-}c}\,(\text{kg}) = \frac{BW_{0\text{-}2}\,(\text{kg}) \times ED_{0\text{-}2}\,(\text{years}) + BW_{2\text{-}6}\,(\text{kg}) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

$$AF_{rec\text{-}c}\left(\frac{\text{events}}{\text{day}}\right) = \frac{AF_{0\text{-}2}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{0\text{-}2}\,(\text{years}) + AF_{2\text{-}6}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

$$EF_{rec\text{-}c}\left(\frac{\text{days}}{\text{year}}\right) = \frac{EF_{0\text{-}2}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{0\text{-}2}\,(\text{years}) + EF_{2\text{-}6}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

$$ET_{rec\text{-}c}\left(\frac{\text{hours}}{\text{day}}\right) = \frac{ET_{0\text{-}2}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{0\text{-}2}\,(\text{years}) + ET_{2\text{-}6}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

$$SA_{rec\text{-}c}\left(\frac{\text{cm}^2}{\text{day}}\right) = \frac{SA_{0\text{-}2}\left(\frac{\text{cm}^2}{\text{day}}\right) \times ED_{0\text{-}2}\,(\text{years}) + SA_{2\text{-}6}\left(\frac{\text{cm}^2}{\text{day}}\right) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

$$IRS_{rec\text{-}c}\left(\frac{\text{mg}}{\text{day}}\right) = \frac{IRS_{0\text{-}2}\left(\frac{\text{mg}}{\text{day}}\right) \times ED_{0\text{-}2}\,(\text{years}) + IRS_{2\text{-}6}\left(\frac{\text{mg}}{\text{day}}\right) \times ED_{2\text{-}6}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years})}$$

Adult

$$ED_{rec\text{-}a}\,(\text{years}) = ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})$$

$$BW_{rec\text{-}a}\,(\text{kg}) = \frac{BW_{6\text{-}16}\,(\text{kg}) \times ED_{6\text{-}16}\,(\text{years}) + BW_{16\text{-}26}\,(\text{kg}) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$AF_{rec\text{-}a}\left(\frac{\text{events}}{\text{day}}\right) = \frac{AF_{6\text{-}16}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{6\text{-}16}\,(\text{years}) + AF_{16\text{-}26}\left(\frac{\text{events}}{\text{day}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$EF_{rec\text{-}a}\left(\frac{\text{days}}{\text{year}}\right) = \frac{EF_{6\text{-}16}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{6\text{-}16}\,(\text{years}) + EF_{16\text{-}26}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$ET_{rec\text{-}a}\left(\frac{\text{hours}}{\text{day}}\right) = \frac{ET_{6\text{-}16}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{6\text{-}16}\,(\text{years}) + ET_{16\text{-}26}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$SA_{rec\text{-}a}\left(\frac{\text{cm}^2}{\text{day}}\right) = \frac{SA_{6\text{-}16}\left(\frac{\text{cm}^2}{\text{day}}\right) \times ED_{6\text{-}16}\,(\text{years}) + SA_{16\text{-}26}\left(\frac{\text{cm}^2}{\text{day}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$IRS_{rec\text{-}a}\left(\frac{\text{mg}}{\text{day}}\right) = \frac{IRS_{6\text{-}16}\left(\frac{\text{mg}}{\text{day}}\right) \times ED_{6\text{-}16}\,(\text{years}) + IRS_{16\text{-}26}\left(\frac{\text{mg}}{\text{day}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

Age-Adjusted

$$ED_{rec}\,(\text{years}) = ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years}) + ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})$$

$$EF_{rec}\left(\frac{\text{days}}{\text{year}}\right) = \frac{EF_{0\text{-}2}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{0\text{-}2}\,(\text{years}) + EF_{2\text{-}6}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{2\text{-}6}\,(\text{years}) + EF_{6\text{-}16}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{6\text{-}16}\,(\text{years}) + EF_{16\text{-}26}\left(\frac{\text{days}}{\text{year}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years}) + ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

$$ET_{rec}\left(\frac{\text{hours}}{\text{day}}\right) = \frac{ET_{0\text{-}2}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{0\text{-}2}\,(\text{years}) + ET_{2\text{-}6}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{2\text{-}6}\,(\text{years}) + ET_{6\text{-}16}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{6\text{-}16}\,(\text{years}) + ET_{16\text{-}26}\left(\frac{\text{hours}}{\text{day}}\right) \times ED_{16\text{-}26}\,(\text{years})}{ED_{0\text{-}2}\,(\text{years}) + ED_{2\text{-}6}\,(\text{years}) + ED_{6\text{-}16}\,(\text{years}) + ED_{16\text{-}26}\,(\text{years})}$$

Return to Equations Table

Surface Water

Noncarcinogenic Child
Ingestion

$$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}c}\left(\mu g/L\right) = \frac{THQ \times AT_{rec\text{-}c}\left(\frac{365\ days}{year} \times ED_{rec\text{-}c}\left(years\right)\right) \times BW_{rec\text{-}c}\left(15\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ED_{rec\text{-}c}\left(years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{rec\text{-}c}\left(\frac{0.05\ L}{hour}\right) \times EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right)}$$

Dermal

FOR INORGANICS:

$$CDI_{rec\text{-}water\text{-}nc\text{-}der\text{-}c}\left(mg/kg\text{-}day\right) = \frac{C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\ mg}{1000\ \mu g}\right) \times EV_{recwc}\left(\frac{events}{day}\right) \times ED_{recwc}\left(years\right) \times EF_{recwc}\left(\frac{days}{year}\right) \times SA_{recwc}\left(6378\ cm^2\right) \times \left(\frac{1\ L}{1000\ cm^3}\right) \times K_p\left(\frac{cm}{hour}\right) \times ET_{recwc}\left(\frac{hours}{event}\right)}{AT_{recw}\left(\frac{365\ days}{year} \times ED_{recwc}\left(years\right)\right) \times BW_{recwc}\left(15\ kg\right)}$$

FOR ORGANICS:

$$CDI_{rec\text{-}water\text{-}nc\text{-}der\text{-}c}\left(mg/kg\text{-}day\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) \times EV_{recwc}\left(\frac{events}{day}\right) \times ED_{recwc}\left(years\right) \times EF_{recwc}\left(\frac{days}{year}\right) \times SA_{recwc}\left(6378\ cm^2\right)}{AT_{recw}\left(\frac{365\ days}{year} \times ED_{recwc}\left(years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right) \times BW_{recwc}\left(15\ kg\right)}$$

where:

$$\text{If } ET_{recwc}\left(\frac{hours}{event}\right) \le t^*\left(hours\right), \text{then } DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = 2 \times FA \times K_p\left(\frac{cm}{hour}\right) \times C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\ L}{1000\ cm^3}\right) \times \sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{recwc}\left(\frac{hours}{event}\right)}{\pi}}$$

or,

$$\text{If } ET_{recwc}\left(\frac{hours}{event}\right) > t^*\left(hours\right), \text{then } DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = FA \times K_p\left(\frac{cm}{hour}\right) \times C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\ L}{1000\ cm^3}\right) \times \left[\frac{ET_{recwc}\left(\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{\left(1+B\right)^2}\right)\right]$$

Noncarcinogenic Adult
Ingestion

$$SL_{rec\text{-}water\text{-}nc\text{-}ing\text{-}a}\left(\mu g/L\right) = \frac{THQ \times AT_{rec\text{-}a}\left(\frac{365\ days}{year} \times ED_{rec\text{-}a}\left(years\right)\right) \times BW_{rec\text{-}a}\left(80\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ED_{rec\text{-}a}\left(years\right) \times \frac{1}{RfD_o\left(\frac{mg}{kg\text{-}d}\right)} \times IRW_{rec\text{-}a}\left(\frac{0.05\ L}{hour}\right) \times EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right)}$$

Dermal

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}nc\text{-}der\text{-}a}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right) \le t^*\,(hour), \text{then } SL_{rec\text{-}water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right) > t^*\,(hour), \text{then } SL_{rec\text{-}water\text{-}nc\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{THQ\times AT_{rec\text{-}a}\left(\frac{365\ days}{year}\times ED_{rec\text{-}a}\,(years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)\times BW_{rec\text{-}a}\,(80\ kg)}{\left(\frac{1}{RfD_o\left(\frac{mg}{kg\text{-}day}\right)\times GIABS}\right)\times EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\,(years)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times SA_{rec\text{-}a}\left(19652\ cm^2\right)}$$

Carcinogenic
Ingestion

$$SL_{rec\text{-}water\text{-}ca\text{-}ing}\,(\mu g/L) = \frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}\times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right)\times ED_{rec\text{-}c}\,(years)\times EF_{rec\text{-}c}\left(\frac{days}{year}\right)\times ET_{rec\text{-}c}\left(\frac{hours}{event}\right)\times IRW_{rec\text{-}c}\left(\frac{0.05\ L}{hour}\right)}{BW_{rec\text{-}c}\,(15\ kg)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\,(years)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times ET_{rec\text{-}a}\left(\frac{hours}{event}\right)\times IRW_{rec\text{-}a}\left(\frac{0.05\ L}{hour}\right)}{BW_{rec\text{-}a}\,(80\ kg)}\right)$$

Dermal

FOR INORGANICS:

$$SL_{rec\text{-}water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{K_p\left(\frac{cm}{hour}\right)\times ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}$$

