MINNESOTA POLLUTION CONTROL AGENCY
SITE REMEDIATION SECTION

DRAFT GUIDELINES
RISK-BASED GUIDANCE FOR THE SOIL - HUMAN HEALTH PATHWAY
VOLUME 2. TECHNICAL SUPPORT DOCUMENT

WORKING DRAFT, January 1999

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NOTICE

THIS DOCUMENT IS A WORKING DRAFT. The Site Remediation Section of MPCA is developing guidelines for evaluating risks to human health and the environment at sites that may require investigation or response actions pursuant to the Minnesota Environmental Response and Liability Act, Minn. Stat. § 115B.01 to 115B.24 (MERLA).

DEVELOPMENT OF A SITE REMEDIATION SECTION SITE EVALUATION MANUAL. The attached document and other documents will be incorporated into a Site Remediation Risk-Based Site Evaluation Manual which will contain guidelines for conducting MERLA-related evaluations, including risk evaluations under the State Superfund program and the MPCA Voluntary Investigation and Cleanup (VIC) Program.

MPCA staff intend to use the policies and procedures in the manual as guidelines to evaluate the need for investigation or remedial actions to address releases and threatened releases of hazardous substances or pollutants or contaminants under MERLA, and the scope and nature of such actions. These policies and procedures are not exclusive and do not have the force and effect of law. MPCA staff may use other policies or procedures to evaluate the need for or adequacy of response actions under MERLA, including procedures set forth in outstanding MPCA Requests for Response Action and Consent Orders. The final standard for all such evaluations is the MERLA statutory requirement that such actions must be reasonable and necessary to protect the public health and welfare and the environment.

~ Continued ~

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~ Continuation ~

The Minnesota state superfund program, governed by the Minnesota Environmental Response and Liability Act (MERLA) and the supplementary rules, and the federal superfund program, governed by the Comprenhesive Environmental Response, Compensation and Liability Act (CERCLA) and the federal regulations in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), work together to clean up various types of sites.

Under CERCLA, failure to act consistently with the NCP can result in a party not recovering its response costs from a RP. There is no NCP consistency requirement in MERLA, although under MERLA the costs must be reasonable and necessary. The guidance documents are intended to function in a similar manner to the NCP. However, because the guidance documents do not require every procedural specification of the NCP, parties are advised to consult an attorney early in the cleanup process if they intend cost recovery under CERCLA, which specifically states that the party seeking reimbursement must show that its costs are "consistent" with the NCP.

For removals, investigations and National Priority List sites, the federal and state governments must act consistently with the NCP. Note that CERCLA requires "consistency," or "accordance," as distinguished from "compliance," with the NCP. This infers some flexibility in selecting the appropriate remedy while following the basic requirements of the NCP. The extent of flexibility is still debated in courts. The NCP provides that a party does not have to comply with every single requirement of the NCP verbatim, but that the response action, when evaluated as a whole, be in "substantial compliance" with the NCP and result in a CERCLA-quality cleanup. The courts have emphasized that the community relations aspects are a part of the NCP response action, including the right of the public to participate in the remedial action selection process.

The preamble to the NCP recognizes government programs, like the Minnesota program under MERLA which has similarities to the NCP, that achieve the same objectives, but are not congruent with the NCP in every respect. EPA believes that these governmental bodies, consistent with CERCLA intent, should have flexibility to implement response actions and bring cost recovery actions for those response actions as long as the response actions are not inconsistent with the NCP, even if achieved by different methods. EPA believes that it is not necessary to define what actions are "not inconsistent with the NCP," and will make determinations on a case-by-case basis.

EXPLANATION:

This draft document presents only a portion of a Risk-Based Site Evaluation process currently under development by the MPCA Site Remediation staff. MPCA staff involved in your Site should be consulted for pre-screening procedures, including determination of the need for ecological assessment, to be conducted prior to implementing the screening procedures outlined in the current document.

Users of this document are responsible for confirming with the MPCA Site staff the version of the working draft to be used.

This document and accompanying Exel spreadsheets are available electronicly on the MPCA web site: www.pca.state.mn.us/cleanup/riskbasedoc.html). *Copies can also be requested from MPCA Site staff. The requester shall provide MPCA Site staff with a formatted disk with a return self-addressed, stamped disk envelope for duplication of the spreadsheets by the mailing list administrator, Eva Johnson.*

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1.0 INTRODUCTION

The nature of decision making about environmental contamination at Superfund sites, "Brownfield" property, and other contaminated sites is evolving. In response, the Minnesota Pollution Control Agency's Site Remediation Section (SRS) is developing guidance that outlines a risk-based approach to decision making during site investigation and remedy selection. Site evaluation and cleanup decisions are and will continue to be made on a site-specific basis. However, the Risk-based Site Evaluation Guidance Manual will provide a preferred process for making decisions by evaluating risks to human health and the environment at adequately characterized sites under the SRS programs.

The basic goal of the SRS has not changed and remains protection of human health, public welfare, and the environment. The purpose of the Guidance Manual is twofold: 1) introduce the evaluation of risk at sites early in the site evaluation process, and 2) to develop a consistent and reasonable risk-based process for making site decisions. In an attempt to balance the need to standardize the cleanup process and the need to consider site-specific information in order to ensure cost-effective decisions a tiered risk-characterization process has been developed.

Risk characterization is used to determine whether additional investigation is to determine whether a remedial response action is necessary, to identify target cleanup levels in the event remedial action is required, and to document that a level of acceptable risk of harm to health, safety, public welfare and the environment has been achieved for a site. In this context, the site risk characterization is a decision making tool with which site decisions may be made in a manner both protective of public health and the environment and consistent from site to site.

The terms "Risk Characterization" and "Risk-based Evaluation" are sometimes used synonymously, however, there is a subtle difference in their meaning. A risk characterization assessment is the systematic scientific characterization of potential adverse health effects resulting from human exposure to hazardous agents or situations. Risk Characterization attempts to answer the question, "What are the risks associated with the contamination at this site?".

Risk-based Evaluation goes beyond Risk Characterization, using statutory, engineering, economic, social and political factors in evaluating alternative regulatory options and choosing among those options. The Risk-based Evaluation answers the questions, "Are those risks significant (important)?" and "What can be done to decrease the risk to acceptable levels? ". Thus Risk-based Evaluation is a process which combines both risk characterization and risk management.

1.1 Purpose of this Document

The purpose of this draft guidance document is to present a risk-characterization approach for evaluating human health effects resulting from the soil-related exposure pathways using a tiered approach which is dependent upon the level of information available or the complexity of the site. Non-soil related exposure pathways (e.g., ground water impacts, ecological receptors) are addressed in other draft guidance documents.

Contaminated soil can be a source of direct and indirect exposure to contaminants. Exposure of humans to contaminants in soil occurs primarily through inhalation of soil vapors/particles, incidental ingestion of soil particles, dermal contact with soil, and ingestion of food (e.g., produce, meat, milk) contaminated via transfer from soil to plants and/or animals. Table 1.1 presents the potential soil-related exposure pathways resulting from site activities and use. Through cross media transfer of contaminants, soil can be a source of contamination for other media. The cross media transfer of contaminants from soil to ground water is addressed in the "Draft Ground Water Risk-Based Decision-Making Guidance" and the "Draft Risk-Based Guidance for the Soil Leaching Pathway". The cross media transfer of contaminants from soil to other media (e.g., soil vapor migration into indoor air) will be addressed in additional draft guidance documents currently under development.

Table 1.1. Soil-related Exposure Pathways.

EXPOSURE ROUTE		
Ingestion	**Dermal**	**Inhalation**
*** Incidental ingestion of contaminated particulates.** * Ingestion of produce contaminated via contaminants transferred from soil. * Ingestion of livestock products contaminated via contaminants transferred from soil or produce. * Mother's milk contaminated by maternal ingestion of contaminated soil or food contaminated via transfer from soil.	*** Contact with contaminanted soil**	*** Inhalation of soil vapors in outdoor air.** *** Inhalation of resuspended soil particulates in air.** * Inhalation of soil vapors migrating inside buildings/structures.

* Bolded pathways are addressed by generic Soil Reference Values. Remaining pathways requires Tier 3 evaluation.

The health risk posed by environmental contaminants is a function of the magnitude of the exposure to the contaminant and the toxic potential of the contaminant. The SRS has developed soil reference values (SRVs) that represent acceptable soil concentrations for specific exposure scenario categories. The SRVs are based on risk assessment methodology, modeling, and risk management policy. The SRS acknowledges that risk assessment and fate-and-transport models cannot be completely accurate in reflecting actual site conditions, due to a number of scientific uncertainties. The SRS nevertheless utilized the process, accepting the uncertainty, because the methodology is the best available, and it provides a consistent approach to making risk-based decisions.

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In calculating SRVs, a set of acceptable risk levels has been established to ensure the same level of protection of human health regardless of the receptor or intended property use or exposure scenario. The acceptable risk levels targeted by the risk-based evaluation process are as follows:

- Carcinogenic effects - a total or cumulative site excess lifetime cancer risk (ELCR) not to exceed 1 in 100,000 (i.e., 1E-5) for chronic exposure. In other words, the acceptable risk level is a maximum of one additional case of cancer per 100,00 chronically exposed individuals above background cancer rates in the general population. For subchronic exposure where higher exposures occur during a shorter exposure period (e.g., 1 year) the acceptable cumulative ELCR is limited to ten percent of the chronic ELCR (i.e., 1E-6); and

- Noncarcinogenic effects - a noncancer risk not to exceed a hazard quotient (HQ) of 0.2 per contaminant for chronic exposure or 1 for subchronic and acute exposure and a cumulative hazard index (HI) of 1 for multiple contaminants with similar target endpoints. The HQ is determined by dividing the site contaminant exposure by the contaminant reference dose, which is an estimate of the daily exposure that is not likely to result in an appreciable risk of deleterious effects. The HI is determined by adding the HQs for each contaminant with similar endpoints.

Note that the acceptable risk levels remain the same regardless of the tier level of evaluation. The individual SRVs are calculated such that risk to human health will be at or below the acceptable risk levels established by the MPCA. Risk is evaluated separately for carcinogenic (cancer-causing) and noncarcinogenic effects. It assumes that the risk posed by individual contaminants with similar target endpoints (i.e., that affect the same parts of the body, such as liver or kidney, or cause the same effect, such as cancer) is additive. Therefore, when multiple contaminants having carcinogenic or noncarcinogenic effects are present at a site, the combined risk posed by the contaminants must be evaluated. The combined risks are referred to as the cumulative site risks. Evaluation of the cumulative site risks is facilitated by a set of Excel spreadsheets available on the MPCA web site.

The MPCA intends the SRVs to be protective without being unduly stringent (i.e., avoiding "cascading conservatism"). The exposure scenarios utilized represent reasonable maximum exposure (RME) activities for the planned use of the site. These activities represent full use of the site and may not be presently occurring but are consistent with the planned use of the property. Recommended default exposure parameters have been developed for residential (applicable to unrestricted commercial use), industrial (applicable to restricted commercial use) and recreational exposure scenario settings. Please see the Working Draft Guidance on Incorporation of Planned Property Use into Site Decisions for complete descriptions of the property use categories. Note that these property categories were developed to aid in determining exposure potential, not to correspond to zoning categories.

In calculating SRVs for the residential and recreational exposure scenarios a child receptor was utilized for evaluating noncarcinogenic risk whereas an exposure scenario encompassing childhood and adult years was utilized for evaluating carcinogenic risk. In calculating SRVs for the industrial exposure scenario an adult site worker receptor was utilized for evaluating both carcinogenic and noncarcinogenic effects. The exposure equations and default values are presented in Appendix 1 “Exposure Equations and Default Values”. The chemical-specific information utilized in the development of the SRVs is presented in Appendix 2 “Chemical-Specific Information”. The generic SRVs are presented in Appendix 3.

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2.0 OVERVIEW OF THE TIERED SOIL REFERENCE VALUE EVALUATION PROCESS

A tiered process was incorporated into the development of human health-based Soil Reference Values (SRVs). SRVs represent a contaminant concentration in soil which under a specified exposure scenario corresponds to acceptable risk levels. The tiered process is a common sense approach to evaluating risk and making site decisions. It is based on the premise of starting simple with limited site-specific information and escalating the level of effort to meet the goals of the users. Table 2.1 presents a summary of the distinctions between the three tiers.

In most situations, it is recommended that contaminant concentrations at a site should be first compared to the default Tier 1 SRVs (including an evaluation of cumulative site risk). This comparison will assist in identifying and defining areas, contaminants, and conditions at a site that require further attention.

Due to limitations of the currently available scientific data and methodology, exposure pathways are limited to the direct pathways (i.e., incidental ingestion, dermal contact, and inhalation of outdoor air) in Tier 1 and 2. "Standardization" of indirect pathways is not possible at this time. The less common exposure pathways must be evaluated on a site-specific basis (i.e., Tier 3) when the pathway is likely to be a significant exposure pathway based on site conditions.

Table 2.1. Tiered Soil Reference Value Approach

Tier 1 Screening	Tier 2 Simple Site-Specific	Tier 3 Detailed Site-Specific
Exposure pathways: Incidental ingestion, dermal contact and inhalation of outdoor vapors or particulates.	*Exposure pathways*: Incidental ingestion, dermal contact and inhalation of outdoor vapors or particulates.	*Exposure pathways*: Include common pathways addressed in Tier 1 and 2, plus indirect such as foodchain.
Exposure Scenario: - Residential property use - Default exposure factors. - Typically use maximum contaminant concentration as surrogate for exposure concentration.	*Exposure Scenario*: - Site-specific property use designation. Institutional controls. - Default exposure factors. - Average concentration within contaminated zone. Consideration of background concentrations.	*Exposure Scenario*: - Site-specific property use designation. Institutional controls. - Site-specific exposure factors (including probabilistic evaluation) with Agency approval. - Average concentration within contaminated zone. With SRS approval, site-specific exposure area. Consideration of background concentrations.
Environmental Fate & Transport: - Default source area and soil characteristics (e.g., soil properties, source area size). - Default chemical properties.	*Environmental Fate & Transport* - Site-specific source area and soil characteristics (e.g., soil properties, source area size). - Default chemical properties.	*Environmental Fate & Transport* - Site-specific source area and soil characteristics. - Site-specific chemical properties (e.g., bioavailability, degradation rates, Kd)

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2.1 Tier 1 (Screening) SRV Risk Characterization

Tier 1 involves comparing a site soil contaminant concentrations to Tier 1 SRVs to estimate risk. If the site concentrations result in an exceedence of individual or cumulative target risk levels then additional site investigation is warranted. Only those contaminants which significantly contribute to the exceedence of the target risk levels (including cumulative site risk levels) need to be carried into the Tier 2 evaluation. Contaminants without SRVs should also be carried into the Tier 2 evaluation.

The SRVs address the three most common exposure pathways - incidental soil ingestion, dermal contact with soil, and inhalation of outdoor vapors and particulates from soil. Less common exposure pathways (e.g., ingestion of contaminated produce) must be evaluated when the pathway is likely to be complete and significant based on site concentrations and contaminant distribution relevant to the location of the receptors.

Minimum Tier 1 Data Requirements:

- Nature of contaminants
- Contaminant concentration(s) in source area(s) (i.e., areas of highest concentrations)

See Section 6 "Tier 1 Soil Reference Value Risk Characterization" for further discussion.

2.2 Tier 2 (Simple Site-Specific) SRV Risk Characterization

Tier 2 evaluations involve comparing the representative site soil contaminant concentrations to default or site-specific derived Tier 2 SRVs to estimate risk. If the site risks exceed the acceptable target risk levels (including cumulative risk targets) then a response action or Tier 3 evaluation is warranted. Typical site-specific data requirements to support a Tier 2 evaluation include:

- Nature of contaminants
- Characterization of the contaminant zone (lateral and vertical extent and magnitude)
- Background contaminant concentrations
- Representative contaminant exposure concentration
- Exposure Scenario and planned property use on site and on surrounding properties
- Soil Properties (bulk density, soil porosity, etc.)
- Soil saturation limits

(Note: more or less site assessment data may be needed depending on site conditions or needs of the user)

Tier 2 does not vary from Tier 1 in terms of : 1) target risk limits; 2) contaminant properties (e.g., toxicity values); and 3) exposure equations and exposure factors. In Tier 2 actual soil vapor monitoring in lieu of volatilization cross-media modeling may be utilized provided that the monitoring is conducted under conditions that would maximize volatilization. See Section 7 "Tier 2 Soil Reference Value Risk Characterization" for further discussion.

2.3 Tier 3 (Detailed Site-Specific) SRV Risk Characterization

In a Tier 3 evaluation, alternative calculation methods may be utilized. It must be demonstrated that these alternative methods: 1) provide an improved characterization of the site conditions or exposure pathways under consideration relative to the Tier 2 methods; 2) will be supported by sufficient site-specific data

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to ensure accurate and reliable results; 3) will be protective of public health and welfare; and 4) will yield results which are verifiable with site data.

Criteria that may not be varied from Tier 2 in the Tier 3 evaluation include: 1) target risk limits; 2) exposure equations; 3) toxicological values; and 4) default exposure factors for residential property use. See Section 8 "Tier 3 Soil Reference Value Risk Characterization" for further discussion.

2.4 Combinations of Tiers for Risk Characterization of Portions of Sites

The ability to apply different tier-based remedial actions for portions of a site may allow the expedited cleanup of areas which are more readily addressed while problems which are more complex or difficult to assess/remediate can be dealt with on a different schedule. Remedial actions for a portion of a site may also be an attractive option in situations where the site includes more than one property. However, different tier-based remedial actions submitted for a *portion* of a site may be problematic, as the risk criteria are expressed as limits on cumulative site risk (i.e., the risk to a receptor received from all applicable site exposure pathways and contaminants). Therefore, by breaking up a site into discrete areas and assessing them separately, the *cumulative* site impact of the contamination may not be adequately addressed.

In order to address these concerns, the following approach is recommended:

- If Tier 1 or 2 SRVs (including cumulative site risk requirements) are used to characterize risk for that portion of a site no further consideration of cumulative site risk is needed assuming that Tier 1 and 2 SRVs are applicable.
- If Tier 3 SRVs are used to characterize risk at one or more portions of the site, particular attention must be paid to how the Tier 3 SRV assessment is conducted and how the results are interpreted in order to insure that the cumulative site risk limits are met for the entire site. In other words, Tier 3 risk characterizations conducted in support of a remedial action for a portion of a site must still address the issue of cumulative site risk. See Section 8.4.5 for further discussion.

This approach for characterizing risk to support a remedial action for a portion of a site allows different risk characterization methods to be used for the different portions of the site, eliminates the need for a final "comprehensive" risk characterization of the site after all the remedial actions for the different portions have been submitted, and addresses the requirement to meet the cumulative site risk limits.

2.5 Risk to Safety and Short-term Hazards

There are some site conditions which warrant immediate attention, including early notification of the SRS and implementation of an interim response action. Section 4 presents guidance on evaluating Safety Hazards and Section 8 presents guidance on evaluating Short-term Exposure Hazards. These evaluations are designed to answer the question " Is a response action required NOW?". It is a form of risk characterization which evaluates the potential health and safety risks associated with current site conditions.

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3.0 SHORT-TERM HAZARD EVALUATIONS

A short-term hazard is a hazard which could pose an unacceptable risk of harm to health if it were present for even a short period of time. The following section describes the process by which site conditions may be assessed to determine whether or not a Short-term Hazard exists. A qualitative judgment concerning a short-term hazard can be made at any point during the site evaluation process. A quantitative judgment can be made after data is available.

The Short-term Hazard evaluation is site-specific in nature, and focuses on *actual, or likely exposures* under *current* site conditions, given the *current site use(s) and site activities* and the surrounding environment, and considering a *short exposure period*. Therefore, the Short-term Hazard evaluation is much narrower in scope than a site risk characterization. In addition, the Short-term Hazard evaluation often focuses on only those contaminants that are most likely to pose a risk following short-term exposures, given their toxicity and site concentrations.

If the results of a short-term hazard evaluation indicate that conditions at the site pose a short-term hazard, an interim response action should be taken to address the hazard. The option to take a response action to address a potential short-term hazard rather than conducting an evaluation to determine whether the conditions do indeed pose a short-term hazard also exists. In fact, for any release which the SRS believes is likely to pose a short-term hazard, immediate action to address the release is recommended rather than conducting an evaluation to confirm whether or not it is a hazard.

3.1 Deciding Whether a Short-term Hazard Evaluation is Necessary

Specific situations or conditions which trigger a short-term hazard evaluation can not be generically defined. Consideration of several general factors and reliance on application of professional judgment determine when site conditions warrant such an evaluation. Short-term hazards can occur at any point in the site investigation and remediation process. Site assessors should be mindful throughout all phases of site investigation and remediation of the possibility that information indicating a potential short-term hazard will come to light.

The general factors considered in the decision to conduct a Short-term Hazard Evaluation include the location and nature of the contamination and the human receptors which may be exposed. It is important to keep in mind that the exposures must be actually occurring (or very likely to occur) in order for a short-term hazard to exist.

A Short-term Hazard evaluation should be considered whenever actual (or likely) exposures to contamination at a site are occurring, such as when there is surficial soil contamination in an area where children play. The types of contaminants to which people are being exposed should also be considered. Contaminants which can cause a severe effect after a one-time or short-term exposure (e.g., acute effects of cyanide), certainly warrant consideration as a possible short-term hazard. Furthermore, short-term exposure to persistent, bioaccumulative contaminants (e.g., PCBs) may increase the body burden to a level where chronic or intergenerational effects may be of concern.

In deciding whether a given situation warrants further investigation as a potential short-term hazard when children are exposed it may be helpful to use the default subchronic and acute SRVs for children presented in Appendix 3 as a guide. The default subchronic child exposure scenario utilizes a young child (< 6

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years) exposed during the summer months. The default acute child exposure scenario utilizes a toddler (1-2 years) incidentally ingesting a bolus of soil. The specific default exposure equations and default input parameters are presented in Appendix 1. The generic Tier 2 Excel file also contains a subchronic SRV worksheet which will present an estimate of subchronic cumulative site risk.

Subchronic or acute child-based SRVs are not available for all contaminants. This is not due to a lack of toxic effects but due to the lack of quantitative toxicity information. A comparison evaluation of the exiting generic subchronic and chronic SRVs found that approximately 70 percent of the subchronic/chronic ratios were a factor of 2 or less. Given this, a "rule of thumb" of modifying the generic chronic residential SRVs by a factor of 2 is recommended for contaminants without subchronic or acute SRVs.

In deciding whether a given situation warrants further investigation as a potential short-term hazard when adult workers are exposed following two options are available depending on the level of exposure likely to occur. The specific default exposure inputs for these two options are presented in Appendix 1.

- Option 1 should be employed if activities resulting in high soil contact are anticipated (e.g., construction work, excavations, landscaping) the short-term adult worker-based subchronic SRVs presented in Appendix 3 can be utilized as a guide. Subchronic worker-based SRVs are not available for all contaminants. A comparison of the generic short-term adult worker and chronic worker SRVs found that approximately 70 percent of the subchronic/chronic ratios were a factor of 2 or less. Given this, a "rule of thumb" of modifying the generic industrial chronic SRVs by a factor of 2 is recommended for contaminants without short-term worker SRVs.

- Option 2 should be employed if high soil contact activities are not likely to occur and exposure conditions more closely resemble the chronic industrial worker exposure scenario the following "rule of thumb" may be helpful. The generic industrial SRVs multiplied by a factor of ten can be utilized as a general indicator of a situation which may warrant further investigation as a short-term hazard.

Used in this way, the default SRVs can provide a general indication as to when site concentrations are approaching levels which could pose a short-term hazard. However, the presence of a contaminant at levels greater than the default subchronic or modified chronic SRVs does not indicate that there is definitely a short-term hazard. It simply suggests that the situation warrants further investigation.

Keep in mind that the default SRVs based on acute effects (e.g., cyanide) can not be modified with a multiplier and should be applied as not to exceed values if young children are potentially contacting the contaminated soil. Acute child-based SRVs are only available for a small number of contaminants. This is due in large part to a lack of quantitative toxicity information. The acute child-based SRVs are presented in Table 3.1. Table A.3.4 of Appendix 3 also contains information regarding the acute health effects.

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Table 3.1 Acutely Toxic Child-based Soil Reference Values

Chemical	Acute SRV (mg/kg)
Antimony	600
Arsenic	110
Barium	1200
Cadmium	55
Copper	100
Cyanide (free)	62
Fluoride, soluble	550
Lead	2000
Pentachlorophenol	220
Phenol	1100

3.2 Short-term Hazard Risk Evaluations for Human Health

The Short-term Hazard evaluation should be conducted following the general procedures for a Tier 3 risk assessment. However, the Short-term Hazard Evaluation will not be as comprehensive as a Tier 3 risk characterization since only current uses and exposures are considered. The documentation of the Short-term Hazard Evaluation must clearly identify and explain the basis for all exposure parameters chosen for the evaluation.

3.2.1 Contaminants of Potential Concern

The Short-term Hazard evaluation may be limited to those chemicals which are likely to of concern from short-term exposure. A contaminant may be eliminated from consideration based upon a determination that it is not likely to contribute significantly to risks. This determination could be made based on comparison with the default subchronic, acute or modified chronic SRVs as appropriate. Note, the cumulative effects from multiple contaminants should be included in the determination.

3.2.2 Exposure Assessment

The focus of a Short-term Hazard Evaluation is on *actual* or *likely exposures* to human receptors under *current* site conditions, considering the *current use(s)* of the site. Note that this differs from the way current activities and uses must be evaluated for the full risk assessment. In the full risk assessment, activities which are not occurring at the time of the assessment, but are consistent with the current use of the site must be evaluated.

As in a full risk characterization, the short-term hazard evaluation should identify the receptor group(s) experiencing the greatest exposure potential or susceptibility to environmental contamination. Young children and women of child-bearing age are often selected as receptors of concern because of these factors. The risk assessor may need to evaluate several receptor groups to ensure that all sensitive subpopulations are being protected. Conversely, the fact that the most sensitive receptors are being evaluated means that other (less exposed) receptors need *not* be evaluated.

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3.2.2.1 Exposure Duration

The exposure duration is the length of time over which the receptor comes into contact with the contaminant. The short-term hazard evaluation focuses on exposures over an appropriate "short period of time". The focus of a Short-term Hazard Evaluation may include multiple time periods including periods longer than one year. The short-term hazard evaluation should evaluate an exposure period that is appropriate considering the toxicity of the contaminant(s) present at the site, what is known about how long exposures have been occurring and how long exposures are expected to continue. Consideration of a longer period of time does not preclude the obligation to also evaluate appropriate shorter exposure periods such as acute (one-day) exposures. Depending on the site-specific situation, it may be appropriate to evaluate exposure periods longer than 1 year, shorter than one year, *or both*.

3.2.2.2 Exposure Points and Exposure Concentrations

Because the focus of a short-term hazard evaluation is on actual exposures and current site uses and activities, the evaluation of soil-related exposures may be limited to contamination in the accessible surface soil. The soils ranging from the top two (0-2) to the top six (0-6) inches will be appropriate for most sites unless soil disturbances (e.g., excavation) is anticipated. Thus, when estimating an exposure concentration for soil in a short-term hazard evaluation, contaminants present at depths greater than six inches typically should not be averaged into the exposure concentration calculations unless site conditions warrant it. The absence or lack of surficial soil data is not an adequate justification for failing to conduct a short-term hazard evaluation. If exposures are currently occurring soil concentration data must be gathered.

For subchronic exposures the exposure concentration should represent a conservative estimate of the average concentration to which the receptor is exposed during the exposure period. However, there are some situations in which it is preferable to use a more conservative estimate of the exposure concentration. There are several situations in which using a maximum concentration for the exposure concentration rather than an estimate of the arithmetic mean should be considered. Situations for which maximum concentrations are recommended are:

- evaluations of acute exposures;
- evaluations of contaminants with lethal or severe health effects;
- evaluations of sites for which there is insufficient site characterization data; or
- screening evaluations which are intended to over-estimate potential exposures.

As in a full risk characterization, a hot spot must be evaluated as a separate exposure area in a short-term hazard evaluation. This ensures that areas with high relative contamination will not simply be averaged into larger areas of lesser contamination, thereby diluting their potential impacts.

3.2.3. Toxicity (Dose Response) Assessment

The identification of a dose-response relationship(s) for each chemical being evaluated is done in the same manner as for a full risk characterization. Consult Section 8.2 for a discussion of the information needed to describe the dose-response relationship. Toxicity information used to characterize risk in

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the short-term hazard evaluation must be appropriate for the type and duration of exposure being evaluated and must be clearly identified and documented in the short-term hazard evaluation report.

3.2.4 Risk Characterization

Conditions at the site pose a Short-term Hazard if estimated cancer and noncancer risks resulting from existing exposure exceed the acceptable noncancer or cancer target risk levels. The documentation of the Short-term Hazard evaluation must clearly state the conditions evaluated and whether they pose a Short-term Hazard.

Generic acute and subchronic SRVs are presented in Appendix 3. SRVs were calculated when toxicity information was available. The Tier 2 Excel file (tier2_98.xls) contains worksheets which will automatically calculate the individual and cumulative site risks

3.2.4.1 Non-Cancer Effects

Non-cancer health effects vary in severity, reversibility, and in the availability and quality of the toxicity values. Special consideration should be given to contaminants for which the potential health effects are severe and irreversible. It is important to recognize that where noncancer risks are of concern the objective is to prevent an adverse health effect. The intent of a short-term hazard evaluation is to make decisions about the need for immediate action based on an exposure that is associated with an adverse health effect and not an exposure that is associated with no adverse effect (i.e. a "safe" dose).

3.2.4.2 Cancer Effects

When evaluating potential cancer risks in a Short-term Hazard Evaluation the cumulative site cancer risk of no more than 10^{-6} should be utilized if exposure duration is significantly less than a lifetime (e.g., one year or less in duration). See Section 8.3.3.2 for additional discussion. When a "short-term" exposure results in an excess lifetime cancer risk higher than the target risk limits, interim measures are recommended. The rationale is that further exposure, before or after long-term remediation is complete, could result in a excess lifetime cancer risk above the target risk limit.

3.3 Safety Hazard Evaluation

The conditions at the site pose a Short-term Hazard to Safety if there is a significant risk to safety *under existing conditions or conditions which are about to occur*. A significant risk to safety exists at a site if a release poses a threat of physical harm or bodily injury to people. Guidance relating to characterizing the risk of harm to safety is provided in Section 4.0. The Short-term Hazard for Safety focus on *existing* conditions (or conditions which are about to occur), and the *receptors actually present* given the current use of the site.

Conditions which pose or could pose a short-term risk to safety may include, but are not limited to:

- the presence of rusted or corroded drums or containers, open pits, lagoons, or other dangerous structures;
- any uncontained materials which exhibit characteristics of corrosivity, reactivity, flammability, or combustibility (see Section 4); and

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- releases resulting in vapors within buildings, structures or underground utility conduits at concentrations equal to, or greater than, 10% of the lower explosive limit.