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) \le t^*\,(hour),\text{then } SL_{rec\text{-}water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{2\times FA\times K_p\left(\frac{cm}{hour}\right)\sqrt{\frac{6\times\tau_{event}\left(\frac{hours}{event}\right)\times ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) > t^*\,(hour),\text{then } SL_{rec\text{-}water\text{-}ca\text{-}der}\,(\mu g/L) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right)\times\left(\frac{1000\ cm^3}{L}\right)}{FA\times K_p\left(\frac{cm}{hour}\right)\times\left[\frac{ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{1+B}+2\times\tau_{event}\left(\frac{hours}{event}\right)\times\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}\,event}\right) = \frac{TR\times AT_{rec}\left(\frac{365\ days}{year}\times LT\,(70\ years)\right)\times\left(\frac{1000\ \mu g}{mg}\right)}{\left(\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right)\times DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)}$$

where:

$$DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right)\times ED_{rec\text{-}c}\,(years)\times EF_{rec\text{-}c}\left(\frac{days}{year}\right)\times SA_{rec\text{-}c}\left(6365\ cm^2\right)}{BW_{rec\text{-}c}\,(15\ kg)}+\frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right)\times ED_{rec\text{-}a}\,(years)\times EF_{rec\text{-}a}\left(\frac{days}{year}\right)\times SA_{rec\text{-}a}\left(19652\ cm^2\right)}{BW_{rec\text{-}a}\,(80\ kg)}\right)$$

and:

$$ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right)\times ED_{rec\text{-}c}\,(years)+ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right)\times ED_{rec\text{-}a}\,(years)\right)}{ED_{rec\text{-}c}\,(years)+ED_{rec\text{-}a}\,(years)}\right)$$

Mutagenic
Ingestion

$$SL_{rec\text{-}water\text{-}mu\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right)}$$

where:

$$IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\begin{array}{l} \frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.05\ L}{hour}\right) \times EV_{0\text{-}2}\left(\frac{events}{day}\right) \times ET_{0\text{-}2}\left(\frac{hours}{event}\right) \times 10}{BW_{0\text{-}2}\left(15\ kg\right)} + \\ \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.05\ L}{hour}\right) \times EV_{2\text{-}6}\left(\frac{events}{day}\right) \times ET_{2\text{-}6}\left(\frac{hours}{event}\right) \times 3}{BW_{2\text{-}6}\left(15\ kg\right)} + \\ \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{0.05\ L}{hour}\right) \times EV_{6\text{-}16}\left(\frac{events}{day}\right) \times ET_{6\text{-}16}\left(\frac{hours}{event}\right) \times 3}{BW_{6\text{-}16}\left(80\ kg\right)} + \\ \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{0.05\ L}{hour}\right) \times EV_{16\text{-}26}\left(\frac{events}{day}\right) \times ET_{16\text{-}26}\left(\frac{hours}{event}\right) \times 1}{BW_{16\text{-}26}\left(80\ kg\right)} \end{array}\right)$$

Dermal

FOR INORGANICS:

$$CDI_{rec\text{-}water\text{-}mu\text{-}der}\,(mg/kg\text{-}day) = \frac{C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\,mg}{1000\,\mu g}\right) \times DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) \times \left(\frac{1\,L}{1000\,cm^3}\right) \times K_p\left(\frac{cm}{hour}\right) \times ET_{recw\text{-}madj}\left(\frac{hours}{event}\right)}{AT_{recw}\left(\frac{365\,days}{year} \times LT\,(70\,years)\right)}$$

where:

$$DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l} \left(\frac{EV_{recw\,0\text{-}2}\left(\frac{events}{day}\right) \times ED_{0\text{-}2}\,(2\,years) \times EF_{recw\,0\text{-}2}\left(\frac{days}{year}\right) \times SA_{0\text{-}2}\left(6378\,cm^2\right) \times 10}{BW_{0\text{-}2}\,(15\,kg)}\right) + \\ \left(\frac{EV_{recw\,2\text{-}6}\left(\frac{events}{day}\right) \times ED_{2\text{-}6}\,(4\,years) \times EF_{recw\,2\text{-}6}\left(\frac{days}{year}\right) \times SA_{2\text{-}6}\left(6378\,cm^2\right) \times 3}{BW_{2\text{-}6}\,(15\,kg)}\right) + \\ \left(\frac{EV_{recw\,6\text{-}16}\left(\frac{events}{day}\right) \times ED_{6\text{-}16}\,(10\,years) \times EF_{recw\,6\text{-}16}\left(\frac{days}{year}\right) \times SA_{6\text{-}16}\left(20900\,cm^2\right) \times 3}{BW_{6\text{-}16}\,(80\,kg)}\right) + \\ \left(\frac{EV_{recw\,16\text{-}26}\left(\frac{events}{day}\right) \times ED_{16\text{-}26}\,(10\,years) \times EF_{recw\,16\text{-}26}\left(\frac{days}{year}\right) \times SA_{16\text{-}26}\left(20900\,cm^2\right) \times 1}{BW_{16\text{-}26}\,(80\,kg)}\right) \end{array}\right]$$

and:

$$ET_{recw\text{-}madj}\left(\frac{hours}{event}\right) = \frac{\left(\begin{array}{l} ET_{recw\,0\text{-}2}\left(\frac{hours}{event}\right) \times ED_{0\text{-}2}\,(2\,years) + ET_{recw\,2\text{-}6}\left(\frac{hours}{event}\right) \times ED_{2\text{-}6}\,(4\,years) + \\ ET_{recw\,6\text{-}16}\left(\frac{hours}{event}\right) \times ED_{6\text{-}16}\,(10\,years) + ET_{recw\,16\text{-}26}\left(\frac{hours}{event}\right) \times ED_{16\text{-}26}\,(10\,years) \end{array}\right)}{ED_{0\text{-}2}\,(years) + ED_{2\text{-}6}\,(years) + ED_{6\text{-}16}\,(years) + ED_{16\text{-}26}\,(years)}$$

FOR ORGANICS:

$$CDI_{rec\text{-}water\text{-}mu\text{-}der}\,(mg/kg\text{-}day) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) \times DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)}{AT_{recw}\left(\frac{365\,days}{year} \times LT\,(70\,years)\right) \times \left(\frac{1000\,\mu g}{1\,mg}\right)}$$

where:

$$\text{If } ET_{recw\text{-}madj}\left(\frac{hours}{event}\right) \le t^*\,(hours), \text{then } DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = 2 \times FA \times K_p\left(\frac{cm}{hour}\right) \times C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\,L}{1000\,cm^3}\right) \times \sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{recw\text{-}adj}\left(\frac{hours}{event}\right)}{\pi}}$$

or,

$$\text{If } ET_{recw\text{-}madj}\left(\frac{hours}{event}\right) > t^*\,(hours), \text{then } DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = FA \times K_p\left(\frac{cm}{hour}\right) \times C_{water}\left(\frac{\mu g}{L}\right) \times \left(\frac{1\,L}{1000\,cm^3}\right) \times \left[\frac{ET_{recw\text{-}madj}\left(\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

Vinyl Chloride

Ingestion

$$SL_{rec\text{-}water\text{-}ca\text{-}vc\text{-}ing}\left(\mu g/L\right) = \frac{TR}{\left(\frac{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) \times \left(\frac{mg}{1000\ \mu g}\right)}{AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right)}\right) + \left(\frac{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times ET_{rec\text{-}c}\left(\frac{hr}{day}\right) \times IRW_{rec\text{-}c}\ \frac{0.05\ L}{hour} \times \left(\frac{mg}{1000\ \mu g}\right)}{BW_{rec\text{-}c}\left(15\ kg\right)}\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}c}\left(\frac{0.05\ L}{hour}\right)}{BW_{recwc}\left(15\ kg\right)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}a}\left(\frac{0.05\ L}{hour}\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

Dermal

$$\text{IF } ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) \le t^{*}\left(hours\right), \text{then } SL_{rec\text{-}water\text{-}vc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hour}\right) \sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) > t^{*}\left(hours\right), \text{then } SL_{rec\text{-}water\text{-}vc\text{-}der}\left(\mu g/L\right) = \frac{DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hour}\right) \times \left[\frac{ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1 + 3B + 3B^2}{\left(1+B\right)^2}\right)\right]}$$

where:

$$DA_{event}\left(\frac{ug}{cm^2\text{-}event}\right) = \frac{TR}{\left(\frac{\left(\frac{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)}{AT_{rec}\left(\frac{365\ days}{year} \times LT\left(70\ years\right)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}\right) + \left(\frac{\left(\frac{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS}\right) \times EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times SA_{rec\text{-}c}\left(6365\ cm^2\right)}{BW_{rec\text{-}c}\left(15\ kg\right) \times \left(\frac{1000\ \mu g}{mg}\right)}\right)}$$

where:

$$DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(6365\ cm^2\right)}{BW_{rec\text{-}c}\left(15\ kg\right)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(19652\ cm^2\right)}{BW_{rec\text{-}a}\left(80\ kg\right)}\right)$$

and:

$$ET_{event\text{-}rec\text{-}adj}\left(\frac{hours}{event}\right) = \left(\frac{\left(ET_{event\text{-}rec\text{-}c}\left(\frac{hours}{event}\right) \times ED_{rec\text{-}c}\left(years\right)\right) + \left(ET_{event\text{-}rec\text{-}a}\left(\frac{hours}{event}\right) \times ED_{rec\text{-}a}\left(years\right)\right)}{ED_{rec\text{-}c}\left(years\right) + ED_{rec\text{-}a}\left(years\right)}\right)$$