3.4 Conclusions of Short-term Hazard Evaluation

The documentation of the Short-term Hazard evaluation must clearly state the conditions evaluated and whether they pose a Short-term Hazard. Interim response actions to address potential short-term hazards must be developed in conjunction with SRS staff and must be approved prior to implementation. Potential interim response actions could include:

- preparation of documentation presenting justification of why interim removal or containment actions are or are not warranted;
- collection of additional site data (e.g., additional sampling to determine the extent of the area containing levels exceeding the short-term hazard concentration);
- installation of fences, warning signs;
- installation of berms, dikes, or impoundments;
- removal or temporary covering of areas of concern; or
- relocation of receptors.

4.0 CONSIDERATION OF SAFETY RISK

This section describes the evaluation of safety risk, including a discussion of the criteria to be used to evaluate safety risks and some descriptions of situations that are presumed to constitute safety hazards. It is anticipated that most evaluations of safety risk will use qualitative rather than quantitative criteria. The safety risk must be looked at separate from, and in addition to the Tier evaluation of risk of harm to health, public welfare, and the environment.

The scope and level of detail of a safety evaluation is expected to vary from site to site, and should be sufficiently detailed to conclude whether a safety problem related to the release or threat of release of contaminants exists at the site. Any identified safety risks must be considered when determining the need for remediation. Remediation may be required based upon safety risk, even if no further remedial response actions are necessary based upon human health considerations. It must also be stressed that in characterizing the safety risk one must look not only at releases which have occurred, but also at the "threat of a release".

The purpose of evaluating the safety risk is to identify conditions which have resulted or may result in a release, currently or in the foreseeable future, that will pose a threat of physical harm or bodily injury to people. Some common examples of conditions that constitute a safety risk are as follows: rusted or corroded drums or containers; weakened berms; the threat of fire or explosion, including the presence of explosive vapors resulting from the release of contaminants; reactive chemical(s) stored or disposed of in a way that does not reasonably preclude uncontrolled reactions; unsecured pits, ponds, lagoons or other dangerous structures; any uncontained materials which exhibit the characteristics of corrosivity, reactivity, flammability, or are considered infectious materials; and the presence of ionizing or nonionizing radiation.

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4.1 Characteristics of Contaminants Which May Pose a Safety Risk

In this section particular characteristics of contaminants, those which pose a safety risk, will be discussed in more depth. These characteristics include: flammability/ignitablity, corrosiveness, reactiveness, or infectiousness.

A material is considered flammable/ignitable if a representative sample exhibits any of the following characteristics: liquid with a flash point of less than 100 degrees Fahrenheit; a non-liquid which is capable under standard temperature and pressure of catching fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited burns so vigorously and persistently that it creates a hazard; a compressed gas that is ignitable or an oxidizing agent.

A material is considered corrosive if a representative sample exhibits any of the following properties: it is aqueous and has a pH equal to or less than 2.0 or equal to or greater than 12.5; it is a liquid and corrodes steel (type SAE 1020) at a rate greater that 6.35 mm per year at a test temperature of 55 degrees Celsius; or it is a liquid that causes visible destruction or irreversible alterations in mammalian skin tissue at the site of contact.

A material is considered reactive if a representative sample exhibits any of the following properties: it is normally unstable and readily undergoes violent changes without detonating; it reacts violently with water; it forms potentially explosive mixtures with water; when mixed with water it generates toxic gases, vapors, or fumes in a sufficient quantity to pose a risk to safety; it is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement; it is readily capable of detonation or explosive decomposition or reaction at a standard temperature and pressure; or it is defined as a forbidden explosive, or a Class A or Class B explosive.

Infectious materials are those materials that, because of their infectious characteristics may: cause, or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of or otherwise managed.

4.2 Applicable or Suitably Analogous Standards, Guidelines, and Policies

At a minimum, current and reasonably foreseeable site conditions and conditions in the surrounding environment must be compared to applicable or suitably analogous safety standards, guidelines, and policies when evaluating safety risk. When assessing the flammability/combustibility of a contaminant the Occupational Safety and Health Administration (OSHA) criteria for classifying flammable and combustible liquids is recommend. In general, contaminants with flash points of less than 100 degrees Fahrenheit are considered flammable and contaminants with flash points of less than 200 degrees Fahrenheit are considered combustible. The National Institute for Occupational Safety and Health (NIOSH) Lower Explosive Level (LEL) criteria can be utilized to evaluate explosive potential. Vapor concentrations greater than ten percent of the LEL may indicate a risk to safety.

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5.0 DATA COLLECTION AND EVALUATION

In order to characterize risk at a contaminated site, information must be gathered and evaluated. Three types of information are needed:

- Contaminant Information

  The type, magnitude, extent, and location of contaminants

- Receptor Information

  Identify potential human receptors and use and activities on the site and surrounding area. The use of a site and surrounding area determines the activities which occur there and the potential for exposure to receptors. Current uses and activities are evaluated in the Short-term Hazard Evaluation and the Safety Hazard Evaluation. The risk characterization of the site must include all activities that are consistent with the current use even though some of the activities may not be occurring at the time of evaluation. Planned use (current as well as the foreseeable future use) must be evaluated in the Tier 2 and 3 SRV Risk Evaluations.

- Exposure Information

  The type and location of contamination relative to the activities occurring on the site and surrounding areas will assist in identifying the relevant exposure pathways and exposure areas.

5.1 Contaminant Data

Exposure assessment is only one of the many purposes for which contaminant data is collected at sites. Other applications include delineating the extent of contamination, identifying contaminants, and determining background levels. The emphasis of this guidance document is on the data needed for risk characterization of environmental contaminants.

5.1.1 Sampling Plans

The sampling plan should ensure the collection of data which can adequately characterize potential exposures at the site. To that end, potential exposure areas, activity patterns of potential receptors, and locations of contamination (if known) should be considered in the development of a sampling plan. If these items are not considered until after sampling has been completed, the data collected may not provide sufficient information to estimate exposure concentrations and further sampling may be required. If exposure patterns are not know the pattern of contamination should be utilized to determine potential exposure concentrations. See Sections 7.4 “Identification of Exposure Areas and Exposure Concentrations” and Section 8.3.3 “Quantitative Estimation of Exposure” for further discussion regarding exposure concentration estimation.

Subdividing the site into areas or strata depending on the likelihood of contamination and identifying areas with similar contaminant patterns can lead to more efficient sampling design for the entire site. These divisions can be based on process knowledge, operational units, historical records, and/or prior sampling efforts. Areas with similar patterns of contamination (e.g., areas of low or no contamination, hot spot

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and source areas) would be expected to exhibit lower variability and the sampling design could therefore, involve a smaller number of samples. The greatest intensity of sampling would be expected to focus on areas of the site where there is greatest uncertainty or greater variability associated with contamination. When relatively large variability in contaminant concentrations is expected, more samples are required to make site decisions.

If sufficient information exists, the site can be subdivided into three patterns of contamination:

1. Areas that are not likely to be contaminated. These areas will require limited confirmational sampling.
2. Areas that are known to be highly contaminated. These areas (e.g., source areas, hot spots) are targeted for surface and subsurface sampling. Information on area and depth are used to determine extent and magnitude of contamination. Hot spot means a discrete area where the concentrations of contamination are substantially higher than those concentrations in the surrounding area. The sampling density needed to detect and delineate a hot spot depends mainly upon its size and will vary from case to case. An elevated concentration at a single sample location does not necessarily constitute a hot spot. However, elevated concentrations in a single sampling location may be indicative of the presence of a hot spot and may warrant further sampling in that area. In deciding whether additional sampling is required, the following factors should be considered: a) the density of existing sampling locations; b) the magnitude of the concentration relative to the concentration variability in the nearby samples; and c) site history.

   As discussed in Sections 7.4 "Identification of Exposure Areas and Exposure Concentrations" and Section 8.3.1.4 "Identification of Exposure Areas", hot spots should be evaluated as exposure areas. The potential for hot spots to exist on the site should be considered in planning the sampling locations and sampling density.
3. Areas that are suspected to be contaminated and cannot be ruled out. These areas are primary subjects for investigation because they represent the greatest uncertainty.

For evaluating soil exposures, the average concentration within the potential exposure area is generally used as a surrogate for the temporal average exposure concentrations. See Sections 7.4 "Identification of Exposure Areas and Exposure Concentrations" and Section 8.3.3 "Quantitative Estimation of Exposure" for more detailed discussions. Systematic or random sampling approaches are preferable for evaluating the areal distribution of contaminant concentrations. However, for a variety of non-risk assessment purposes, biased sampling is often conducted. If distinct areas within a site boundary are specifically selected for sampling (i.e., biased selection) a random or systematic sampling pattern within the selected sampling area should be used.

An arithmetic mean concentration for an exposure area best represents the exposure to site contaminants over a long period of time. Composite samples may provide an efficient way of estimating the average concentration of the subsamples. However, important information about the subsample concentrations is lost. The range of the concentrations cannot be determined from a composite sample because the highest concentration contributed by a subsample is diluted by mixing with subsamples of lower concentrations. Further more, since the highest concentrations are not detected, hot spots may not show up in the data. Therefore, while compositing may be an efficient way to obtain an average, it generally does not provide complete information on the range and distribution of concentrations within the area sampled. **In general composite sampling should not be done. Because of the loss of information composite samples can not be evaluated utilizing parametric statistical manipulation (e.g., descriptive distributional statistics such as arithmetic average, 95 percentile upper confidence limit of the average, etc.).**

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If it can be adequately demonstrated that sufficient information exists to partition the site into homogeneous areas of contamination, compositing within these areas may be considered. Before individual specimens are composited for chemical analysis, they should be homogenized and split. One split should be utilized for compositing, the other should be stored. By compositing one portion of each specimen with the other specimens and storing one portion for potential future analysis, the spatial integrity of each specimen is maintained. If the concentration of a contaminant in a composite sample is high, the splits of the individual specimens from which it was composed can be analyzed discretely to determine which individual specimen contributed the high concentration. **Soil samples should *not* be composited if the contaminant pattern is unknown or variable or if matrix interference among contaminants is likely. Compositing also can not be utilized when evaluating acute exposure or volatile contaminants.**

The objective of the sampling plan and the quality of the data obtained should be clearly stated. The quality of data should be adequate to answer the specific question being posed. Several decision points where data is utilized are:

1. determining the presence or absence of contamination;
2. identifying the contaminants present;
3. delineating the extent of contamination;
4. comparing the site concentrations to background concentrations;
5. deciding where to focus sampling efforts;
6. estimating exposure concentrations;
7. estimating remediation processes; and
8. verifying remediation effectiveness.

At decision points related to the delineation of extent of contamination, field/screening methods are useful. Decisions related to characterization of contamination, estimating exposure concentrations, comparing site concentrations to background levels, etc. complete characterization of contamination is required. For example, limited sampling information on hot spots may be adequate for a Tier 1, Screening evaluation (i.e., is there a potential concern at this site that warrants further investigation?), whereas more extensive sampling would be necessary to adequately characterize exposure and risks at the site.

5.1.2 Data Quality Considerations

A comprehensive discussion of data quality issues and criteria is presented in EPA's Guidance for Data Usability in Risk Assessment (EPA 540G-90/008, October 1990). The following section summarizes the key points of this guidance.

Data quality indicators provide quantitative measures of data quality. Data quality indicators which should be evaluated are:

- comparability - are data sets from different sources or different time periods equivalent?;
- completeness - are the range of contaminant concentrations, the suite of contaminants detected and the extent of contamination in the environmental media under consideration fully represented in the data set?;

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- representativeness - are the data used to estimate exposure point concentrations adequate to define the true nature, extent and concentrations of the contaminants of concern to which receptors may be exposed?;
- precision - is the variability introduced by measurement error small?;
- accuracy - is the reported concentration close to the true value?

5.1.2.1 Data Sources

It is not appropriate to use all data collected during the field investigation. Site data which do not apply to a specific compound (e.g., DRO), or which result from insensitive analytical methods (e.g., portable field instruments) may be useful when locating sources of contamination or estimating potential fate and transport of contaminants. However, such analytical results usually are not appropriate for a human health risk-based evaluation. Also eliminate from further *quantitative* use, data resulting from analytical methods associated with few, unknown, or no quality assurance/quality control (QA/QC) procedures. Note: These data may be useful for *qualitative* discussions of risk or in planning additional investigation.

If site data is available from multiple sampling events, decide whether to combine data. It may be inappropriate to compare or combine data from a variety of sources (e.g., data from several different sampling periods, and which may have been analyzed using several different analytical methods). However, it may be appropriate to combine data, if the analytical methods, QA/QC procedures, and concentrations between sampling periods are similar.

First evaluate data from different time periods to determine whether concentrations are similar, or whether changes have occurred between sampling periods. If concentrations of chemicals change significantly between sampling periods, it is desirable to keep the data separate and to evaluate risks separately. Significant fluctuations in concentrations may indicate the need for additional sampling to resolve the inconsistency. Changes in concentrations over time may indicate trends (e.g., natural bio-degradation) or may reflect analytical problems which may require additional sampling to evaluate.

5.1.2.2 Analytical Methods and Detection Limits

The term detection limit is often used without qualification, but it is a very general term. There are several methods of calculating the detection limit, and the method used in the risk assessment should always be specified in the report. Types of detection limits include:

- Instrument detection limit (IDL) includes only the instrument portion of detection, not sample preparation, concentration/dilution, or method specific parameters;
- Method detection limit (MDL) is the minimum amount of an analyte that can be routinely identified using a specific method. In most cases the MDL will underestimate the SQL;
- Sample quantitation limit (SQL) is the MDL adjusted to reflect sample-specific action, such as dilution or use of a smaller sample aliquot for analysis due to matrix effects the high concentration of some analytes;
- Practical quantitation limit (PQL) is the lowest level that can be reliably achieved within specified limits of precision and accuracy during laboratory operating conditions.

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The sample quantitation limit (SQL) should be reported whenever possible. The SQL is the *actual* detection limit for the specific sample and analysis being reported. The MDL or PQL, which are reported more often, are typical values for the method, but may not represent the actual detection limit for the analysis under consideration. Do not use the IDL as an SQL.

For the risk assessment, analytical methods with detection limits well below concentrations of potential concern should be selected. When chemicals are reported at concentrations near the detection limit, the data have a greater possibility of containing false negative or false positive results. If detection limits of conventional methods are above or near concentrations of concern for the chemical(s) being evaluated, then an analytical chemist should be consulted to assist in identifying alternative methods.

5.1.3 Analytical Data Presentation

The documentation supporting the risk characterization should describe the nature and extent of contamination, including a characterization of sources, nature, and vertical and horizontal extent of contamination at the site. The analytical testing results should be tabulated, including background concentrations where appropriate. In addition, the documentation of data should contain summary tables which clearly indicate which contaminants have been identified in each medium at the site. The table should provide basic descriptive statistics (and background levels of each contaminant, if appropriate) including: (Note: The data set (or subset) used to calculate the statistics should be clearly referenced and available.)

- The type of detection limit and the limits of detection;
- the number of observations (total number of samples analyzed)
- the frequency of detection (# of samples with detected concentrations/total number of samples evaluated);
- the range of reported concentrations (minimum and maximum);
- median;
- arithmetic mean and standard deviation;
- geometric mean and standard deviation; and
- coefficient of variation

The range is the spread in the data and is represented by the difference between the largest (maximum) value and the smallest (minimum) value. The median is the 50th percentile value; half of the values in the data set are above the median and half of the values are below. The arithmetic mean is calculated by summing the concentration values and dividing by the number of samples. The geometric mean is the antilog of the arithmetic mean of the log-transformed data. The standard deviation is calculated by taking the square root of the distribution variance. The median and mean (arithmetic and geometric) are indicators of the central portion of the contaminant concentration distribution, and allow for a comparison of the differences in the central value between site and background levels or risk-based criteria. Comparison of the mean and median may also give an indication of normal vs. lognormal distribution. The range (minimum to maximum), standard deviation and coefficient of variation measure the spread and variability in the contaminant levels among the samples.

Remember averages, medians and standard deviations should not be calculated for composite samples. Each composite sample concentration represents an average concentration of the subsamples however, the information regarding the variability between subsamples is lost.

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The above simple statistical parameters will typically allow for comparison between site contaminant concentrations and background levels or risk-based criteria concentrations. Most computer spreadsheet programs have macros which will automatically calculate these parameters. The State of Washington Department of Ecology has developed statistical guidance and software (MTCAStat) which may be useful for evaluating background data sets.

Statistical evaluation should not be solely relied upon when making site decisions. The quality of the data set limits the usefulness, accuracy and level of the statistical evaluation. The use of simple summary statistics *and* professional judgment by the assessor considering all relevant site information (including historical use of the site, etc.) is less likely to lead to erroneous conclusions than the use of a formal inferential statistical test with inadequate (e.g., small or poor quality) data sets or the use of inappropriate statistical methods. For example, when site concentrations are truly above background levels or risk-based criteria, the assessor is less likely (than a statistical test with insufficient power) to erroneously conclude that the site concentrations are consistent with background levels or risk-based criteria. Every report using a statistical evaluation of site contamination should contain a discussion of the power, confidence level and the minimum detectable relative difference between site contaminant concentrations and background or risk-based criteria contaminant concentrations.

Provided that site contamination has been adequately characterized (i.e., the sample distribution is representative of the site contamination distribution) some simple "rules of thumb" can be utilized to conduct a preliminary assessment of site concentrations. If the median and the maximum values for the site data set are less than the background levels or risk-based criteria, then it can be concluded that the site data are consistent with background levels or are not likely to pose an unacceptable risk. Conversely, if both the median and maximum values are greater than the corresponding background or risk-based values, then it should be concluded that the site data are not consistent with background or potentially represent an unacceptable risk. For site concentrations that do meet either of the above situations a more detailed evaluation of the site concentrations is needed. See Sections 7.4 "Identification of Exposure Areas and Exposure Concentrations" and Section 8.3.3 "Quantitative Estimation of Exposure".

Appendix V of the Guidance for Data Usability (EPA 1992) contains equations that can be used to estimate the number of samples required to achieve specific statistical goals, such as levels of confidence and minimum detectable relative difference. The range of concentrations reported is as important as the magnitude of the concentrations. The Guidance for Data Usability gives specific examples to demonstrate the influence that variability among samples has on the number of samples required at a site.

A diagram(s) showing the pattern of contamination at the site is also strongly recommended. This diagram(s) for each strata should present:

- the location of each sample;
- the contaminant concentration at each sample location; and
- if appropriate, identify the area over which an exposure concentration was estimated.

5.2 Selection of Contaminants of Potential Concern

The purpose of determining contaminants of potential concern (COPCs) is to identify contaminants which are site-related and to eliminate from further consideration contaminants which are not site-related. Determination of COPCs can be complete only after analytical data have been collected, evaluated, and

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found to be of acceptable quality. All contaminants detected at the site should be considered contaminants of potential concern and should be carried through the risk characterization, unless there is a specific, justifiable rationale for dropping the contaminant. The results of the risk characterization will determine which contaminants pose an unacceptable potential risk and therefore should be the focus of further investigation and possible response action.

The selection of contaminants of potential concern should be evaluated in light of specific conditions associated with each individual site. The process for identifying contaminants of potential concern must be documented. In general, contaminants can be eliminated from consideration if one of the following conditions is met:

- the contaminant is present at low frequency of detection and in low concentrations for all relevant media;
- the contaminant is present at levels which are consistent with background concentrations and there is no evidence that its presence is related to site activities; or
- the contaminant is due to field or laboratory contamination.

The following section discusses criteria that can be utilized in the determination of COPCs. The following criteria can only be applied to data which has undergone a data quality evaluation and found to be acceptable (e.g., detection limits were adequate, sampling methods were acceptable). If the data are of questionable quality a determination of COPCs should not be done.

5.2.1 Frequency of Detection

The frequency of detection will be evaluated based upon the total number of samples collected, the sampling design and the total area sampled. In order to establish that the frequency of detection is very low, the assessor should first determine that the total number of samples collected was adequate to characterize the extent of contamination at the site. There is no established criteria for what constitutes very low frequency of detection. This number will be a function of total sample size and as such it would not be appropriate to consider contaminants detected in one to two samples as very low frequency when the total number of samples was only five or six. For example, if a 5% frequency is used as a criterion then *at least* 20 samples must be collected. Generally, speaking, unless there are at least ten samples (the lowest frequency detected would be 1 out of 10 or 10%), very low frequency ought not even be discussed. It is also critical when considering total sample size that the samples included in the total were collected under similar conditions. The spatial relationship of the samples relative to other samples at the site should also be considered. For example, a contaminant may only be detected in 2 out of 20 total samples, but those two might be located in a particular portion of the site and may in fact represent an important localized area of contamination.

Detection of a particular chemical in more than one sampled medium may indicate that some media are sources of contamination of other media. For example, do not eliminate as a site soil contaminant a chemical infrequently detected in soil (a potential source of ground water contamination), if the same chemical has been frequently detected in ground water. Also remember to consider the differences in detection limits for different media.

A contaminant should not be ruled out as a contaminant of concern, even if detected at very low frequency, when there is evidence of historical or present use of the chemical at the site.

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5.2.2 Evaluation of Non-Detects

For the contaminant to be identified as a COPC it must be present in a concentration above the detection limit. The assessor should evaluate the type of detection limit identified in the site data as part of the evaluation of overall quality of the data. The detection limit should be below levels of health concern.

A contaminant should not be ruled out as a contaminant of concern, even if levels are detected in very low concentrations, when there is evidence of historical or present use of the chemical at the site.

5.2.3 Qualified Data

All qualifiers should have been evaluated as part of the data quality evaluation. Either laboratories conducting data analysis or persons validating sample data attach qualifiers to the data, and analytical results exhibit these qualifiers. Because the purpose of validating data is to assess the effect of QC issues on data usability, the data validator attaches validation qualifiers to the data after the laboratory has attached qualifiers, and they supersede the laboratory qualifiers.

EPA's "Risk Assessment Guidance for Superfund" (RAGS) presents a list of qualifiers which the CLP permits laboratories to use, as well as a discussion of their potential uses in risk assessments (EPA, 1989, pages 5-12 through 5-14). Ensure that the laboratory has provided current definitions for the data qualifiers used in the data set for the site.

The "J" qualifier (i.e., the chemical identity is certain, but the concentration is an estimated quantity) is the most commonly encountered data qualifier. Use J-qualified data in the same way as positive data that do not have this qualifier. If possible, note potential uncertainties associated with the qualifier, so that, if data qualified with a "J" appear to contribute significantly to risk, the risk evaluation can include appropriate precautionary notes.

5.2.4 Background

Background means those levels of chemicals or substances which are ubiquitous and consistently present in the environment and that would exist in the absence of the site of concern. It is important to note that contamination from one release cannot be considered background for another release. Comparing sample contaminant concentrations to background concentrations helps identify non-site-related chemicals or substances found at or near a site. Generally speaking, background levels are most important for the various naturally occurring metals and trace elements found in the environment.

Published generic background levels may not be representative of Minnesota conditions and may not be comparable to the data obtained at the site (e.g., different soil type). Typically they are collected over a large geographic region, including areas which would not be representative of Minnesota conditions (e.g., the USGS Shacklette, 1984). Compilations of generic background levels may also include data taken from a number of sources, with internal variation of sample collection, handling and analytical techniques. Thus, the assessor should avoid using any list of generic background levels which has not been specifically recommended or approved by the SRS.

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Background samples should be collected in locations that are relatively undisturbed, unstained and unlikely to have been used for handling or storing contaminants, or to have been affected by contaminants migrating to that location. The sampling location should be based upon similarity of the soil conditions at the background area and the site conditions. It may be necessary to collect background samples at various depths at a site to adequately characterize background conditions. Some specific considerations when selecting background sample locations include: geologic unit, sample collection depth, use and extent of fill, and soil characteristics.

A sufficient number of samples must be taken to allow a meaningful comparison of background concentrations to site concentrations. At simple sites (in terms of geology and number and distribution of contaminants) 4 to 5 samples are considered the minimum number of samples. Generally speaking **more** background samples are required if:

- there is high variation in the concentration of analytes in the background data set, or
- contamination exists in more than one medium, or
- small differences between site concentrations and background may be of concern.

The Guidance for Data Usability (EPA, 1992, Appendix IV) contains equations that can be used to calculate the minimum number of samples required to achieve specific statistical goals, such as levels of power, confidence and minimum detectable relative difference. The range of chemical concentrations reported is as important as the magnitude of the concentrations when making site-to-background comparisons. The Guidance for Data Usability gives specific examples to demonstrate the influence that variability among samples has on the number of background samples required at a site. See Section 7.3 "Comparing Site Contaminant Concentrations to Background Levels" for a more detailed discussion.

It is possible that the background levels may exceed levels of health concern. If background risk is a concern, calculate it separately from site-related risks. If the calculation suggests significant risk, notify the Site Assessment and Consultation Unit at the Minnesota Department of Health.

5.2.5 Field or Laboratory Contamination

Contamination may be introduced into a sample during sample collection, transport, or laboratory handling and analysis. Equipment blanks, trip blanks and method blanks should be collected and analyzed to determine whether contaminants were introduced by field or laboratory practices rather than as a result of a release. When assessing the potential for field or laboratory contamination the assessor should consider:

- the concentration of contaminants detected in both the environmental and blank samples;
- the type of contaminants detected in the samples, with particular attention to chemicals commonly used in a laboratory; and
- historical information regarding chemical use at the site.

When the concentrations detected in the site samples are greater than the concentrations in the quality control samples, the chemical or substance should be considered a contaminant of potential concern. When the concentrations detected in the quality control blank samples are comparable to the

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concentrations detected in the site samples, that contaminant may be eliminated from the quantitative risk assessment , unless it is otherwise associated with the site based upon other evidence, such as history of prior use of that chemical or associated chemicals.

EPA has established guidelines to use when comparing results from analysis of blanks and of environmental samples (Risk Assessment Guidance for Superfund (RAGS), EPA, 1989). However, this approach is generally not recommended for screening out chemicals at sites. Resampling to confirm the presence or absence of the contaminant is the best alternative for determining whether the contaminant is present as a result of a release or if it was introduced during sample collection or handling.

5.2.6 Additional Issues of Consideration

Additional issues which may need to be considered in determining COPCs include items such as chemical speciation, toxicity screening, tentatively identified compounds, and analytical results for chemical groups.

5.2.6.1 Toxicity Screening

The use of toxicity screening to eliminate contaminants prior to the risk characterization is not recommended. The risk assessment process itself considers toxicity in estimating risks and it is premature to eliminate contaminants before the risk assessment is performed. The EPA concentration-toxicity screen presented in RAGS (EPA 1989) is considered to be outdated methodology.

5.2.6.2 Chemical Species

When identifying contaminants of concern it may be important to consider the specific form (chemical speciation) of the contaminant. Depending upon the specific form of the contaminant present there may be different health or environmental effects associated with the chemical. This phenomenon is commonly encountered with differences in oxidation states of metals. For example, hexavalent chromium is more toxic than trivalent chromium. In addition, some compounds may degrade over time and products of degradation may have different toxicity parameters than the parent compound (e.g., trichloroethylene and vinyl chloride).

5.2.6.3 Groups of Compounds

Some of the data for contaminants may be presented for groups of contaminants rather than for each individual component. Data on groups of contaminants is generally not useful in the risk assessment process. Toxicity information used to estimate risk is compound specific; therefore, the estimation of risk associated with exposure to contaminants that are identified as a group can be highly inaccurate or impossible, and as a result is generally not recommended. Polychlorinated biphenyls (PCBs) are an exception to this recommendation. See Section 8.2.4.3 for further discussion.

5.2.6.4 Tentatively Identified Compounds

When gas chromatography-mass spectrometry (GC-MS) is used to analyze for the presence of organic compounds, the instrument is calibrated for certain chemical standards. When compounds are identified in the sample, but the GC-MS instrument is not specifically calibrated for those

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compounds, they are designated as tentatively identified compounds (TICs). There are several techniques which can be employed to increase the confidence in identification and quantification of TICs:

- the TIC data should be reviewed by an analytical chemist trained in the interpretation of mass spectra and chromatograms;
- the identification of the TICs should be checked against the chromatographic retention indices or relative retention times;
- the TICs should be compared to available site information regarding past use of the site and chemicals associated with prior use of the site;
- the sample could be reanalyzed using a specific standard;
- evaluate whether the TIC is likely to be associated with other compounds detected at the site.

The assessor must use his/her professional judgment in dealing with TICs, especially when the TICs are potentially associated with a significant health risk. The concentration of TICs vs. concentration of identified compounds should be discussed in terms of the overall risk associated with the site.

5.2.6.5 Comparison to Regulatory Standards and Guideline Criteria

A chemical should not be ruled out as a contaminant of concern because it is below a standard regardless of the risk characterization method used. It is appropriate to compare individual exposure point concentrations to standards or guideline criteria when conducting a Tier 1 or Tier 2 risk characterization, as this is the actual risk characterization process for those methods. However, when conducting a Tier 3 risk characterization, eliminating contaminants from the risk assessment simply because they are below applicable or suitable analogous standards is not appropriate.

5.2.6.6 Mobility, Persistence and Bioaccumulation Potential

When identifying contaminants of concern it is not appropriate to eliminate them from the risk analysis based upon physical or biological properties that suggest reduction of the contaminant in the future.

6.0 TIER 1 (SCREENING) RISK CHARACTERIZATION

The Tier 1 (Screening) risk characterization was developed as a screening evaluation to determine the potential for harm to health from contact with contaminated soil and the need for further site investigation. Generic Soil Reference Values (SRVs) corresponding to acceptable target risk levels were developed to provide a mechanism by which site soil concentrations could be easily be converted to an estimate of potential risk. The use of generic SRVs in the risk characterization has many benefits:

- The assessment process is simplified.
- The generic criteria are stated in terms that are familiar to the lay public and site assessment specialists alike: concentrations of the contaminant in soil.

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- There is greater consistency in remedial decisions. Because the Acceptable Target Risk Levels are explicit, there is little opportunity for varied interpretation from site-to-site.
- The cost and time required for the risk characterization is reduced, freeing resources to be used for focused investigation and remediation.

Because of the generic nature of the Tier 1 SRVs, they may not be applicable to all sites. The SRVs address the three most common exposure pathways - incidental soil ingestion, dermal contact with soil, and inhalation of outdoor vapors and particulates from soil. Less common exposure pathways (e.g., ingestion of contaminated produce) are not addressed but must be evaluated when the pathway is likely to be complete and significant based on site concentrations and contaminant distribution relevant to the location of the receptors.

The primary condition for use of the Tier 1 SRVs is that the exposure pathways of concern and site conditions match the assumptions underlying the SRV calculations. At all sites it is necessary to identify likely source areas, exposure pathways, and potential receptors to determine the extent to which the Tier 1 SRVs can be applied to the site.

6.1 General Approach

A Tier 1 SRV risk characterization always includes the following steps, although the scope and level of effort of the risk characterization will depend upon the complexity of the site.