Trichloroethylene
Ingestion

$$SL_{rec\text{-}water\text{-}tce\text{-}ing}\left(\mu g/L\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\ (70\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{CSF_0\left(\frac{mg}{kg\text{-}day}\right)^{-1} \times RBA \times \left(\left(CAF_0\ (0.804) \times IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right)\right)\right) + \left(MAF_0\ (0.202) \times IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right)\right)}$$

where:

$$IFW_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\left(years\right) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times ET_{rec\text{-}c}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}c}\left(\frac{0.05\ L}{hour}\right)}{BW_{rec\text{-}c}\ (15\ kg)} + \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\left(years\right) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times ET_{rec\text{-}a}\left(\frac{hours}{event}\right) \times IRW_{rec\text{-}a}\left(\frac{0.05\ L}{hour}\right)}{BW_{rec\text{-}a}\ (80\ kg)}\right)$$

where:

$$IFWM_{rec\text{-}adj}\left(\frac{L}{kg}\right) = \left(\frac{ED_{0\text{-}2}\left(years\right) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times IRW_{0\text{-}2}\left(\frac{0.05\ L}{hour}\right) \times EV_{0\text{-}2}\left(\frac{events}{day}\right) \times ET_{0\text{-}2}\left(\frac{hours}{event}\right) \times 10}{BW_{0\text{-}2}\ (15\ kg)} + \frac{ED_{2\text{-}6}\left(years\right) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times IRW_{2\text{-}6}\left(\frac{0.05\ L}{hour}\right) \times EV_{2\text{-}6}\left(\frac{events}{day}\right) \times ET_{2\text{-}6}\left(\frac{hours}{event}\right) \times 3}{BW_{2\text{-}6}\ (15\ kg)} + \frac{ED_{6\text{-}16}\left(years\right) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times IRW_{6\text{-}16}\left(\frac{0.05\ L}{hour}\right) \times EV_{6\text{-}16}\left(\frac{events}{day}\right) \times ET_{6\text{-}16}\left(\frac{hours}{event}\right) \times 3}{BW_{6\text{-}16}\ (80\ kg)} + \frac{ED_{16\text{-}26}\left(years\right) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times IRW_{16\text{-}26}\left(\frac{0.05\ L}{hour}\right) \times EV_{16\text{-}26}\left(\frac{events}{day}\right) \times ET_{16\text{-}26}\left(\frac{hours}{event}\right) \times 1}{BW_{16\text{-}26}\ (80\ kg)}\right)$$

Dermal

FOR ORGANICS:

$$\text{IF } ET_{event\text{-}rec\text{-}madj}\left(\frac{1\ hour}{event}\right) \le t^{*}\ (hours), \text{then } SL_{rec\text{-}water\text{-}tce\text{-}der}\ (\mu g/L) = \frac{DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}\ event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{2 \times FA \times K_p\left(\frac{cm}{hour}\right) \sqrt{\frac{6 \times \tau_{event}\left(\frac{hours}{event}\right) \times ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right)}{\pi}}}$$

or,

$$\text{IF } ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right) > t^{*}\ (hours), \text{then } PRG_{rec\text{-}water\text{-}tce\text{-}der}\ (\mu g/L) = \frac{DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}\ event}\right) \times \left(\frac{1000\ cm^3}{L}\right)}{FA \times K_p\left(\frac{cm}{hour}\right) \times \left[\frac{ET_{event\text{-}rec\text{-}madj}\left(\frac{hours}{event}\right)}{1+B} + 2 \times \tau_{event}\left(\frac{hours}{event}\right) \times \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]}$$

where:

$$DA_{tce\text{-}event}\left(\frac{ug}{cm^2\text{-}\ event}\right) = \frac{TR \times AT_{rec}\left(\frac{365\ days}{year} \times LT\ (70\ years)\right) \times \left(\frac{1000\ \mu g}{mg}\right)}{\frac{CSF_o\left(\frac{mg}{kg\text{-}day}\right)^{-1}}{GIABS} \times \left(\left(AF_o\ (0.804) \times DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)\right) + \left(MAF_o\ (0.202) \times DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right)\right)\right)}$$

where:

$$DFW_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left(\begin{array}{l} \frac{EV_{rec\text{-}c}\left(\frac{events}{day}\right) \times ED_{rec\text{-}c}\ (years) \times EF_{rec\text{-}c}\left(\frac{days}{year}\right) \times SA_{rec\text{-}c}\left(6365\ cm^2\right)}{BW_{rec\text{-}c}\ (15\ kg)} + \\ \frac{EV_{rec\text{-}a}\left(\frac{events}{day}\right) \times ED_{rec\text{-}a}\ (years) \times EF_{rec\text{-}a}\left(\frac{days}{year}\right) \times SA_{rec\text{-}a}\left(19652\ cm^2\right)}{BW_{rec\text{-}a}\ (80\ kg)} \end{array}\right)$$

where:

$$DFWM_{rec\text{-}adj}\left(\frac{events\text{-}cm^2}{kg}\right) = \left[\begin{array}{l} \left(\frac{EV_{0\text{-}2}\left(\frac{events}{day}\right) \times ED_{0\text{-}2}\ (years) \times EF_{0\text{-}2}\left(\frac{days}{year}\right) \times SA_{0\text{-}2}\left(6365\ cm^2\right) \times 10}{BW_{0\text{-}2}\ (15\ kg)}\right) + \\ \left(\frac{EV_{2\text{-}6}\left(\frac{events}{day}\right) \times ED_{2\text{-}6}\ (years) \times EF_{2\text{-}6}\left(\frac{days}{year}\right) \times SA_{2\text{-}6}\left(6365\ cm^2\right) \times 3}{BW_{2\text{-}6}\ (15\ kg)}\right) + \\ \left(\frac{EV_{6\text{-}16}\left(\frac{events}{day}\right) \times ED_{6\text{-}16}\ (years) \times EF_{6\text{-}16}\left(\frac{days}{year}\right) \times SA_{6\text{-}16}\left(19652\ cm^2\right) \times 3}{BW_{6\text{-}16}\ (80\ kg)}\right) + \\ \left(\frac{EV_{16\text{-}26}\left(\frac{events}{day}\right) \times ED_{16\text{-}26}\ (years) \times EF_{16\text{-}26}\left(\frac{days}{year}\right) \times SA_{16\text{-}26}\left(19652\ cm^2\right) \times 1}{BW_{16\text{-}26}\ (80\ kg)}\right) \end{array}\right]$$

and:

$$ET_{event\text{-}recw\text{-}madj}\left(\frac{hours}{event}\right) = \frac{\left(\begin{array}{l} ET_{event\text{-}rec\ (0\text{-}2)}\left(\frac{hours}{event}\right) \times ED_{0\text{-}2}\ (years) + ET_{event\text{-}rec\ (2\text{-}6)}\left(\frac{hours}{event}\right) \times ED_{2\text{-}6}\ (years) + \\ ET_{event\text{-}rec\ (6\text{-}16)}\left(\frac{hours}{event}\right) \times ED_{6\text{-}16}\ (years) + ET_{event\text{-}rec\ (16\text{-}26)}\left(\frac{hours}{event}\right) \times ED_{16\text{-}26}\ (years) \end{array}\right)}{ED_{0\text{-}2}\ (years) + ED_{2\text{-}6}\ (years) + ED_{6\text{-}16}\ (years) + ED_{16\text{-}26}\ (years)}$$

Return to Equations Table

Trespasser

Soil or Sediment

Calculates using Recreator Soil or Sediment Equations and trespasser exposure defaults.
Return to Equations Table

Surface Water

Calculates using Recreator Surface Water Equations and trespasser exposure defaults.
Return to Equations Table

Appendix 3. Construction Worker Groundwater Trench Model

The computations for constructions worker groundwater are based on RSL residential groundwater formulae with the following computational variations and the construction worker exposure values provided in Appendix 4.

Exposure of Workers to Volatiles in a Construction/Utility Trench

There are no well-established models available for estimating migration of volatiles from groundwater into a construction/utility trench. VDEQ recommends the following approach -- based upon a combination of a vadose zone model to estimate volatilization of gases from contaminated groundwater into a trench, and a box model to estimate dispersion of the contaminants from the air inside the trench into the above-ground atmosphere -- to estimate the EPC for air in a construction trench. Two different methods are used to estimate volatilization into the trench. The choice of method depends on the site-specific depth to groundwater.

Airborne concentration of a contaminant in a trench can be estimated using Equation 3-1:

$$C_{trench} = C_{GW} \times VF \qquad (3\text{-}1)$$

Where:

C_{trench}	=	concentration of contaminant in the trench	ug/m^3
C_{GW}	=	concentration of contaminant in groundwater	ug/L
VF	=	volatilization factor (see equations 3-2 and 3-4)	L/m^3

VDEQ assumes that a construction project could result in an excavation as deep as 15 feet. At some sites there is a high probability that construction projects with deeper excavations may occur. Contact your VDEQ project manager and risk assessor to discuss the appropriate assumptions for your site.

If groundwater at the site is greater than 15 feet deep assume that the worker would not have direct contact with the groundwater but could still be exposed to vapors released from the soil in the bottom of the trench. In that case Equation 3-2 should be used to calculate VF.

If the depth to groundwater at a site is less than 15 feet VDEQ assumes that a worker would encounter groundwater when digging an excavation or a trench. The worker would then have direct exposure to the groundwater. The worker would also be exposed to contaminants in the air inside the trench that would result from volatilization from the groundwater pooling at the bottom of the trench. Equation 3-4 should be used to calculate VF.

VDEQ assumes that the trench is 3 feet wide by 8 feet long. These dimensions may be too restrictive depending on the nature of anticipated projects. Appropriate documentation should be provided if values other than the defaults are used. Contact VDEQ to discuss appropriate assumptions for individual sites.

Groundwater Greater Than 15 Feet Deep

$$VF = \frac{(Hi \times Dair \times ACvad3.33 \times A \times F \times 10\text{-}3 \times 104 \times 3600)}{(R \times T \times Ld \times ACH \times V \times Porvad2)} \quad (3\text{-}2)$$

Where:

H_i	=	Henry's Law constant for contaminant (RSL table)	atm-m^3/mol
D_{air}	=	diffusion coefficient in air (RSL table)	cm^2/s
AC_{vad}	=	volumetric air content in vadose zone soil	cm^3/cm^3
A	=	area of trench	m^2
F	=	fraction of floor through which contaminant can enter	Unitless
R	=	ideal gas constant	atm-m^3/ mole-K
T	=	average system absolute temperature	K
L_d	=	distance between trench bottom and groundwater (Equation 3-3)	Cm
ACH	=	air changes per hour	h^{-1}
V	=	volume of trench	m^3
Por_{vad}	=	total soil porosity in vadose zone	cm^3/cm^3
10^{-3}	=	conversion factor	L/cm^3
10^4	=	conversion factor	cm^2/m^2
3600	=	conversion factor	s/hr

The value for R is 8.2 x 10^{-5}. A default value of 298K may be used for the average system absolute temperature.

Studies of urban canyons suggest that if the ratio of trench width -- relative to wind direction -- to trench depth is less than or equal to 1, a circulation cell or cells will be set up within the trench that limits the degree of gas exchange with the atmosphere. In consultation with EPA Region III, VDEQ has assumed an ACH in this case of 2/hr -- based upon measured ventilation rates of buildings.

$$Ld = Lgw - Dtrench \quad (3\text{-}3)$$

Where:

Lgw	=	depth to groundwater	Cm
Dtrench	=	depth of trench	Cm

For chemicals that are not included on RSL table, the participant should calculate exposure point concentrations for air in a construction trench according to the method described above. References should be provided for the chemical-specific parameters used.

Return to Equations Table

Groundwater Less Than or Equal to 15 Feet Deep

VDEQ assumes that the trench would only intercept the groundwater for a few inches since a groundwater pool of more than a few inches would likely require dewatering. Therefore trench depth should be set to equal the actual depth to groundwater at the site. The default input values and the equations are described in this section.

$$VF = (Ki \times A \times F \times 10\text{-}3 \times 104 \times 3600) / (ACH \times V) \quad (3\text{-}4)$$

Where:

K_i	=	overall mass transfer coefficient of contaminant (Equation 3-5)	cm/s
A	=	area of the trench	m^2
F	=	fraction of floor through which contaminant can enter	Unitless
ACH	=	air changes per hour	h^{-1}
V	=	volume of trench	m^3
10^{-3}	=	conversion factor	L/cm^3
10^4	=	conversion factor	cm^2/m^2
3600	=	conversion factor	s/hr

Studies of urban canyons suggest that if the ratio of trench width -- relative to wind direction -- to trench depth is less than or equal to 1, a circulation cell or cells will be set up within the trench that limits the degree of gas exchange with the atmosphere. In consultation with EPA Region III, VDEQ has assumed an ACH in this case of 2/hr -- based upon measured ventilation rates of buildings.

$$Ki = 1 / \{(1/kiL) + [(R\ T) / (Hi\ kiG)]\} \quad (3\text{-}5)$$

Where:

kiL	=	liquid-phase mass transfer coefficient of i (Equation 3-6)	cm/s
R	=	ideal gas constant	atm-m3/mole-K
T	=	average system absolute temperature	K
H_i	=	Henry's Law constant of I	$atm\text{-}m^3/mol$
K_{iG}	=	gas-phase mass transfer coefficient of i (Equation 3-7)	cm/s

The value for R is 8.2×10^{-5}. A default value of 298K may be used for the average system absolute temperature.

kiL = (MWO2/MWi)0.5 x (T/298) x kL,O2 (3-6)

Where:

kiL	=	liquid-phase mass transfer coefficient of component i	cm/s
MWO2	=	molecular weight of O2	g/mol
MWi	=	molecular weight of component i	g/mol
kL, O2	=	liquid-phase mass transfer coefficient of oxygen at 25oC	cm/s

The value of k_L, O_2 is 0.002 cm/s.

kiG = (MWH2O/MWi)0.335 x (T/298)1.005 x kG, H2O (3-7)

Where:

k_{iG}	=	gas-phase mass transfer coefficient of component i	cm/s
MW_{H2O}	=	molecular weight of water	g/mol
k_G,H_2O	=	gas-phase mass transfer coefficient of water vapor at 25^oC	cm/s

The value of k_G, H_2O is 0.833 cm/s.
(*Superfund Exposure Assessment Manual*, EPA, Office of Remedial Response, April, 1988.)

Appendix 4. Exposure Defaults Tables

The following exposure defaults are provided by EPA RSL User's Guide or calculated from EPA RSL equations where provided by EPA. Exposure defaults are grouped by Media for consistency with the VURAM report output.

For recreator and trespasser physical defaults, such as surface area and body weight, EPA RSL residential values are used for consistency. In cases where EPA RSL recommends site specific values VDEQ values are used and marked with VDEQ in the descriptions below. Industrial/Commercial defaults represent composite worker. General defaults cover a range of study areas and are related to all media as applicable. All other defaults are grouped by media.

General

Default Value	Description
365	Construction Worker Averaging Time (days/yr)
365	Residential Averaging Time (days/yr)
365	Recreator Averaging Time (days/yr)
365	Trespasser Averaging Time (days/yr)
365	Worker - Composite Averaging Time (days/yr)
80	Construction Worker Body Weight (kg)
80	Residential Body Weight - adult (kg)
15	Residential Body Weight - child (kg)
80	Recreator Body Weight - adult (Kg)
15	Recreator Body Weight - child (Kg)
80	Trespasser Body Weight - adult (kg)
15	Trespasser Body Weight - child (kg)
80	Worker - Composite Body Weight (kg)
2	Exposure Duration - age segment 0-2 (yr)
10	Exposure Duration -age segment 16-26 (yr)
4	Exposure Duration - age segment 2-6 (yr)
10	Exposure Duration -age segment 6-16 (yr)
1	Construction Worker Total Exposure Duration (yr) - VDEQ
26	Residential Total Exposure Duration - child+ adult (yr)
20	Residential Exposure Duration - adult (yr)
6	Residential Exposure Duration - child (yr)
26	Recreator Exposure Duration - child+ adult (yr)
20	Recreator Exposure Duration - adult (yr)
6	Recreator Exposure Duration - child (yr)
25	Worker - Composite Total Exposure Duration (yr)
250	Construction Worker Exposure Frequency (days/yr)
350	Residential Exposure Frequency (days/yr)
350	Residential Exposure Frequency - adult (days/yr)
350	Residential Exposure Frequency - child (days/yr)
195	Recreator Exposure Frequency (days/yr)

Default Value	Description
24	Trespasser Exposure Frequency - adult (days/yr)
250	Worker - Composite Exposure Frequency (days/yr)
24	Residential Exposure Time - adult (hrs/day)
24	Residential Exposure Time - child (hrs/day)
1	Events - age segment 0-2 (events/day)
1	Events - age segment 16-26 (events/day)
1	Events -age segment 2-6 (events/day)
1	Events - age segment 6-16 (events/day)
0.18	Infiltration Rate (m/yr)
0.5	Andelman (L/m3)
70	LifeTime Residential/Industrial/Construction/Recreator/Trespasser (yrs)
9490	Noncancerous Average Time - adult: 365days * 26yrs (days)
7300	Noncancerous Average Time difference of adult - child: 365 days* 20 yrs (days)
2190	Noncancerous Average Time child : 365days*6yrs (days)
1360000000	Particulate emission Factor - Minneapolis (m3/kg)
3.1415926	Mathematical pi estimate
3527	Construction Worker Surface Area (cm2/day)
19652	Residential Water Surface Area - adult (cm2/day)
6365	Residential Water Surface Area -child (cm2/day)
365	Construction Worker Total Time which construction occurs (days) - VDEQ
1	Target hazard quotient
0.000001	Target risk

Soil

Default Value	Description
0.3	Construction Worker Soil Adherence Factor (mg/cm2)
0.07	Recreator Soil Adherence Factor - adult (mg/cm2)
0.2	Recreator Soil Adherence Factor - child (mg/cm2)
0.07	Residential Soil Adherence Factor - adult (mg/cm2)
0.2	Residential Soil adherence Factor - child (mg/cm2)
0.07	Trespasser Soil Adherence Factor- adult (mg/cm2)
0.2	Trespasser Soil Adherence Factor - child (mg/cm2)
0.12	Worker - Composite - Composite Soil Adherence Factor (mg/cm2)
238602	Recreator Soil Mutagenic Dermal Contact Factor - age adjusted (mg/kg)
428260	Residential Soil Mutagenic Dermal Contact Factor - age adjusted (mg/kg)
29366.4	Trespasser Soil Mutagenic Dermal Contact Factor - age adjusted (mg/kg)
57603	Recreator Soil Dermal Contact Factor - age adjusted (mg/kg)
103390	Residential Soil Dermal Contact Factor - age adjusted (mg/kg)
7089.6	Trespasser Soil Dermal Contact Factor - age adjusted (mg/kg)
26	Trespasser Soil/Sediment Exposure Duration - child+ adult (yr)