- Information gathered as part of the site investigation is used to determine the extent and magnitude of contamination.
- Affirm the applicability of Tier I criteria
- Evaluation of short-term hazard, if applicable (Section 3).
- The safety risk is characterized (Section 4)
- The exposure point concentrations are compared to the applicable Tier 1 SRVs.
- A conclusion is drawn as to whether site conditions pose a potential unacceptable risk of harm to health and safety.

Note that Tier 1 SRVs represents a streamlined approach to the risk characterization process, *not* to the site assessment process; an adequate knowledge of the site and the contamination present is still necessary to employ this approach. Of course, the resources required for the site assessment will vary from site-to-site, depending upon the nature and complexity of the release under investigation: the scope and level of effort required for the site investigation and the risk characterization will be determined using the professional judgment of the investigator considering site-specific circumstances.

The assessor should keep in mind that a Tier 1 SRV evaluation does not adequately address potential short-term hazards which may be present at the site. If site conditions suggest that a quantitative Short Term Hazard Evaluation be performed the guidance provided in Section 3 of this document should be followed. Such evaluations are *not* required at all sites.

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6.1.1 Acutely Toxic Contaminants

The acute toxicity of a contaminant refers to its ability to do systemic damage as a result of a one-time exposure to relatively large amounts of the contaminant. When acutely toxic contaminants are present in accessible soil at a site, a short term hazard evaluation of the potential risk should be done automatically, regardless of which risk assessment tier is being used. Of all of the chemicals commonly detected at sites, acutely toxic contaminants are the only ones which could pose a significant health risk from a "one-time" exposure to concentrations that are often found in the environment. Although acute exposures to some other contaminants could pose a health risk at some level, the concentrations at which acute exposures are of concern are much higher than levels typically found in the environment.

With acutely toxic contaminants, the risk estimate for a "one time" exposure may exceed the risks from long term exposures when the magnitude of exposure during the acute episode is very high. Acute (i.e., "one time") risk estimates are based on the highest concentration detected. Typically the Tier 1 SRVs are based on a chronic exposure scenario and chronic target risk levels. The Tier 1 SRVs for acutely toxic contaminants are based on the concentration above which a "one-time" dose could pose a significant risk. SRVs based on acute toxicity are highlighted on the Tier 1 SRV table in Appendix 3 (Table A3.1). Utilizing a site average soil concentration as the Tier 1 exposure concentration does not protect against potential health risks from an acute exposure.

6.2 Contaminant Data

Section 5.1 of this document presented general guidance on determining the nature, extent, distribution, and magnitude of contamination at sites for the purpose of risk characterization. At the start of the Tier 1 risk characterization process the assessor at a minimum should know what contaminants are present, the environmental media in which the contaminants are located, and the concentration of the contaminants in the most highly impacted areas of the site.

Overall confidence in the assessment process is directly related to the site characterization: if the assessor fails to analyze the affected environmental media, if contaminants have not been identified, if too few samples were taken or taken in dubious locations or analyzed following the wrong methodology to describe the nature and magnitude of contamination, then the conclusions drawn from the risk characterization will be meaningless.

6.2.1 Identification of Contaminants of Potential Concern (COPCs)

Once a contaminant(s) at the site has been identified for each contaminated environmental medium, the process of selecting the contaminants of potential concern may proceed. The contaminants of potential concern are those contaminants which are carried through the risk characterization process. General guidance on the selection of contaminants of potential concern is provided in Section 5.2 of this document. At some sites there may be a single contaminant of potential concern, while the list of COPCs may be lengthy at others.

The discussion in Section 5.2 identifies basic criteria used to select or eliminate a contaminant for further consideration in the risk characterization.

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6.3 Characterizing Safety Risks

The Tier 1 risk characterization process does not specifically look at potential safety risks posed by the site, as safety is a concept which is difficult to distill down to a set of generic standards. As a result, the safety risk must be evaluated separately at all sites. Section 4.0 of this guidance document discusses the evaluation of safety concerns. The characterization of site safety risk should be included as part of the overall documentation of the Tier 1 risk characterization.

6.4 Affirmation of Tier 1 SRV Applicability

The risk characterization should include documentation that the use of Tier 1 SRVs to characterize risk at the site is appropriate. There may be a bias towards the use of Tier 1 due to its simplicity and ease of use which could result in the use of Tier 1 SRVs in situations where they are not appropriate. By requiring documentation the assessor is compelled to think through the applicability criteria at every site.

The primary condition for use of the Tier 1 SRVs is that the exposure pathways of concern match the assumptions underlying the SRV calculations. **Before applying the Tier 1 SRVs**, the assessor should consider whether the exposure pathways at the site are fully accounted for in the SRV calculations. To determine the appropriateness of the SRVs, ask the following questions:

- are there other likely human exposure pathways not considered in development of the SRVs (e.g., homegrown produce consumption, vapor migration)?;
- are there unusual site conditions which are likely to result in exposures exceeding the SRV exposure scenario and/or to invalidate model results (e.g., large areas of contamination, high fugitive dust levels, contaminant saturated soil, etc.)?; and
- are there contaminants of concern for which SRVs are not available?

If any of these conditions exist, a simple Tier 1 SRV Evaluation will not be adequate to evaluate the potential risk to human health from exposure to contaminated soil. For example, if persistent or bioaccumulative contaminants are present on site and potential foodchain exposure pathways exist the Tier 1 SRVs must be supplemented by using Tier 3 to evaluate the risk from these additional pathways. If highly volatile contaminants are present and soil vapor migration impacts are of concern a Tier 3 evaluation must supplement the Tier 1 evaluation.

6.5 Derivation of Additional Tier 1 SRVs

Tier 1 SRVs have been developed by SRS staff for approximately one hundred and sixty contaminants or groups of contaminants. These contaminants were targeted as being those most commonly encountered at sites. When a contaminant is encountered which does not have a SRV, the SRS risk assessor should be contacted. SRVs will be developed by SRS risk assessors if adequate toxicity information is available.

The process and equations utilized for existing Tier 1 SRVs will be used to develop the additional Tier 1 SRVs in order that the values generated will be consistent and comparable to existing SRVs. The number of contaminants with SRVs will be expanded over time, and will be updated as necessary.

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6.6 Application of Tier 1 SRVs

The Residential SRVs utilized in Tier 1 are provided in Appendix 3. To facilitate evaluations these tables are also available as Excel spreadsheets. The SRV information is organized into two worksheets: 1) an informational summary table; and 2) a risk estimation table.

The Tier 1 SRVs were derived in consideration of potential direct soil contact exposures (incidental ingestion, dermal contact and inhalation of resuspended particulates) and the potential for contaminants to volatilize from soil into outdoor air (inhalation of vapors) under a residential setting. The inhalation pathway is evaluated somewhat differently than the ingestion and dermal pathways. The inhalation pathway involves the estimation of an air contaminant concentration. To estimate air concentrations a particulate emission factor and a volatilization factor must be calculated.

The particulate emission factor (PEF) relates the contaminant concentration in soil to the concentration of particles in the air due to fugitive dust emissions from contaminated soils (EPA Risk Assessment Guidance for Superfund (RAGS), 1989). Appendix 1 presents the PEF model. The default particulate emission factor utilized in Tier 1 SRV calculations is 3 $\mu g/m^3$. This default value is based on partially vegetated soil and dust generation largely from wind erosion. It does not account for conditions that may lead to significantly higher emissions due to mechanical disturbances (e.g., vehicle traffic), tilled agricultural soils, or construction activities. If these conditions exist on the site the Tier 1 SRV may not be adequately protective.

The volatilization factor (VF) defines the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. The VF model presented in Appendix 1 represents a change in the fundamental volatilization model used to derive the VF equation in EPA's Risk Assessment Guidance for Superfund RAGS), 1989).

Tier 1 SRVs for volatile organic compounds (VOCs) are based on the following default source area and soil characteristics: 5 acre source area, soil moisture content of 10 percent, dry soil bulk density of 1.5, soil particle density of 2.65, and soil organic carbon content of 0.5 percent. If the site-specific source area or soil characteristics are significantly different than the default values the generic SRV may be too high or too low and the assessor should consider making a site-specific modification to the SRVs. For further discussion of the VF model see Appendix 1.

There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration is above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. The determination of Csat is important as it sets the upper concentration limit at which the soil-to-air volatilization model is valid. The Henry's Law constant used in the VF model is invalid above the saturation limit. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous

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phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When the inhalation pathway is the driving pathway and the calculated SRV exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. For further discussion of Csat see Appendix 1.

Note that soil vapor migration into indoor air, soil leaching to groundwater, runoff to surface water or sediment, food production, or ecological impacts may also be of concern at a site and may result in a more restrictive risk characterization. For example, the leaching to ground water pathway is often more sensitive (i.e., produces a lower allowable soil concentration) for mobile contaminants than the pathways addressed by the SRVs.

6.6.1 Identification of Tier 1 Exposure Concentrations

Ideally, the exposure concentrations for soil are representative concentrations for contaminants within each exposure area. Typically the exposure concentration would be the arithmetic mean of the contaminant concentration within the exposure area. Adequate sample size (e.g., ten or more discrete samples within each area of concern) is required for utilization of estimates of the mean. At the Tier 1 level the number of samples within each area of concern may be quite small. When site data is limited (e.g., small number of samples but confident that source areas are identified) or when evaluating acutely toxic contaminants it is recommended that the maximum concentration be utilized if there is reasonable certainty that the value represents the upper range of contaminant concentrations. See Sections 7.4 “Identification of Exposure Areas and Exposure Concentrations” and 8.3.3 “Quantitative Estimation of Exposure” for further discussion of exposure concentrations.

The Tier 1 exposure area is defined such that it excludes uncontaminated soil, analytical results from "clean" areas of the site should not be incorporated into the exposure concentration, only the area of contamination would be considered a potential exposure area. Hot spots are specifically identified as distinct exposure areas. The identification of a "*hot spot*" is discussed in more detail in Section 5.1.1 of this document, but is defined as a discrete area with substantially higher contamination relative to the surrounding area.

Soil at various depths are considered an exposure area due to the potential for future excavation and contact. Such potential future exposures are part of the basic risk characterization, the assessor cannot eliminate this exposure pathway (determine that such exposure would never occur, and that the soil at depth does not constitute an exposure area).

6.6.2 Characterizing Potential Risk Using Tier 1 SRVs

Having determined the applicability of Tier 1 SRVs (Section 6.3) and having identified the appropriate site concentrations (Section 6.5.1), the Tier 1 risk characterization consists of simply comparing the site concentrations and the applicable Tier 1 SRVs to calculate potential risk. The MPCA considers short-term or interim measures (e.g., fences, soil cover, filtration systems) to be temporary in nature--do **not** consider them in the Tier 1 evaluation. Consider short-term risk to have been mitigated *only* if permanent measures are implemented immediately, or if interim measures are implemented pending completion of the remedy. See Section 3 “Short-term Hazard Evaluation” for further guidance.

The purpose of the Tier 1 (screening) risk characterization is to determine whether further investigation and/or remediation may be necessary, based on an estimate of the potential health hazard from contamination at the site. The Tier 1 risk characterization will also assist in deciding whether further site

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assessment is necessary. The calculated screening risk estimates do not provide an absolute estimate of actual risks, but instead quantify the potential long-term risk from site conditions for the defined set of exposure conditions.

Except where noted for specific contaminants the acceptable risk limits are: 1) individual and total (i.e., cumulative risk from the site) excess lifetime cancer risk (ELCR) is not to exceed 1 in 100,000 (i.e., 1E-5); and 2) noncancer risk is not to exceed a hazard quotient (HQ) of 0.2 per contaminant and a total hazard index (HI) of 1 for contaminants with similar target endpoints (e.g., liver, kidney, etc.). The following equations provide a contaminant-specific hazard quotient (HQ) and/or excess lifetime cancer risk (ELCR) for each site contaminant:

For noncarcinogenic risk evaluation -

$$HQ_s = HQ_{SRV}\ (C/SRV)$$

For carcinogenic risk evaluation -

$$ELCR_S = ELCR_{SRV}(C/SRV)$$

where:

HQ_S	=	site contaminant HQ;
C	=	site exposure concentration (mg/kg);
HQ_{SRV}	=	HQ associated with the SRV;
SRV	=	soil reference value (mg/kg);
$ELCR_S$	=	site contaminant ELCR; and
$ELCR_{SRV}$	=	ELCR associated with the SRV.

The SRS assumes risks to be additive for noncarcinogens with similar target endpoints and for carcinogens. The potential for additive effects has not been "built in" to the SRVs. Therefore, when multiple contaminants with similar endpoints occur the cumulative site risk must also be evaluated. Derive a cumulative hazard/risk for the site by summing the HQ or ELCR values for individual contaminants. To facilitate additivity evaluations of site-specific mixtures a calculation worksheet is available in the Excel SRV spreadsheet. The assessor is responsible for obtaining the most current version of the SRV tables.

6.6.2.1 Characterizing Risk Using TPH Data

Total Petroleum Hydrocarbon, or TPH, is a loosely defined parameter which provides an estimate of the total concentration of petroleum hydrocarbons in a sample. Minnesota Department of Health (MDH) and SRS staff are currently evaluating available carbon fraction specific methodologies for potential use in developing SRVs. Development of carbon fraction specific SRVs would make it possible to more easily address, in a quantitative manner, the bulk of the compounds in petroleum products which have been difficult to evaluate and which have been largely ignored in quantitative risk assessments in the past.

The carbon fraction specific TPH approaches do not consider all of the compounds that may be present in petroleum products. The constituents of TPH which can be identified and quantified easily and for which good toxicity information exists are not included. Examples of these constituents

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are benzene, ethylbenzene, toluene, xylene, and polycyclic aromatic hydrocarbons (PAHs). These constituents must be evaluated separately from the carbon fraction specific TPH methodology. In addition, additives that may be present in some petroleum products are not included.

It is important to note that if one wants to use the carbon-fraction specific TPH approach more than just a TPH analysis will be needed to evaluate petroleum hydrocarbons. Selecting an analytical method(s) should be done considering the type of petroleum products that was released. If the petroleum product contained benzene, toluene, ethylbenzene, xylene (BTEX) or PAHs, such compounds must be specifically analyzed for.

6.7 Conclusions of a Tier 1 SRV Risk Characterization

The overall purpose of the Tier 1 SRV risk characterization is to determine whether or not the site requires further investigation of potential direct human health impacts from contact with contaminated soil. There are four possible outcomes of the Tier 1 SRV risk characterization:

1. the site clearly "passes" the screening for one or more contaminants;
2. the site barely passes the screening process;
3. the site barely fails the screening process; or
4. the site clearly "fails" the screening process.

Sites where site risks for all site related contaminants fall below the acceptable target risk limits (and where there is no risk to safety), Outcome 1, require no further site investigation regarding human health concerns resulting from direct contact with soil.

If a site is a candidate for release from further investigation based on health risk analysis for direct exposure (Outcome 2), confirmation sampling may be requested if the assessor has concerns regarding the quality of the existing sampling data. If the confirmation sampling supports the original conclusion that the site does not pose an unacceptable risk no further action is required based on potential risk associated with direct human exposure. Remember, potential ecological, surface water, and/or ground water impacts must be evaluated separately before releasing the site completely from further investigation.

If risks associated with one or more site contaminants exceed the acceptable target risk limits (including cumulative site risk) (Outcome 3 or 4), additional site evaluation is required. A more site-specific risk characterization approach (Tier 2 or Tier 3) may be employed to evaluate the site. For some sites where a Tier 1 SRV risk characterization has indicated that a potential human health concern exists at the site, the site-specific approach might demonstrate that, in fact, a concern does not exist. (Of course the more detailed evaluation could also reach the same conclusions as the Tier 1 assessment, but at significantly greater cost). Another option available is to conduct a remedial response action designed to reduce the concentrations of contamination to levels which would not pose an unacceptable risk based on the Tier 1 evaluation.