Default Value	Description
20	Trespasser Soil/Sediment Exposure Duration - adult (yr)
6	Trespasser Soil/Sediment Exposure Duration - child (yr)
250	Construction Worker Soil Exposure Frequency (days/yr)
125	Construction Worker Soil Exposure Frequency (days/yr) - VRP Only - VDEQ
8	Construction Worker Soil Exposure Time (hrs/day)
2	Recreator Soil Exposure Time (hr/day) - VDEQ
24	Residential Soil Exposure Time (hrs/day)
2	Trespasser Soil Exposure Time (hrs) - VDEQ
8	Worker - Composite Soil Inhalation Exposure Time (hr/day)
92950	Recreator Mutagenic Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
166833.33	Residential Mutagenic Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
114400	Trespasser Mutagenic Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
20475	Recreator Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
36750	Residential Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
2520	Trespasser Soil Ingestion Rate - age adjusted (mg-yr/kg-day)
1170	Recreator Soil Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
25200	Residential Soil Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
144	Trespasser Soil Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
330	Construction Worker Soil Ingestion Rate (mg/day)
100	Recreator Soil Ingestion Rate - adult (mg/day)
200	Recreator Soil Ingestion Rate - child (mg/day)
100	Residential Soil Ingestion Rate - adult (mg/day)
200	Residential Soil Ingestion Rate - child (mg/day)
200	Soil Ingestion Rate - Age Segment 0-2 (mg/day)
100	Soil Ingestion Rate - Age Segment 16-26 (mg/day)
200	Soil Ingestion Rate - Age Segment 2-6 (mg/day)
100	Soil Ingestion Rate - Age Segment 6-16 (mg/day)
100	Trespasser Soil Ingestion Rate - adult (mg/day)
200	Trespasser Soil Ingestion Rate - child (mg/day)
100	Worker - Composite Soil Ingestion Rate (mg/day)
250	Noncancerous Averaging Time Construction Worker Soil: 250 days * 1yr (days)
3339236953.22437	Construction Worker Soil Particulate Emission Factor - Calculated using EPA Soil Screening Guidance - Philadelphia (m3/kg)
6032	Recreator Soil Surface Area - adult (cm2/day)
2373	Recreator Soil Surface Area - child (cm2/day)
6032	Residential Soil Surface Area - adult (cm2/day)
2373	Residential Soil Surface Area -child (cm2/day)
6032	Trespasser Soil Surface Area - adult (cm2/day)
2373	Trespasser Soil Surface Area - child (cm2/day)
3527	Worker - Composite Soil Surface Area (cm2/day)

Groundwater

Default Value	Description
8191633	Residential Groundwater Mutagenic Dermal Contact Factor - age adjusted (cm2-event/kg)
2610650	Residential Groundwater Dermal Contact Factor - age adjusted (cm2-event/kg)
125	Construction Worker Groundwater Exposure Frequency (days/yr) - VDEQ
4	Construction Worker Groundwater Exposure Time (hr/day)
0.71	Residential Groundwater Exposure Time -adult (hr/event)
0.6708	Residential Groundwater Exposure Time -age adjusted (hr/event)
0.54	Residential Groundwater Exposure Time - child (hr/event)
24	Residential Groundwater Inhalation Exposure Time (hrs/day)
1	Construction Worker Groundwater Events (event/day)
1	Residential Groundwater Events (event/day)
1019.9	Residential Mutagenic Drinking Groundwater Ingestion Rate - age adjusted (L/kg)
327.95	Residential Drinking Groundwater Ingestion Rate - age adjusted (L/kg)
25200	Residential Groundwater Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
0.02	Construction Worker Groundwater Ingestion Rate (L/day)
2.5	Residential Drinking Groundwater Ingestion Rate - adult (L/day)
0.78	Residential Drinking Groundwater Ingestion Rate - child (L/day)
365	Noncancerous Averaging Time Construction Worker Groundwater (days)
19652	Residential Water Surface Area - adult (cm2/day)
6365	Residential Water Surface Area -child (cm2/day)
2	Trench-air changes per hour (hr)-1 - VDEQ
0.25	Trench Advection Coefficient Groundwater greater than 15ft (cm3/cm3) - VDEQ
0.001	Trench conversion Factor-1 (L/cm3)
10000	Trench conversion Factor-2 (cm2/m2)
3600	Trench conversion Factor-3 (s/hr)
8	Trench Default Depth in feet (ft) - VDEQ
4.57	Trench Default Depth greater than 15ft in meters (meter) - VDEQ
2.44	Trench Default Depth less than 15ft in meters (meter) - VDEQ
4	Trench Construction Worker Exposure Time Dermal (hr/day) - VDEQ
0.17	Trench Construction Worker Exposure Time Inhalation (hr/day) - VDEQ
1	Trench Construction Worker Events Frequency (event/day) - VDEQ
1	Trench Fraction of floor through which contaminant can enter (unitless) - VDEQ
30	Trench Thickness of vadose zone Groundwater greater than 15 ft (cm) - VDEQ
0.833	Trench-gas-phase mass transfer coefficient of water vapor at 25deg C (cm/s) - VDEQ
0.002	Trench-liquid-phase mass transfer coefficient of oxygen at 25deg C (cm/s) - VDEQ
8	Trench default length in feet (ft) - VDEQ
488	Trench depth to groundwater (cm) - VDEQ
2.44	Trench default length in meters (meter) - VDEQ
18	Trench molecular Weight of Water (unitless) - VDEQ
32	Trench molecular Weight of Oxygen (unitless) - VDEQ

Default Value	Description
0.44	Trench Porosity in Vadose Zone Groundwater greater than 15ft (cm3/cm3) - VDEQ
0.000082	Trench-ideal gas constant (atm-m3/mol-K) - VDEQ
77	Trench default temperature in degree Fahrenheit (F) - VDEQ
298	Trench default temperature in Kelvin (K) - VDEQ
0.38	Trench default Width to Depth Ratio (unitless) - VDEQ
3	Trench default width in feet (ft) - VDEQ
0.91	Trench default width in meters (meter) - VDEQ

Air

Default Value	Description
250	Construction Worker Air Exposure Frequency (days/yr)
24	Residential Air Inhalation Exposure Time (hrs/day)
8	Worker - Composite Air Inhalation Exposure Time (hr/day)
604800	Residential Air Inhalation Exposure Duration Mutagen Calculated - age adjusted (hr)

Surface Water

Default Value	Description
4561277.5	Recreator Surface Water Mutagenic Dermal Contact Factor - age adjusted (cm2-event/kg)
561388	Trespasser Surface Water Mutagenic Dermal Contact Factor - age adjusted (cm2-event/kg)
1453188.75	Recreator Surface Water Dermal Contact Factor - age adjusted (cm2-event/kg)
178854	Trespasser Surface Water Dermal Contact Factor - age adjusted (cm2-event/kg)
2	Recreator Surface Water Exposure Time (hr/event) - VDEQ
2	Trespasser Surface Water Exposure Time (hrs) - VDEQ
1	Recreator Surface Water Events (events/day)
1	Trespasser Surface Water Events (events/day)
51.35	Recreator Mutagenic Surface Water Ingestion Rate - age adjusted (L/kg)
6.32	Trespasser Mutagenic Surface Water Ingestion Rate - age adjusted (L/kg)
12.675	Recreator Surface Water Ingestion Rate - age adjusted (L/kg)
1.56	Trespasser Surface Water Ingestion Rate - age adjusted (L/kg)
0.05	Recreator Surface Water Ingestion Rate - adult (L/hr)
0.05	Recreator Surface Water Ingestion Rate - child (L/hr)
0.05	Surface Water Ingestion Rate - Age Segment 0-2 (L/hour)
0.05	Surface Water Ingestion Rate - Age Segment 16-26 (L/hour)
0.05	Surface Water Ingestion Rate - Age Segment 2-6 (L/hour)
0.05	Surface Water Ingestion Rate - Age Segment 6-16 (L/hour)
0.05	Trespasser Surface Water Ingestion Rate - adult (L/hr)
0.05	Trespasser Surface Water Ingestion Rate - child (L/hr)
19652	Recreator Surface Water Surface Area - adult (cm2/day)
6365	Recreator Surface Water Surface Area - child (cm2/day)

Default Value	Description
19652	Trespasser Surface Water Surface Area Surface - adult (cm2/day)
6365	Trespasser Surface Water Surface Area - child (cm2/day)