The screening evaluation process will provide information indicating the contaminated areas of greatest concern, and can serve as an indicator of priority for further investigation or remediation. Because SRS has developed a standardized approach to site screening, the results can be qualitatively compared to determine which sites may pose the highest potential risks. This facilitates focusing more quickly on those sites of greatest concern, and using limited resources (e.g., staff, money, time, etc.) more efficiently.

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6.8 Uncertainty Analysis

The documentation of the Tier 1 SRV risk characterization should contain a brief discussion of the possible sources of uncertainty present in the site assessment and risk characterization process which could have an effect on the conclusions of the assessment. To the extent that it is known, the uncertainty discussion should describe whether the uncertainty is due to an incomplete knowledge of the site (e.g., limited sampling, unidentified hot spot), incomplete data from the scientific literature or other information source (e.g., lack of toxicity information for some COPCs), or from the effects of natural, unquantified variability (e.g., natural fluctuation in moisture content of soil). The discussion should also indicate whether or not the uncertainty has a biased impact on the risk characterization results (e.g., lead to an over- or under-estimation of risk) and, if possible, the magnitude of the effect.

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Tier 1 Attachment - Tier 1 SRV Risk Characterization Documentation Framework

The following topics have been identified for assessing the completeness of Tier 1 Risk Characterization Documentation. Seven main subject areas have been delineated. Each of these topics should be addressed in the risk characterization. Depending upon site specific considerations, some areas may require a more detailed discussion than others. This outline has been prepared as a simple guide to determine whether a report has addressed the major points of a Tier 1 risk characterization. It does not substitute for knowledge of current risk assessment methodologies or regulatory requirements. Specific references to a more detailed discussion are provided.

1. Adequate Site Characterization

- Have all the impacted media been assessed?
- Have all the sources of contamination been identified? (Note: level of detection limit)
- Has a list of contaminants been adequately identified for the site? Are all the chemicals on that list considered to be Contaminants of Potential Concern to be carried through the risk assessment process? If some chemicals have been eliminated, what was the basis for their elimination and was it proper?
- Are the data representative of site contaminant conditions or at a minimum representative of the upper range of contaminant concentrations?

For additional discussion please see:
Section 5 "Data Collection and Evaluation" and the Draft Risk-Based Site Characterization and Sampling Guidance.

2. Short-term Hazard Evaluation

- Are there conditions at the site which may pose a Short-term Hazard?
- Has the Short-term Hazard evaluation been properly conducted?
- Are the results of the Short-term Hazard Evaluation clearly stated?

For additional information please see:
Section 3 "Short-term Hazard Evaluation".

3. Evaluation of Safety Risk

- Are there conditions at the site which might pose a risk to safety?

For additional information please see:
Section 4 "Consideration of Safety Risk".

4. Appropriateness of the Use of Tier 1 SRV Criteria

- Does exposure to human receptors occur predominantly through contact with soil?
- Are contaminants which are known to bioaccumulate in the foodchain present in soil?
- Do Tier 1 criteria exist for all contaminants of concern?

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For additional information please see:
Section 6 "Tier 1 Soil Reference Value Risk Characterization".

5. Exposure Concentrations

- Is it clear how the soil exposure concentrations were determined?

  NOTE: The soil exposure point concentrations should only include areas which are contaminated. Hot spot areas should be addressed as separate exposure point concentrations. Have Hot Spots been identified? Is the report clear on how the Hot Spots were identified?

For additional information please see:
Sections 5.1.1 "Sampling Plans" and 6.5.1 "Identification of Tier 1 Exposure Concentrations".

6. Identification of Tier 1 SRVs

- Does the report identify the correct Tier 1 SRVs?

For additional information please see:
Sections 6.3 "Affirmation of Tier 1 SRV Applicability" and 6.4 Derivation of Additional Tier 1 SRVs".

7. Conclusions

- Does the report state whether a condition of acceptable risk of harm to human health and safety from direct soil exposure pathways exists?
- Does the report state the level of confidence the assessor has in the Tier 1 SRV results, including a discussion of the source of the uncertainties?
- Does the report state whether there is a need for the evaluation of other media or other receptors to adequately assess the risk to health, welfare and the environment?

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7.0 TIER 2 (SIMPLE SITE-SPECIFIC) RISK CHARACTERIZATION

As described in Section 6.0 of this document, Tier 1 risk characterization relies upon the use of generic, residential soil reference values (SRVs) for chemicals in soil to characterize potential risk. As described in Section 8.0 of this document, a Tier 3 risk characterization employs detailed site-specific information to characterize potential risks posed by contamination at a site. Thus, Tier 1 and Tier 3 represent the extremes on the generic/site-specific continuum.

Tier 2 risk characterization is a mixture of those two methods. Tier 2 allows for *limited* modification of the generic SRV equations and defaults based upon site-specific information. Since a Tier 2 risk characterization builds upon the Tier 1 risk characterization methodology, all the limitations and options for Tier 1 SRVs discussed in Section 6 also apply to Tier 2 SRVs. Specifically, Tier 2 SRVs may be used at sites where exposure to human receptors occurs predominantly through contact with soil. The Tier 2 approach provides some flexibility over Tier 1 SRVs, but since the modifications under Tier 2 are typically focused, Tier 2 results are not as site-specific as those obtained using Tier 3. The Tier 2 approach can be used in the following ways:

- Tier 2 can incorporate planned property use information. A more detailed discussion is presented in Section 2 and 3 of the Draft Guidance Document for Incorporation of Planned Property Use into Site Decisions (August 25,1997).
- Tier 2 can be used to incorporate site-specific soil characteristics to determine the SRVs for volatile contaminants.
- Tier 2 can incorporate determination of background concentrations into the selection of COPCs.

Tier 1 SRVs based on acute effects if children are potential receptors or set at the maximum allowable soil concentration (i.e., 100,000 mg/kg) may not be modified in a Tier 2 evaluation if children are potential receptors.

The exposure scenario is characterized by the type of potential receptors (child or adult) present and activities that occur on the property. Several property use categories based on potential exposure have been developed to facilitate cleanup decisions. The property use categories are based on type of receptor and activities not on zoning classifications and include: agricultural, residential, unrestricted commercial, restricted commercial, industrial, and recreational. A complete description of the property use categories are contained in the glossary.

Often the use of properties in the surrounding area (e.g., adjacent land) may give an indication of potential exposures on the property under investigation, and thus they should also be considered (e.g., a property located next to an elementary school is likely to be routinely visited by school-age children). Note that both the current and future use of the land must be considered in the evaluation of planned property use and remediation decision process.

The process of risk characterization under Tier 2 is similar to that of Tier 1, i.e., site risks are estimated based on comparison of site exposure concentrations to the Tier 2 SRV criteria. If the estimated site risks are equal to or less than the acceptable target risk levels (including cumulative site risk) then the assessor may conclude that the site does not pose an unacceptable risk of harm to public health. Depending on the type of receptor, the potential for exposure, as well as the extent, magnitude and location of residual contamination an institutional control may be required. Refer to the Draft Guidelines for Incorporation of Planned Property Use into Site Decisions (August 25, 1997) for guidance regarding institutional controls.

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The exposure equations and recommended default exposure parameters for the various property use exposure scenarios (i.e., residential, recreational and industrial property use) are summarized in Appendix 1. The generic Tier 2 SRVs produced by using all of the default inputs are presented in Appendix 3.

7.1 Applicability of Tier 2 SRVs

The applicability of Tier 2 SRVs is similar to that of Tier 1, as both approaches rely upon the use of chemical-specific criteria in soil. The reader is referred to Sections 6.3 and 6.5 of this document which describe the applicability and basis of Tier 1 SRVs. At certain sites the assessor will use a combination of Tier 1 SRVs and Tier 2 SRVs, at some sites the risk assessor may have to supplement the Tier 2 risk characterization with some form of a Tier 3. The documentation of the risk characterization should affirm and document the applicability of Tier 2 to the site. See Sections 2.4 and 8.4.5 for further discussion regarding combining Tiers for risk characterization.

A Tier 2 SRV risk characterization should always be conducted in combination with an evaluation of short-term hazard, if appropriate, and the safety risk posed by the contaminant conditions. See Sections 3 "Short-term Hazard Evaluation" and 4 "Consideration of Safety Risk".

Like Tier 1, Tier 2 SRVs were derived in consideration of potential direct soil contact exposures (incidental ingestion, dermal contact and inhalation of resuspended particulates) and considering the potential for contaminants to volatilize from soil into outdoor air (inhalation of vapors). The remainder of this section focuses on the differences between Tier 1 SRVs and Tier 2 SRVs, which are related to the derivation and values of the criteria used to characterize risk. A Tier 2 SRV risk characterization includes the steps outlined in Section 6.1 for Tier 1 with the additional steps.

- Determination of the extent of contamination. See Section 5 for further discussion regarding characterization of contaminant pattern;
- Identification of exposure and property use on the site and the surrounding area. See Section 7.0 and the Draft Guidelines for Incorporation of Planned Property Use into Site Decisions (August 25, 1997);
- Identification of site specific soil characteristics affecting environmental fate and transport for volatile contaminants; and
- If appropriate, determination of background concentrations.

The scope and level of effort of the risk characterization will depend upon the complexity of the site and the response action being taken.

7.2 Modification of Tier 2 Defaults

7.2.1 Modification of Tier 2 Exposure Defaults

In developing the Tier 2 generic SRVs, standard exposure scenarios were developed for the residential, recreational and industrial property use categories. The standard exposure scenarios are based on reasonable maximum exposure (RME) activities. These activities may not be presently occurring but their occurrence is consistent with the current or planned property use. For example, the standard exposure scenario for industrial property use includes limited outdoor as well as indoor work activities. Likewise, the standard exposure scenario for recreational property use includes exposure to soil in play areas. The standard scenarios

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should be reasonably conservative for most sites and allow for relatively unlimited use within the designated property use category. If the standard exposure scenario is not applicable to the site under consideration a site-specific (Tier 3) RME scenario must be evaluated. Input from the local community is strongly recommended in developing site-specific exposure scenarios. Typically modification to exposure factor defaults will not be allowed under Tier 2 but will be considered under Tier 3.

7.2.2 Modification of Tier 2 Volatilization Factor Model Defaults

In developing the generic SRVs for volatile contaminants, the SRS developed default inputs into the volatilization factor model to ensure that the SRVs represent an acceptable risk level at sites to which they are applicable. Tier 2 model defaults are the same as for Tier 1. Other than soil concentration value, the air-filled porosity is the most significant soil parameter affecting the flux of VOCs from soil. Air-filled porosity is based on soil density measurements and soil moisture. For any given site, investigations may reveal that the volatilization factor model defaults overestimate (or underestimate) potential risks. Under Tier 2, site-specific information may be used to demonstrate and document that a concentration of contaminant which is different than the default-based SRV does not pose an unacceptable risk. Such a concentration would be used in the risk characterization process as the site-specific Tier 2 SRV. For further discussion of the VF model see Appendix 1. Direct environmental monitoring may also be employed in lieu of modeling provided that the monitoring is conducted under conditions that would maximize volatilization.

7.3 Comparing Site Contaminant Concentrations to Background Levels

It should be assumed that a detected contaminant is present above background concentrations unless it can be otherwise demonstrated. Determination of whether site conditions are consistent with background can be reliably made with appropriate statistical techniques provided adequate quality data is available. The sampling design and number of samples necessary to compare the site contaminants to background levels are determined by the distribution of contaminants, the variation in contaminant levels at the study and background sites, and the statistical methodology used for comparison. In order to eliminate or minimize bias from the site to background comparison a valid sampling design and appropriate test statistic should be used. See Section 5.2.4 “Background” for additional discussion.

Summary or descriptive statistics for both site and background samples should be provided in a table. The data used to calculate the statistics should be clearly referenced and available. The table should provide the descriptive statistics for the site and background levels of each contaminant. See Section 5.1.3 “Data Presentation” for additional discussion of descriptive statistics.

There are numerous statistical methods that could be used for comparing site and background contamination levels. These methods can be generally divided into two categories (parametric and nonparametric), and selection of the appropriate method depends on the distribution of the contaminant data. It may not always be necessary to conduct a statistical test of site data and background data. If the median and maximum values for the site data set are equal to or less than the background median and maximum value, then it can be concluded that the site data are consistent with background. Conversely, if both the median and maximum values are greater than the corresponding values from the background data set, then it should be concluded that the site data are not consistent with background.

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Nonparametric tests have more relaxed assumptions than parametric tests but they tend to be less sensitive to differences between data sets than parametric tests. For this reason, parametric tests, when applicable, are preferred for comparing site and background data. Nonparametric tests (e.g., Wilcoxon Rank Sum Test or Kruskal-Wallis Test) can be used effectively and may be appropriate in some cases for comparison of site data to background levels.

One of the assumptions of many parametric tests is that the data are normally distributed. There are several tests to assess whether data are normally distributed, all of which need ten samples or more to have much validity. If the data are not normally distributed, there are a number of transformations which could be used to achieve normally distributed data.

Every report using a statistical test for site contamination should contain a discussion of the power, confidence level and the minimum detectable relative difference between site and background contaminant levels.

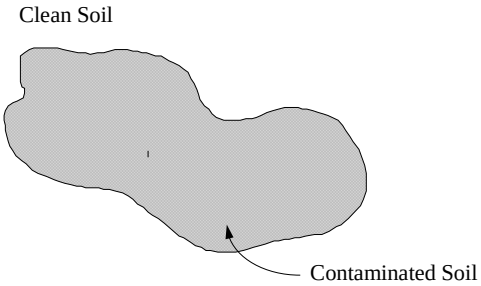
7.4 Identification of Exposure Areas and Exposure Concentrations

The area (or point) at which contact with the contaminant occurs is referred to as the exposure area (or exposure point). Chronic and subchronic exposure to soil typically occurs within an area rather than at a specific point. Note: acute soil exposures may occur at a specific point.

Typically an exposure area can not be accurately defined, particularly when evaluating potential future exposure. To determine if exposure to an area of contamination poses a potential risk the contaminated area is evaluated as an exposure area. The following discussion addresses identification of chronic and subchronic exposure areas. In order to identify the soil exposure areas for a Tier 2 risk characterization the investigator must know the extent of contamination. Figures 7-1 through 7-3 describe situations which may arise when identifying soil exposure areas.

Tier 2 soil exposure areas encompass only continuous areas of contaminated soil and do not include clean soil. Thus, the boundary of an exposure area is no larger than the extent of the soil contamination at the site. Figure 7-1 illustrates that only the area of contamination would be considered the soil exposure area.

Figure 7-1



Hot spots are specifically identified as distinct exposure areas. The identification of a “hot spot” is discussed in more detail in Section 4.1.1 and is defined as a discrete area with substantially higher contamination relative to the surrounding area. If a hot spot exists within a larger area of contamination, there would be at least two exposure areas identified: the larger area of more generalized contamination and the hot spot. See Figure 7-2 for illustration.

Figure 7-2

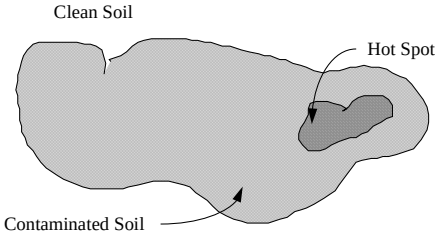


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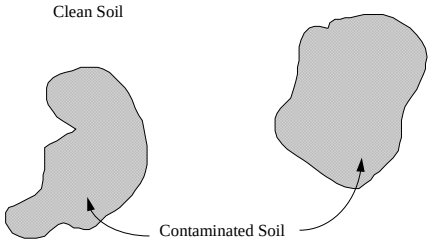
Figure 7-3



If the area of contamination is not contiguous, then discrete areas of contaminated soil which exists at the site are treated as a separate exposure area. Figure 7-3 illustrates this point.