Sediment

Default Value	Description
0.2	Recreator Sediment Adherence Factor - adult (mg/cm2)
0.3	Recreator Sediment Adherence Factor - child (mg/cm2)
0.2	Trespasser Sediment Adherence Factor - adult (mg/cm2)
0.3	Trespasser Sediment Adherence Factor - child (mg/cm2)
413774.4	Recreator Sediment Mutagenic Dermal Contact Factor - age adjusted (mg/kg)
50926.08	Trespasser Sediment Mutagenic Dermal Contact Factor - age adjusted (mg/kg)
114340.2	Recreator Sediment Dermal Contact Factor - age adjusted (mg/kg)
14072.64	Trespasser Sediment Dermal Contact Factor - age adjusted (mg/kg)
26	Trespasser Soil/Sediment Exposure Duration (yr)
20	Trespasser Soil/Sediment Exposure Duration - adult (yr)
6	Trespasser Soil/Sediment Exposure Duration - child (yr)
2	Recreator Sediment Exposure Time (hr/day) - VDEQ
2	Trespasser Sediment Exposure Time (hrs) - VDEQ
92950	Recreator Mutagenic Sediment Ingestion Rate - age adjusted (mg-yr/kg-day)
11440	Trespasser Mutagenic Sediment Ingestion Rate - age adjusted (mg-yr/kg-day)
20475	Recreator Sediment Ingestion Rate - age adjusted (mg-yr/kg-day)
2520	Trespasser Sediment Ingestion Rate - age adjusted (mg-yr/kg-day)
1170	Recreator Sediment Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
144	Trespasser Sediment Inhalation Exposure Duration Mutagen Calculated - age adjusted (days)
100	Recreator Sediment Ingestion Rate - adult (mg/day)
200	Recreator Sediment Ingestion Rate - child (mg/day)
100	Trespasser Sediment Ingestion Rate - adult (mg/day)
200	Trespasser Sediment Ingestion Rate - child (mg/day)
6032	Recreator Sediment Surface Area - adult (cm2/day)
2373	Recreator Sediment Surface Area - child (cm2/day)
6032	Trespasser Sediment Surface Area - adult (cm2/day)
2373	Trespasser Sediment Surface Area - child (cm2/day)

Food

Default Value	Description
0.15	Food Eggs Ingestion Rate (kg/day) - VDEQ
0.054	Food Fish/Shellfish Ingestion Rate (kg/day)
0.122	Food Fruits/Vegetables Ingestion Rate (kg/day)

Default Value	Description
0.28	Food Meat/dairy Ingestion Rate (kg/day) - VDEQ
150000	Residential Food Eggs Ingestion Rate (mg/day)
54000	Residential Food Fish/Shellfish Ingestion Rate (mg/day)
122000	Residential Food Fruit/Vegetables Ingestion Rate (mg/day)
280000	Residential Food Meat/Dairy (mg/day)

Appendix 5. Chemical Parameter Notes

PROXY CHEMICALS: For some chemicals with similar toxicity properties, proxy values are used. The proxy chemicals list was developed using "Langley Air Force Base Remedial Investigation Report for IRP Sites LF-01, LF-05, LF-15, LF-18, LF-22, and FT-41, Radian, November 1998."

VDEQ CAS REVISIONS: For chemicals included in EPA RSL that have no CAS, or have a duplicate CAS with distinct chemical properties, then an unofficial value is assigned in VURAM to facilitate database function.

Proxy Chemcicals

Target Chem	Target CAS	Prox Chem	Prox CAS
trans-1,3-Dichloropropene	10061-02-6	1,3-Dichloropropene	542-75-6
cis-1,3-Dichloropropene	10061-01-5	1,3-Dichloropropene	542-75-6
1,3-Dichlorobenzene (meta)	541-73-1	1.4-dichlorobenzene	106-46-7
gamma-Chlordane	5103-74-2	1.4-dichlorobenzene	12789-03-6
delta-BHC	319-86-8	alpha-BHC (Hexachlorocyclohexane, Alpha-)	319-84-6
alpha-Chlordane	5103-71-9	Chlordane	12789-03-6
Endosulfan Sulfate	1031-07-8	Endosulfan	115-29-7
Endosulfan II	33213-65-9	Endosulfan	115-29-7
Endosulfan I	959-98-8	Endosulfan	115-29-7
Endrin Ketone	53494-70-5	Endrin	72-20-8
Endrin Aldehyde	7421-93-4	Endrin	72-20-8
isopropyltoluene	99-87-6	Isopropylbenzene (cumene)	98-82-8
Total PCBs	1336-36-3	PCBs-high risk	1336-36-3-HIRSK
Aroclor 1268	11100-14-4	PCBs-high risk	1336-36-3-HIRSK
Aroclor 1262	37324-23-5	PCBs-high risk	1336-36-3-HIRSK
Acenaphthylene	208-96-8	Pyrene	129-00-0
Benzo(g,h,i)perylene	191-24-2	Pyrene	129-00-0
Phenanthrene	85-01-8	Pyrene	129-00-0

VDEQ CAS Revisions

CAS	Analyte
HXCLRDIB-p-DXN	~Hexachlorodibenzo-p-dioxin, Mixture
1336-36-3-HIRSK	~Polychlorinated Biphenyls (high risk)
1336-36-3-LORSK	~Polychlorinated Biphenyls (low risk)
1336-36-3-LOSTRSK	~Polychlorinated Biphenyls (lowest risk)
THIOCYANATES	~Thiocyanates
7440-43-9S-F	Cadmium (Diet)
7440-43-9W	Cadmium (Water)
CREO-SO-TE	Creosote
DIBUTYLTINS	Dibutyltin Compounds
DIESEL-ENG-EXH	Diesel Engine Exhaust
DINTRO-TOL-MIX	Dinitrotoluene Mixture, 2,4/2,6-
ENDRIN-MET	Endrin metabolites
ETHBIS-DTH-SLT	Ethylenebisdithiocarbamic acid, salts and esters
HpCDBpD	Heptachlorodibenzo-p-dioxins
HpCDBF	Heptochlorodibenzofurans
JET-PROPEL-7	JP-7
7439-96-5D	Manganese (Diet)
7439-96-5S-W	Manganese (Non-diet)
NI-RFNRY-DST	Nickel Refinery Dust
NICO-SLT	Nicotine salts
NM-HYCD-SLT	Nitrogen mustard, hydrochloride salt
NMNO-HYCD-SLT	Nitrogen mustard, N-oxide, hydrochloride salt
PCDBF	Pentachlorodibenzofurans
PHTH-ACD-ESTR	Phthalic acid esters, N.O.S.
PCDBpD	Polychlorinated dibenzo-p-dioxins; PCDD's
REF-CER-FBR	Refractory Ceramic Fibers
SACCH-SLT	Saccharin salts
STYRE-ACR-TRI	Styrene-Acrylonitrile (SAN) Trimer
TtCDBF	Tetrachlorodibenzofurans
TtCDBpD	Tetrachlorodibenzo-p-dioxins
TPH-AL-HI	Total Petroleum Hydrocarbons (Aliphatic High)
THP-AL-LOW	Total Petroleum Hydrocarbons (Aliphatic Low)
TPH-AL-MED	Total Petroleum Hydrocarbons (Aliphatic Medium)
TPH-AR-HI	Total Petroleum Hydrocarbons (Aromatic High)
TPH-AR-LOW	Total Petroleum Hydrocarbons (Aromatic Low)
TPH-AR-MED	Total Petroleum Hydrocarbons (Aromatic Medium)
TRIBUTYTINS	Tributyltin Compounds
URANIUM-SOL-SLT	Uranium (Soluble Salts)

Appendix 6. VDEQ's Risk Based Closure Guidance

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RISK-BASED CLOSURE

1. Introduction

This document discusses the protocol for conducting a risk assessment to implement closure of hazardous waste management unit (HWMU) in accordance with Title 9 of the Virginia Administrative Code, Section 20-60-10 et seq. (Formerly the Virginia Hazardous Waste Management Regulations).

1. Risk-Based Evaluation In order to estimate the risk for chemicals of concern (COCs) a risk assessment will be conducted according to the Virginia DEQ document titled "Guidance for development of health based cleanup goals using decision tree/REAMS program (herein after "Virginia Risk Guidance") (November 1, 1994) prepared by Old Dominion University and the approved closure plan. The risk assessment report will contain the following sections:

! site evaluation,
! development of a site conceptual model,
! identification of contaminants of concern,
! identification of media and exposure pathways,
! toxicity assessment,
! estimation of contaminant concentration at the point of exposure, and
! summary of health risks.

The submission instructions contained in Appendix IX of the Virginia Risk Guidance will be reviewed prior to submitting the report to confirm that all necessary risk issues have been addressed. The risk goals/performance standards will be a hazard index of 1.0 for non-carcinogens and an individual carcinogenic risk of 1E-06 and cummulative carcinogenic risk of 1E-04.

Compliance with the closure standard will be verified by comparing the calculated individual and cumulative risk/hazard for all the contaminants of concern (COC) that failed background comparison to the risk-based performance standards.

The risk assessment will be conducted assuming a future residential/industrial use of the property. The methodology/equation for estimating the exposure concentration is presented in subsequent sections.

The initial step in the risk assessment will be to develop a site conceptual exposure model (SCEM) which depicts all potential exposure routes and media for the site and the receptors which may be exposed. The procedure for identification of contaminants of concern for health based is presented in section 2.... (from other section in the closure plan)

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Once the SCEM is completed, the exposure assumptions outlined in the Virginia Risk Guidance will be employed to estimate the health risks and develop a cleanup criteria. Information will also be taken as needed from U.S. EPA documents and databases (e.g., the Risk Assessment Guidance for Superfund (RAGS), and the Integrated Risk Information System (IRIS)). The chemical intake equations and exposure parameter assumptions used to calculate estimate risks (obtained from Virginia risk assessment guidance/REAMS) are shown in Tables 1 through 4. Additional details on the approach and assumptions used for each potential exposure pathway are provided below.