It is important to remember that the exposure areas exists in three dimensions. Figures 7-1 through 7-3 present exposure areas in two dimensions for simplicity, but there is a depth component as well. For example, a volume of contaminated soil five feet below the ground surface would be considered an exposure area, and that exposure area would not include the uncontaminated soil on the surface. Hot spots and disconnected contamination would be considered in the same manner in three dimensions as they were described above for two dimensions.

Soil at depth is considered an exposure area due to the potential for future excavation and contact. Such potential future exposure is part of the Tier 2 risk characterization, the assessor cannot eliminate this exposure pathway (i.e., determine that such exposure would never occur, and that the soil at depth does not constitute an exposure area).

The exposure concentrations for soil are representative concentrations for the contaminant within each exposure area. Theoretically, the exposure concentration should be the arithmetic average of the contaminant concentration, although consideration should be given to using the maximum concentration reported or an upper percentile of the range of concentrations reported when the site data may not be adequate, when evaluating acute exposures or when evaluating chemicals associated with lethal or severe health effects. Since the exposure area is defined such that it excludes uncontaminated soil, analytical results from "clean" areas of the site should not be incorporated into the exposure concentration estimation.

EPA has issued specific guidance regarding calculation of the exposure concentration term (EPA Office of Solid Waste and Emergency Response (OSWER) Memo, Publication 9285.708I, May 1992). For assessment of contaminated sites, the exposure concentration is an estimate of the arithmetic average concentration for the contaminant based on a set of discrete site samples. Note, composite sampling results can not be evaluated with statistical methods, results from discrete samples must be utilized.

The average concentration is the most representative of the concentration that would be contacted over time. Because of the uncertainty associated with estimating the true average concentration the 95 percent upper confidence limit (UCL) of the arithmetic mean should be evaluated. The 95 percent UCL of a mean is defined as a value that, when calculated repeatedly for randomly drawn subsets of the site data, equals or exceeds the true mean 95 percent of the time. Although 95 percent UCL of the mean provides a conservative estimate of the average (or mean) concentration, it should not be confused with the 95th percentile of site concentration data. Sampling data from sites have shown that data sets with fewer than 10 samples per exposure area provide poor estimates of mean concentration (i.e., there is a large difference between the sample mean and the 95 percent UCL), while datasets with 10 to 20 samples per exposure area provide somewhat better estimates of the mean, and data sets with 20 to 30 samples provide fairly consistent estimates of the mean (i.e., the 95 percent UCL is close to the sample mean). The 95 percent UCL accounts for uncertainties due to limited sampling. As sampling data become less limited at a site, uncertainties decrease, the UCL moves closer to the true mean, and the exposure evaluations using either the mean or UCL of the mean produce similar effects.

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In the absence of specific information regarding activity patterns the average concentration contacted over time would equal the spatially averaged concentration over the exposure area assuming a fairly random pattern of activity. It is unlikely that an individual will actually exhibit a truly random pattern of movement across an exposure area, however, in the absence of pattern information the assumption of equal time spent in different parts of the exposure area is a reasonable but simple approach. For exposure areas with limited amounts of data or extreme variability in measured or modeled data, the UCL can be greater than the highest measured or modeled concentration. In these cases, additional sampling should be conducted. If additional data cannot be obtained, the highest measured or modeled value should be evaluated as the potential concentration term. The uncertainties associated with utilization of this value should be discussed in detail in the uncertainty section of the risk characterization.

It is not uncommon for data sets to include a number of samples reported to be below the detection limit. See Section 5.1.2.2 "Analytical Methods and Detection Limits" regarding evaluation of detection limits. Non-detect results generally result from one of two site situations. First, if the contaminant is truly not present at the site (virtually all the samples are reported as non-detect), and there is no history of a release of that contaminant. In this case the assessor may conclude that the contaminant should be dropped from the risk characterization. Second, if the contaminant is reported at the site ranging from below the detection limit to some detected site maximum, the assessor may conclude that the non-detect values actually represent a range of values from zero to the detection limit. The non-detect results contribute useful information about the contaminant at the site and should be incorporated into the risk characterization.

There is a third possible site situation which result in non-detect values. The spatial pattern of detected and non-detect results may indicate that contamination is localized to specific areas. This would represent a combination of the first and second situations presented above.

A variety of methods exist for dealing with values below the detection limit. If no more than 30 to 40 percent of the values are censored (i.e., below the detection limit) a simple straightforward approach may be utilized to estimate exposure concentrations. This simple approach utilizes one-half the sample quantitation limit (SQL) to be the sample contaminant concentration. The SQL is the actual quantitation limit for each analysis, and it accounts for sample dilution that may occur. If only the Method Detection Limit is reported, and if the sample is heavily contaminated with any constituent, the assessor should attempt to determine whether the sample was diluted. For samples that have been diluted (a factor of 10 is not unusual), the assessor could substantially underestimate the concentration by using the Method Detection Limit or the Practical Quantitation Limit as a basis for the estimate.

The benefits of the simple one-half the detection limit approach must be weighed against the bias which is introduced in the resulting exposure estimate. It is up to the assessor to judge the level of sophistication appropriate to the data set. If more than 50 percent of the data set values are censored parametric methods will need to be utilized.

If changes in contaminant distribution are anticipated, the extent of contamination under future environmental conditions may have to be evaluated in addition to present conditions. Future concentrations cannot be measured and must be modeled. Modeling will be discussed in somewhat greater detail in Section 8.

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Although biodegradation may be an important attenuation mechanism at some sites, predicting degradation rates that will actually occur in the field at a specific site is difficult. The application of degradation rates observed under controlled laboratory conditions to field conditions can lead to significant underestimation of future concentrations. The assumption, in the absence of site-specific data, that the concentrations will be decreased at a certain rate by biodegradation is discouraged for risk assessment purposes.

7.5 Tier 2 Soil Reference Value (SRV) Risk Characterization

The process for a Tier 2 SRV risk characterization in general follows Tier 1 risk characterization. The documentation for a Tier 2 risk characterization must include:

- Identify nature and extent of site-related contamination;
- Identify the site and surrounding property activities and planned uses to determine potential exposure;
- Identify exposure pathways;
- Affirm applicability of Tier 2 SRV criteria;
- Determine contaminant concentrations and spatial distributions for use in identifying exposure areas (including hot spots) and exposure concentrations;
- Compare the exposure concentrations to applicable Tier 2 criteria;
- Clearly state conclusions of the risk characterization (including short-term hazards and safety risks);

Having determined the Tier 2 SRVs applicable to the site and the site exposure concentrations, the risk characterization consists of simply comparing the site exposure concentrations to the applicable Tier 2 SRVs to estimate potential site risks. A condition of acceptable risk of harm to health resulting from direct contact with soil exists if the estimated site risks do not exceed the target risk limits (including cumulative site risk limits). The report which documents the risk characterization should include cumulative site risk evaluation tables ordered by exposure area.

7.6 Characterizing Safety Risks

The Tier 2 risk characterization process does not specifically look at potential safety risks posed by the site, as safety is a concept which is difficult to distill down to a set of generic standards. As a result, the safety risk must be evaluated separately at sites. Section 4.0 of this guidance document discusses the evaluation of safety concerns. The characterization of site safety risk would be included as part of the overall documentation of the risk characterization.

7.7 Conclusions of a Tier 2 SRV Risk Characterization

The overall purpose of the risk characterization is to determine whether the site poses an acceptable risk of harm to health from contact with contaminated soil. A clear statement of the results in the documentation of the Tier 2 risk characterization is required.

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Sites where risks associated with site exposure concentrations fall below the target risk limits (and where there is no safety risk) may not require remedial response action. Depending on the location and concentration of the residual contamination, potential exposure and the planned property use category selected, institutional controls may be recommended. Refer to the Draft Guidance on Incorporation of Planned Property Use into Site Decisions (August 25, 1997) for further guidance.

It is important to remember that achieving a condition of acceptable risk from direct contact with soil is not the only requirement. Additional remedial actions may be required for the elimination of impacts to ground water, surface water, indirect exposure pathways (e.g., foodchain impacts, vapor migration into buildings) and ecological impacts.

If one or more site contaminant concentrations result in an exceedence of the target risk limits a condition of Acceptable Risk has not been achieved, and response actions are recommended, although implementing a remedial response action is not the only course of action available. A more site-specific risk characterization approach (Tier 3) may be employed to further evaluate the site. For some sites where a Tier 2 risk characterization has indicated that a condition of Acceptable Risk has not been achieved, the Tier 3 evaluation might demonstrate that, in fact, a level of Acceptable Risk does exist. (Of course the more detailed evaluation could also reach the same conclusions as the Tier 2 assessment, but at significantly greater cost.) Guidance for conducting a Tier 3 risk characterization is contained in Section 8 of this document.

Another option available is to conduct a remedial response action designed to reduce the concentrations of the contaminants to levels which would meet the acceptable target risk limits. A third approach would be to combine the above approach (i.e., reduction of concentration) with institutional controls. Refer to the Draft Guidance for Incorporation of Planned Property Use into Site Decisions (August 25, 1997) and the Draft Guidance for Remedy Selection for additional guidance on institutional controls and remedy selection. If institutional controls (including engineering controls, monitoring and maintenance) are utilized to limit or interrupt exposure an evaluation of the potential for the control to fail should be considered. The magnitude of the potential risk posed as a result of control failure should be evaluated and considered in the remedial response action decision.

7.8 Uncertainty Analysis

The documentation of the Tier 2 SRV risk characterization should contain a discussion of the possible sources of uncertainty present in the site assessment and risk characterization process which could have an affect on the conclusions of the assessment. To the extent that it is known, the uncertainty discussion should describe whether the uncertainty is due to incomplete knowledge of the site (e.g., unidentified areas of contamination, unknown property use or activities), incomplete data from the scientific literature or other information source (e.g., lack of toxicity information) or from the effects of natural, unquantified variability (e.g., natural fluctuation of the soil moisture content). The discussion should also indicate whether or not the uncertainty has a biased impact on the risk characterization results (e.g., lead to an over- or under-estimation of risk) and, if possible, the magnitude of the effect.

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Tier 2 Attachment - Tier 2 SRV Risk Characterization Documentation Framework

The following framework is presented to assist in determining whether the Tier 2 Risk Characterization documentation adequately addresses the fundamental points of this approach. The Framework for Tier 1 (See Section 6) identified seven subject areas that should be addressed in a Tier 1 Risk Characterization for completeness. These topics are equally applicable to a Tier 2 Risk Characterization. When checking a Tier 2 Risk Characterization for completeness the first step should be to apply the criteria set forth in the Tier 1 Framework. The Tier 1 Framework criteria included:

1. Adequate Site Characterization
2. Short-term Hazard Evaluation
3. Evaluation of Safety Risk
4. Appropriateness of the Use of Tier 1 SRVs
5. Exposure Concentrations
6. Identification of Tier 1 SRVs
7. Conclusions

These criteria are identified and discussed in the Framework for Tier 1 and therefore are only summarized here. In addition to the Tier 1 Framework there are particular criteria which must be addressed when Tier 2 is used. These topics are identified and discussed briefly below. It is important to remember that this outline has been prepared as a simple guide to determine whether a report has addressed the major points of a Tier 2 Risk Characterization. It does not substitute for a thorough knowledge of current risk assessment methodologies or regulatory requirements.

1. Adequate Site Characterization

The criteria identified in the Tier 1 Framework should be expanded to include determining the horizontal and vertical extent of the release.

2. Site Activities & Uses

* Have all planned property uses and potential exposure scenarios been considered and evaluated at the site?

NOTE: The categorization of property use is based upon the site and surrounding property uses and activities. In determining the appropriate use category you must consider: the type of receptor present (children vs. adults only), the frequency of use of the site, the intensity of the activities occurring on the site and the surrounding properties, and the accessibility of the contamination.

<u>For additional information please see:</u>
See Section 7 and Working Draft Guidance on Incorporation of Planned Property Use into Site Decisions.

3. Background Concentrations

* Has the assessment identified "background levels" of contaminants?
* Have the levels been accurately established and documented in the report?

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* Were background samples collected in areas separate from this release or any other release?
* Was the comparison between site data and background concentrations conducted appropriately?

For additional information please see:
See Sections 5.2.4 "Background" and 7.3 "Comparing Site Contaminant Concentrations to Background Levels".

4. Modification of Tier 2 Default Values

* Were the modifications to the volatilization factor model default values based upon adequate site data?

For additional discussion please see:
See Section 6.5 "Application of Tier 1 SRVs" and 7.2 "Modification of Tier 2 Defaults" as well as Appendix 1.

5. Exposure Concentrations

The criteria identified in the Tier 1 Framework for exposure concentration determination should be expanded to include:

* Were non-detect values dealt with appropriately in the report?

For additional discussion please see:
See Section 7.4 "Identification of Exposure Areas and Exposure Concentrations".

6. Conclusions

The criteria identified in the Tier 1 Framework for conclusions should be expanded to include:

* Does the report state whether there is a need for institutional controls to maintain an acceptable risk condition at the site (e.g., risk based on exposure an adult worker and industrial property use)?

For additional information please see:
See Sections 7.7 "Conclusions of a Tier 2 SRV Risk Characterization", Section 7.8 "Uncertainty Analysis" and the Working Draft Guidance on Incorporation of Planned Property Use into Site Decisions.

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8.0 TIER 3 (DETAILED SITE-SPECIFIC) RISK CHARACTERIZATION

This section provides guidance on conducting a Tier 3 SRV risk characterization. The SRV evaluation is just one of possibly several distinct assessments (e.g., soil leaching to ground water, ecological impacts) which may comprise a Tier 3 risk characterization. Tier 3 is indicated for unique and complex situations in which the SRVs derived from default assumptions are not applicable. A Tier 3 evaluation requires derivation of site-specific SRVs using the procedure outlined in Sections 8.1 - 8.5.

Site investigation of extent and magnitude, evaluation of COPCs, short-term hazard evaluation, safety risk evaluation, and determination of exposure concentrations in a Tier 3 risk characterization are conducted in a similar fashion as in a Tier 2 risk characterization.

Tier 3 human health-based soil risk characterization approach involves five steps: hazard identification, toxicity (dose-response) assessment, exposure assessment, risk characterization and uncertainty analysis. A brief discussion of each step is presented below. It is anticipated that the individual(s) performing the risk assessment is qualified to conduct a site-specific risk characterization and therefore in depth guidance is not required. It is also the responsibility of the risk assessor to obtain approval from MPCA/SRS staff prior to conducting the risk characterization.

Hazard Identification involves identification of contaminants of potential concern**.**

The **Toxicity (Dose-Response) Assessment** describes the relationship between the level of exposure and the likelihood and/or severity of an adverse effect, i.e., describes the toxicity potential of the contaminant.

The **Exposure Assessment** involves identifying potential routes of exposure; characterizing the populations exposed; and determining the frequency, duration and extent of exposure.

The **Risk Characterization** combines information from the previous three steps to describe the type (e.g., carcinogenic or non-carcinogenic) and magnitude of risks to exposed populations.

The **Uncertainty Analysis** identifies the nature and, when possible, the magnitude of the uncertainty and variability inherent in the characterization of risks. The results of any risk assessment reflect scientific uncertainty resulting from limitations in available data and assumptions that are made in the absence of such data, and the variability in exposure and toxicological response expected given the diversity within the human population. The assumptions and limitations which are a part of all risk characterizations should be explicitly discussed.