As a part of the Risk Exposure and Analysis Modeling System (REAMS) evaluation, fate and transport modeling is necessary to demonstrate that the residual soil concentrations of contaminants of concern would not result in contamination of other environmental media of concern including the groundwater underneath the closure unit. For this purpose, representative soil sample(s) will be collected around the unit (subjected to closure) for analysis of the properties listed on page 62 of the REAMS document. [It is often less expensive to obtain this information from an agriculture lab rather than from an environmental lab]. In certain situations, groundwater sampling may be preferable.

2. <u>Identification of Contaminants of Concern</u>

Contaminants of concern includes those constituents detected during the closure soil and groundwater sampling which may be related to past waste management practices and whose concentrations statistically exceeded background levels. Please note that if the concentration of contaminants detected in the soil and groundwater did not exceed the background levels, no further risk-based evaluation will be required. Only those constituents of concern having concentrations that are statistically greater than background concentrations will be subject to REAMS evaluation to estimate the risks.

Also, for the purpose of evaluating the impact to groundwater, only those constituents which statistically exceeded the upgradient or background well concentration will be subjected to REAMS evaluation.

3. <u>Exposure Assessment</u>

The exposure assessment will identify transport mechanisms for the contaminants of concern that may potentially impact human receptors. The results of this assessment will be used to document the current and future exposure potential posed by the site.

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With regard to soil, the following exposure assumptions will apply. Initially, a residential exposure will be assumed for the purpose of attempting to document unrestricted closure of the soil. If the risk for potential residential exposure does not exceed the performance standards, unrestricted closure of soil will be documented/accepted. If the site cannot be clean closed for residential use, then the option to pursue restricted closure (commercial/industrial) will be exercised. Closure to commercial/industrial scenario will requirement the facility to enact a deed restriction that eliminates the possibility of future residential use of the site. The requirements for establishing such a deed restriction are detailed in VDEQ=s Guidelines for Developing Health-Based Cleanup Goals Using Risk Assessment at A Hazardous Waste Site Facility for Restricted Industrial Use, dated June 1995. (A copy of this document is attached.)

Exposure routes will include ingestion, dermal absorption, and inhalation of vapors and dust particles.

With regard to groundwater, REAMS fate and transport modeling[1] will be required to assess residual soil contamination impacts to the groundwater. If the groundwater does not qualify for clean closure, the scope of future groundwater monitoring will be discussed with VDEQ. The groundwater exposure routes to be evaluated include ingestion, dermal absorption, and inhalation of volatiles emitted from the contaminated groundwater.

The exposure assumptions presented in the following sections are based on residential exposure. These constitute a reasonable maximum exposure scenario (RME), an exposure which is unlikely to occur but is reasonably possible. The exposure pathways for residential exposure include ingestion of soil, dermal contact with soil, inhalation of resuspended soil particulates, and inhalation of volatile organic compounds. Exposure to groundwater at the site is discussed in Section xxx.

3.1.1 Ingestion of Soil

[1] REAMS includes the unsaturated zone fate and transport model SESOIL. The purpose of running the model is two fold: a) determine whether the contaminants will reach the groundwater table in next 30 years. b) calculate the risk associated with the estimated concentration in the groundwater. For constituents with a promulgated MCL, the estimated concentration will be directly compared against the MCL. However, prior to running the SESOIL model the facility should obtain all the information identified on page 62, of the Virginia guidance document. The closure report must include evaluation of model results (concentrations reaching the groundwater) and a copy of SESOIL output file.

The equation for potential chemical intake by soil ingestion for residential scenario on site is included in Table 1. This scenario also assumes that weather or other conditions (e.g., frozen ground/ snow /other cover) do not affect exposure and that all soil ingested is from contaminated areas of the site. These assumptions are protective of human health and the environment.

3.1.2 Dermal Contact with Soil

The equation for calculating the potential absorbed chemical dose by dermal contact with contaminated soil is provided in table 1. This scenario assumes that weather or other conditions (e.g., frozen ground/ snow or other cover) do not affect exposure, that contaminated soil remains on the skin long enough for the COCs to be absorbed and that all soil adhering to the skin is from contaminated areas of the site.

The skin surface areas (SA) used in the dermal pathway have been identified in REAMS guidance as 4,860 cm^2 for adults, which is the 50th percentile value for the arms, hands and lower legs (U.S. EPA, 1989b - See Attachment A).

A skin-soil adherence factor of 1.45 mg/cm^2 will be used in the dermal intake calculations. The U.S. EPA guidance for dermal exposure assessment (*Dermal Exposure Assessment: Principles and Applications*, EPA/600/8-91/011B) states that a range of values from 0.1 mg/cm^2 to 1.5 mg/cm^2 per event appear possible for dermal adherence factors (AF). The
In order to estimate the amount of a particular COC which may potentially be absorbed through the skin, chemical-specific dermal absorption factors (ABS_{derm}) are used.

3.1.3 Inhalation of Resuspended Soil

The equation for potential chemical intake by inhalation of resuspended contaminated soil is included in Table 1. An inhalation rate of 0.83 m^3/hr will be used as specified in the Virginia Risk Guidance. This scenario assumes that the concentration of COCs in indoor dust will be equal to that in outdoor soil and that weather or other conditions, (e.g., frozen ground/snow or other cover) do not affect resuspension or exposure.

However, an appropriate model or equations in table-1, will be used to estimate the potential amount of respirable particulate matter generated by wind erosion. The estimated generation rate for eroded particulate matter will then be used derive an ambient air particulate concentration. Documentation for these models will be presented to the Department.

3.1.4 Inhalation of Volatilized COCs in Soil

Since the COCs have appreciable vapor pressures, they are expected to volatilize from soil. Inhalation of COCs as volatilized vapors is considered for this risk assessment. The equations in Table-1 will be considered for estimating the intake for this condition.

4. Toxicity Assessment

The two principle indices of toxicity used in risk assessment are the reference dose (RfD) and the cancer slope factor (SF). An RfD is the intake or dose per unit of body weight (mg/kg-day) that is unlikely to result in toxic (non-carcinogenic) effects to human populations, including sensitive subgroups (e.g., the very young or elderly). The RfD allows for the existence of a threshold dose below which no adverse effects occur.

The SF is used to express the cancer risk attributable to a discrete unit of intake; that is, the cancer risk per milligram ingested per kilogram of bodyweight per day ($[mg/kg\text{-}day]^{-1}$). The SF is an estimate of the upper-bound probability of an individual developing cancer as a result of exposure to a particular carcinogen. Unlike the RfD, the SF assumes that there is no threshold dose below which the probability of developing cancer is zero. Note that SFs are only developed for those chemicals which have been shown to be carcinogens in man or in at least several animal species. A carcinogenic weight of evidence rating is used to describe the strength of the experimental evidence for carcinogenicity. The U.S. EPA has developed SFs for most chemicals with weight of evidence ratings of "A" (known human carcinogen) or "B" (probable human carcinogen).

RfDs and SFs are derived by the U.S. EPA for the most toxic chemicals generally associated with chemical releases to the environment for which adequate toxicological data are available. If both the carcinogenic and non-carcinogenic effects of a particular compound are significant, both values may be established. However, in most cases only one value is available.

4.1 Inhalation and oral RfDs and SFs -

SFs pertinent to the oral and inhalation exposure pathways will be obtained from U.S. EPA's IRIS database. The IRIS (Integrated Risk Information System) on-line database was established by the U.S. EPA to provide risk assessors with peer reviewed toxicological data on chemicals commonly encountered at environmental sites of contamination. If data is not available from IRIS, it will be obtained from the Health Effects Assessment Summary Tables (HEAST), a compilation of toxicity values produced by the USEPA on a quarterly basis. The hierarchy presented in Appendix III of Virginia Risk guidance will be followed for using these sources.

4.2 Dermal RfDs and SFs -

Chemical specific oral-route absorption values (ABS_{oral}) are used to adjust the oral RfD or SF, which is computed from an administered dose, for use in the dermal exposure pathway. This correction is necessary due to the differences in absorption between the skin and the gastrointestinal tract. By correcting the administered-dose oral RfD or SF for the fraction expected to be absorbed in the gut, a dermal absorption factor can be used to estimate the correct dose received through the skin.

5. Evaluation of Risks

Using the toxicity criteria and identified exposure pathways discussed above, and the procedures described in the VDEQ guidance document (REAMS, November 1994), the risks presented by the COC will be estimated. The estimated risks will consider the effects from multiple constituents and all routes of exposure. The risk goals will be a total cumulative hazard index of 1.0 for multiple noncarcinogens and a total cumulative carcinogenic risk of 1E-04 for multiple carcinogens. However, the risk from each individual carcinogen shall not exceed 1E-06 (i.e., one case of cancer per 1,000,000 population).

5.1 Estimation of exposure concentration

For the contaminants detected at the site, an exposure point concentration (EPC) for each exposure pathway will be calculated for each contaminant by estimating the 95th upper confidence limit (UCL) on the arithmetic mean of the concentrations. If the calculated 95th UCL is greater than the maximum detected concentration, then the maximum detected concentration will be used as the EPC. The risks for contaminants will be calculated as per the equations and assumptions described in Table 1 through Table 4. If for a contaminant both carcinogenic and noncarcinogenic risk-based cleanup goal exists, the lower of the two will be used as a pathway specific to estimate the risk.

5.2. Risk Estimation

Health risk assessments are based on the relationship between risk, dose and toxicity:

$$Risk = Dose * Toxicity$$

Since dose is the product of the contaminant concentration multiplied by exposure (the intake), equation (1) becomes:

$$Risk = Intakerate * Contaminant\ conc. * Toxicity$$

(Please note that the term CDI in attached tables 1-4, includes intake rate and contaminant conc)

To estimate the intake, the exposure equations and assumptions discussed in Section 1, are used. The intake estimates for each route of exposure are then combined with the RfDs or SFs to determine the resulting risk.

For Carcinogens Risk:

$$Cancer\ Risk = (Intake_{oral} * Cont.conc. * SF_{oral})$$

$$+ (Intake_{inhal} * Cont.conc. * SF_{inhal}) + (Intake_{derm} * Cont.conc. * SF_{derm})$$

For Noncarcinogens:

$$Hazard\ Index = (Intake_{oral} * Cont.conc. * \frac{1}{RfD_{oral}}) + (Intake_{inhal} * Cont.conc. * \frac{1}{RfD_{inhal}})$$

$$+ (Intake_{derm} * Cont.conc. * \frac{1}{RfD_{derm}})$$

where, taking into account all COCs and relevant exposure pathways, the excess cancer risk is 10^{-6} or the hazard index is 1.0.

Using REAMS software a maximum acceptable contaminant concentrations will be calculated which meets the cumulative risk criteria. This process will be used in this risk assessment to derive the health-based cleanup criteria for the site. If the estimated risks satisfy the risk based performance standards, the soils/groundwater will be considered clean closed.

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Table 1
Risk Assessment Algorithm for Carcinogenic Exposure

Exposure Route	Chronic Daily Intake (CDI), mg/L-day	
	Residential Exposure	Occupational/Industrial Exposure
Ground Water		
Ingestion	$\frac{CW \times IRW_{adj} \times EF}{AT_c}$	$\frac{CW \times IRW_a \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation	$\frac{CW \times IRA_{adj} \times EF \times K}{AT_c}$	$\frac{CW \times IRA_a \times EF_o \times ED_o \times K}{BW_a \times AT_c}$
Dermal	$\frac{CW \times SAW_{adj} \times PC \times ET \times EF \times CF}{AT_c}$	$\frac{CW \times SAW_a \times PC \times ET \times EF_o \times ED_o \times CF}{BW_a \times AT_c}$
Soil		
Ingestion	$\frac{CS \times IRS_{adj} \times CF \times FI \times EF}{AT_c}$	$\frac{CS \times IR \times CF \times FI \times EF_o \times ED_o}{BW_a \times AT_c}$
Dermal	$\frac{CS \times CF \times SAS_{adj} \times AF \times ABS \times EF}{AT_c}$	$\frac{CS \times CF \times SAS_a \times AF \times ABS \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation of vaporizing VOCs from soil	$\frac{CS \times 1/VF \times IRA_{adj} \times ET \times EF}{At_c}$	$\frac{CS \times 1/VF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_c}$
Inhalation of emitting particles from soil	$\frac{CS \times 1/PEF \times IRA_{adj} \times ET \times EF}{AT_c}$	$\frac{CS \times 1/PEF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_c}$

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Table 2
Risk Assessment Algorithm for Non-carcinogenic Exposure

Exposure Route	Chronic Daily Intake (CDI), mg/L-day	
	Residential Exposure	Occupational/Industrial Exposure
Ground Water		
Ingestion	$\frac{CW \times IRW_c \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CW \times IRW_a \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation	$\frac{CW \times IRA_c \times EF \times ED_c \times K}{BW_c \times AT_n}$	$\frac{CW \times IRA_a \times EF_o \times ED_o \times K}{BW_a \times AT_n}$
Dermal	$\frac{CW \times SAW_c \times PC \times ET \times EF \times ED_c \times CF}{BW_c \times AT_n}$	$\frac{CW \times SAW_a \times PC \times ET \times EF_o \times ED_o \times CF}{BW_a \times AT_n}$
Soil		
Ingestion	$\frac{CS \times IRS_c \times CF \times FI \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times IRS_a \times CF \times FI \times EF_o \times ED_o}{BW_a \times AT_n}$
Dermal	$\frac{CS \times CF \times SA_c \times AF \times ABS \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times CF \times SA \times AF \times ABS \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation of vaporizing VOCs from soil	$\frac{CS \times 1/VF \times IRA_c \times ET \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times 1/VF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_n}$
Inhalation of emitting particles from soil	$\frac{CS \times 1/PEF \times IRA_c \times ET \times EF \times ED_c}{BW_c \times AT_n}$	$\frac{CS \times 1/PEF \times IRA_a \times ET \times EF_o \times ED_o}{BW_a \times AT_n}$

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Note: [illegible]

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Table 3
Age Adjusted Factors

$$IRA_{adj} = \frac{ED_c \times IRA_c}{BW_c} + \frac{(ED_{tot} - ED_c) \times IRA_a}{BW_a}$$

$$IRW_{adj} = \frac{ED_c \times IRW_c}{BW_c} + \frac{(ED_{tot} - ED_c) \times IRW_a}{BW_a}$$

$$SAW_{adj} = \frac{ED_c \times SAW_c}{BW_c} + \frac{(ED_{tot} - ED_c) \times SAW_a}{BW_a}$$

$$IRS_{adj} = \frac{ED_c \times IRS_c}{BW_c} + \frac{(ED_{tot} - ED_c) \times IRS_a}{BW_a}$$

$$SAS_{adj} = \frac{ED_c \times Sa_c}{BW_c} + \frac{(ED_{tot} - ED_c) \times SA_a}{BW_a}$$

.....

Note regarding age adjusted factor:

Because contact rate with tap water, ambient air, and residential soil are different for children and adults, carcinogenic risks during the first 30 years of life were calculated using age adjusted factor. These factors approximate the integrated exposure from birth until age 30 by combining contact rates, body weights, and exposure durations for two age groups - small children and adults.

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Table 4
Exposure Variables Included in Tables 1, 2, and 3

Symbol	Term	Unit	Value	Reference
ABS	Absorption factor	-	User specified	
AF	Adherence factor	-	1.45	a, c
AT_c	Averaging time carcinogens	days	25550	
AT_n	Averaging time non-carcinogens	days	ED x 365	
BW_a	Body weight adult	kg	70	c
BW_c	Body weight child	kg	15	c
CF	Conversion factor	-	0.000001	-
CS	Chemical concentration in soil	mg/Kg-day	User specified	
CW	Chemical concentration in water	mg/L	User specified	
ED_C	Exposure duration child	years	6	c
ED_{total} ED	Exposure duration for carcinogen total or Residential	years	30	c
ED_O	Exposure duration occupational	years	25	c
EF	Exposure frequency residential	days	350	c
ET	Exposure Time General/Occupational Groundwater Surface Water - ingestion Surface water - dermal Air -inhalation	hrs/day	 8.0 0.2 2.6 2.6 24.0	c, d
FI	Fraction ingested Residential Occupational	-	 1.0 0.5	b
IRA_a	Inhalation rate air adult	m^3/day	20	b
IRA_{adj}	Inhalation rate - air adjusted	-	11.66	
IRA_c	Inhalation rate child	m^3/day	12	b
IRA_a	Inhalation rate adult	m^3/day	20	b
IR	Ingestion rate food Fruit/veggies	kg/day	0.28 0.122	c,d

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	Fish		0.054	
IRS_a	Ingestion rate soil adult	mg/day	100	b
IRS_c	Ingestion rate soil child	mg/day	200	b
IRS_{adj}	Ingestion - soil adjusted	-	114.29	
IRS_c	Ingestion rate soil child	mg/day	200	b
IRW_a	Ingestion rate water adult	L/day	2	b
IRW_{adj}	Ingestion -water adjusted	L-y/kg-d	1.09	
IRW_c	Ingestion rate water child	L/day	1	b
K	Volatilization factor, water to air	-	0.5	
PC	Permeability constant	cm/hr	User specified	b
PEF	Particulate emission factor	m^3/kg	6.789926E08	f
SAW_c	Surface area child groundwater dermal surface water dermal	cm^2	7500	b.e
SAS_a SAS_c	Surface area soil occupational - adult child	cm^2/event	4500 1875	e
SAS_{adj}	Surface area soil ajusted	cm^2/event	2290	
SAW_a	Surface area for water contact adult	cm^2	820	b
SAW_{adj}	Surface area for water contact	cm^2/event	9200	
VF	Volatilazation factor. soil to air	m^3/kg	User specified	-

References:

a. Risk Assessment Guidance for Superfund, Volume I, EPA/540/1-89/002, December 1989.

b Region III values

c. Exposure Factors handbook. EPA/600/8-89/043, July 1989

d. Human health evaluation manual supplemental guidance, OSWER Directive 9285.6-03. March 25, 1991.

e. Dermal exposure Assessment, Principles and Applications, Interim Report. EPA/600/8-91/011b January 1992.

f. Technical Background Document for Draft Soil Screening Level Guidance. Office of Solid Waste and Emergency Response. EPA/540/R-94/101. December 1994

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