It is important to remember that risk estimates generated in the risk assessment are not measures of actual or absolute risks. Rather, risk assessments are a tool - a method of providing valuable information regarding potential risks to public health

The MPCA/SRS have determined following Acceptable Risk limits:

1) a cumulative site excess lifetime cancer risk of one in 100,000 (i.e., 1E-5) for chronic exposure and one in 1,000,000 (i.e., 1E-6) for subchronic exposure where higher exposures occur during a shorter exposure period, regardless of the number of carcinogenic contaminants or exposure routes that exist at a site; and

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2) a chronic noncarcinogenic risk (hazard quotient, HQ) of 0.2 for individual contaminant. A subchronic and acute noncarcinogenic HQ of 1 for individual contaminants. A cumulative site noncarcinogenic risk (hazard index, HI) of 1 for multiple contaminants with similar target endpoints. The cumulative target risk level (HI = 1) is the same for chronic, subchronic and acute exposures.

Under Tier 3 soil evaluation, remediation of the site is required if the estimated cancer or non-cancer risks associated with exposure to contaminants exceed the Acceptable Risk Limits. Remedial alternatives must be evaluated to determine if they attain an Acceptable Risk condition.

8.1 Hazard Identification

The Hazard Identification portion of Tier 3 risk characterization identifies the Contaminants of Potential Concern (COPCs). The Hazard Identification section of the risk characterization report should contain: an identification of the COPCs and a summary of the analytical data which have been collected, presented by specific environmental medium. See Sections 5.2, 6.2.1 and 7.3 for a detailed discussion.

8.2 Toxicity (Dose Response) Assessment

The dose-response assessment describes the observed or potential toxic effects in humans and/or laboratory animals associated with particular exposures (or doses) of the chemical of concern. This information is obtained from published literature describing epidemiologic or toxicologic studies involving the particular chemical. For most chemicals reported at sites, the dose-response information needed to conduct a risk characterization may be found in secondary sources published by the USEPA or other government agencies, as summarized below.

The dose-response relationship(s) for each COPC must be identified in the risk characterization report. This information is later coupled with knowledge of the nature and magnitude of potential exposures to characterize risk.

The dose-response information provides:

- Toxicity information associated with noncarcinogenic (toxicity threshold) health effects.
- Toxicity information concerning carcinogenicity, either from human epidemiologic data or from laboratory studies.

All COPCs should be evaluated for potential noncarcinogenic health effects. In addition, any COPC considered to be a known, probable or possible carcinogen should also be evaluated for its potential carcinogenic effect.

8.2.1 Noncarcinogenic (Toxicity Threshold) Effects

For noncarcinogenic health effects, it is believed that a dose (or exposure) level exists at and below which no adverse health effects would be expected. Such a level is referred to as a *toxicity* ***threshold dose***. In theory, the threshold dose would be safe for all receptors who might be exposed at that level.

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The goal of the dose-response assessment is to identify the toxicity threshold dose, or a close approximation, given the toxicological information currently available. It may be impossible, however, to specify this theoretical threshold dose for a given chemical due to the inadequacy of the scientific data. It is possible to approximate this threshold dose in a health-protective manner that accounts for the data limitations by identifying a *sub-threshold* dose: such a value is typically derived from the ***No Observable Adverse Effects Level*** (NOAEL) of an animal study by application of uncertainty factors (UF) and a modifying factor (MF) (EPA, Integrated Risk Information System (IRIS), 1998). Uncertainty Factors are applied to account for interspecies variation, exposure duration and protection of sensitive populations. Additional Uncertainty Factors may be applied if the toxicological study identified a ***Lowest Observable Adverse Effects Level***, or LOAEL, rather than a NOAEL. Each Uncertainty Factor is typically equal to a factor of one to ten, and the product of all the Uncertainty Factors may be as high as 10,000 (10 x 10 x 10 x 10). A Modifying Factor may be applied to reflect additional uncertainties in the critical study and the entire data base not addressed by the Uncertainty Factor. The value of the Modifying Factor is greater than zero and less than or equal to ten; the default value for the Modifying Factor is one. Important factors to consider when identifying and using such a sub-threshold dose include, at a minimum:

- the route of administration from the study (inhalation, oral, dermal contact, etc.);
- the duration of exposure (lifetime, chronic, subchronic, or acute exposure);
- the absorption efficiency ; and
- the exposure population (age, sex, etc.).

The subthreshold dose, RfD (mg/kg/day) or RfC (mg/m^3), is an estimate of the daily exposure to the human population that is likely to be without appreciable risk of deleterious effects during the exposure period (Health Effects Assessment Summary Tables, July 1997). In the case of a subchronic RfD or RfC the period of exposure can be several weeks to several years whereas for a chronic RfD or RfC the period of exposure can be several years to a lifetime. The RfD (mg/kg-day) or RfC (mg/m^3) is derived by dividing the NOAEL or LOAEL by an uncertainty factor (UF) times a modifying factor (MF):

$$\text{RfD or RfC} = \frac{\text{NOAEL or LOAEL}}{\text{UF and / or MF}}$$

There are a number of different sources of subthreshold toxicity values. When selecting toxicity information for use in quantitative risk assessment, the risk assessor should ensure that the information is appropriate for the assessment being conducted and that it is up-to-date. The following presents a list of sources of toxicity information in the order of preference:

1) **Minnesota Department of Health (MDH) Toxicity Values -** The Minnesota Department of Health develops chronic and subchronic health risk limits and health risk values for chemicals. Many are IRIS values which after review are adopted unchanged. However, occasionally values are derived from available toxicity information. These values are based on available toxicological data and standard USEPA approaches for developing reference doses for threshold effects.

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2) **Integrated Risk Information System (IRIS) -** IRIS is an USEPA data base that contains only those chronic RfDs/RfCs which represent a consensus judgment of USEPA RfD/RfC Workgroup which is composed of scientists from various EPA offices and the Office of Research and Development. It is the preferred source of toxicity information. An updated IRIS database is maintained at the EPA website, www.epa.gov/ngispgm3/iris. For more information on how to access IRIS, call IRIS user support at (513) 569-7254.

3) **Health Effects Assessment Summary Tables (HEAST) -** HEAST is prepared by USEPA's Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, OH. HEAST contains subchronic RfDs/RfCs and *provisional* chronic RfDs/RfCs. These chronic values have undergone review by individual USEPA program offices, but are not recognized as agency-wide consensus values. HEAST is scheduled to be updated annually and can be obtained by contacting the National Technical Information Services (NTIS) Subscriptions Department at (703) 487-4630.

4) **National Center for Environmental Assessment (NCEA) Superfund Technical Support Center (STSC) -** NCEA prepares interim toxicity values in response to site specific requests. The support center staff can be contacted at (513) 569-7300.

5) Soil Screening Level Inhalation Benchmark Values - For a number of contaminants commonly found at Superfund sites, inhalation benchmark values are not available from IRIS or HEAST. Many of these contaminants exhibit systemic toxicity. The inhalation pathway tends to be the most significant exposure pathway for volatile contaminants. Risk estimates based only on the noninhalation pathways may not be protective for inhalation exposure, particularly for volatile contaminants. To address this concern EPA evaluated potential approaches for deriving inhalation benchmarks. In this evaluation EPA considered a number of issues concerning route-to-route extrapolation. See the Soil Screening Guidance: Technical Background Document, May 1996 for more discussion. As a result of this effort inhalation benchmarks were derived for 50 contaminants. The SSL inhalation benchmarks were utilized for contaminants without inhalation benchmarks when available.

6) **California Environmental Protection Agency (Cal/EPA) -** Cal/EPA produces a compilation of cancer potency factors developed or approved by the Cal/EPA Office of Environmental Health Hazard Assessment (OEHHA), the Department of Pesticide Regulation, and the Department of Toxic Substances Control.

7) **Agency for Toxic Substances Disease Registry (ATSDR) -** ATSDR produces Toxicological Profiles for 275 hazardous substances found at NPL sites. The priority list of hazardous substances is published in the Federal Register. An announcement of the release of Toxicological Profile documents appears in the Federal Register and the documents are available from the National Technical Information Service (NTIS) at (800) 553-6847 or (703) 487-4650.

If sufficient toxicity information exists ATSDR develops ***Minimal Risk Levels*** (MRLs) for threshold effects of some chemicals. These values are updated when the profiles are revised, if appropriate. An MRL is defined as an estimate of the daily human exposure to a substance that is likely to be free of appreciable risk of adverse noncarcinogenic effects over a specified duration of exposure.

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8) **Calculation of a dose-response value using toxicity information from the literature.** Dose-response values may be derived by a qualified risk assessor or toxicologist if none of the above sources provides a toxicity value, but adequate toxicity studies are available, *or* if more recent, credible and relevant data becomes available. USEPA approaches to development of RfDs are described in *Risk Assessment Guidance for Superfund* (USEPA, 1989) and in Appendix A to IRIS. Approaches to the development of RfCs are described in *Interim Methods for Development of Inhalation Reference Doses* (USEPA, 1990, EPA/600/8-88/066F). The review and approval of such a proposed value would depend upon the justification and documentation provided to support it. The development of an alternative value when a reference dose or reference concentration is available is rarely justifiable and the risk assessor should contact the MPCA/SRS staff early on in the site assessment process before proceeding.

8.2.2 Carcinogenic Effects

Unlike non-carcinogenic health effects, the dose-response assessment for carcinogens assumes that there is no toxicity threshold dose for carcinogenicity; that there is no dose of a carcinogenic substance that is not associated with increased risk. USEPA evaluates available toxicity data and, based on this evaluation, the chemical is assigned to a weight-of-evidence class. The system for characterizing the overall weight of evidence for a chemical's carcinogenicity developed by USEPA is based on the availability of animal, human, and other supportive data (USEPA, 1986). The weight-of-evidence classification rates the likelihood that an agent is a human carcinogen, and it may qualitatively affect the interpretation of potential health risks. In assessing the carcinogenic potential of a chemical, the Human Health Assessment Group (HHAG) of EPA classifies the chemical into one of the following groups, according to the weight of evidence (HEAST, 1997).

Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B - Probable Human Carcinogen (B1 - limited evidence in humans; B2 - sufficient evidence in animals with inadequate or lack of evidence in humans)

Group C - Possible Human Carcinogen (limited evidence in animals and inadequate or lack of evidence in humans)

Group D - Not Classifiable as to Human Carcinogenicity (inadequate or lack of evidence)

Group E - Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

The ability of a chemical to increase the incidence of cancer in a target population (i.e., the risk) is described by one of two measures: the cancer ***slope factor*** or the ***unit risk***. Cancer Slope Factors or Unit Risks are typically calculated for chemicals in Groups A, B1 and B2. Slope factors for chemicals in Group C are calculated on a case-by-case basis.

EPA has proposed replacing the above six alphanumeric categories with three descriptor categories (i.e., "known/likely", "cannot be determined", and "not likely"). These suggested categories have not been formally adopted (USEPA, Proposed Guidelines for Carcinogen Risk Assessment. April 1996. EPA/600/P-92/003C).

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The carcinogenic potential is estimated through the use of mathematical extrapolation models, commonly the linearized multistage model, the largest possible linear slope (within the 95% Confidence Limit) consistent with the available data is estimated at low extrapolated doses. For some chemicals, human epidemiologic data are the basis of an estimate of the carcinogenic potency, although the most common basis of these values is an animal study. The potential risk characterized as an upper-bound estimate, i.e., the true risk to humans, while not known, is not likely to exceed the upper-bound estimate and may actually be lower.

The cancer Slope Factor (CSF) is expressed as a plausible upper-bound estimate of the probability of the risk per unit dose, and is typically given in units of $(mg/kg/day)^{-1}$. Use of the slope factor assumes that the calculated dose received is expressed as a lifetime average.

The Unit Risk (UR) is the upper 95% Confidence Limit of the mean incremental lifetime cancer risk estimated to result from lifetime exposure to an agent if it is in the air at a concentration of 1 $\mu g/m^3$ or in the drinking water at a concentration of 1 $\mu g/L$. These values are used in lieu of the chemical's slope factor when an estimate of a lifetime average media concentration of the chemical is available.

There are a number of different sources of carcinogenic potency information. When selecting toxicity information for use in quantitative risk assessment, the risk assessor should ensure that the information is appropriate for the assessment being conducted and that it is up-to-date. The list of sources of cancer potency information are the same as those provided for noncarcinogenic toxicity information.

8.2.3 Toxicity Profiles - - Presentation of Toxicity Information

The presentation of toxicity information, i.e., a toxicity profile, serve several purposes:

1) provide a summary of the potential adverse human health effects which may be associated with exposure to a particular contaminant;
2) contain references for the dose-response assessment;
3) provide information used to group chemicals by health endpoint and mechanism of toxicity in order to estimate cumulative noncancer risk (i.e., target endpoint specific Hazard Indices); and
4) serve as reference material for non-toxicologists who are involved with or interested in activities at the site and who want to understand the potential health impacts associated with contaminants at the site.

The scope and level of detail of a Toxicity Profile will vary depending upon the nature and quantity of information available for a particular chemical. For example, if the toxicological information used is the same as the information utilized by the MPCA/SRS in generating Tier 1 or 2 SRVs, only a short descriptive summary table is needed.

For the noncancer (toxicity threshold) effects, separate tables should be presented for chronic and subchronic effects. Information that should be presented in the table includes:

- Contaminant Name and CAS Number;
- Toxicity value;
- Source of toxicity value (i.e. IRIS, HEAST), including date;
- Study Type - how the chemical was administered, animal species, duration, etc.;

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- Confidence Level - identified by USEPA;
- Critical Effect - target organ(s) and toxic effect(s) on which the dose-response value is based; and
- Uncertainty of modifying factors - factors listed by agency generating the toxicity value.

For carcinogenic (nonthreshold) effects, the information that should be presented in the table includes:

- Contaminant Name and CAS Number;
- Potency Value or Unit Risk;
- Source of toxicity value (i.e. IRIS, HEAST), including date;
- Study Type - how the chemical was administered, animal species, duration, etc.;
- Weight of Evidence - USEPA weight of evidence classification; and
- Cancer type - tumor type listed by the agency establishing the toxicity value.

If a dose-response value was derived a more detailed Toxicity Profile is required. The Toxicity Profile should contain a comprehensive profile of the toxicokinetics, human and animal mechanisms of toxicity, genotoxicity, carcinogenicity, and developmental/reproductive toxicity. Structure Activity relationships and interaction with other chemicals should also be discussed as appropriate. In preparing the Toxicity Profile, only credible, peer-reviewed sources of information such as controlled, epidemiologic investigations, clinical trials, experimental animal studies, metabolic and pharmacokinetic experiments, *in vitro* studies and structure-activity studies should be considered. All references should be provided to document the sources of information used to prepare the Toxicity Profile.

8.2.4 Groups of Chemicals

The discussion in this section has focused on the toxicity information available for specific chemicals. There are several groups of closely related compounds for which alternative approaches to the identification of dose-response values have been proposed. These groups include:

- Chlorinated Dioxins and Furans
- Polycyclic Aromatic Hydrocarbons (PAHs)
- Polychlorinated Biphenyls (PCBs)
- Total Petroleum Hydrocarbons (TPH)

8.2.4.1 Chlorinated Dioxins and Furans and Dioxin-like Polychlorinated Biphenyls (PCBs)

The polychlorinated dibenzo-p-dioxins (PCDDs) include 75 individual compounds, and the polychlorinated dibenzofurans (PCDFs) include 135 individual compounds. These individual compounds are technically referred to as congeners. Only 7 of the 75 congeners of PCDDs are thought to have dioxin-like toxicity; these are ones with chlorine substitutions in, at least, the 2,3,7, and 8 positions. Only 10 of the 135 possible congeners of PCDFs are thought to have dioxin-like toxicity; these also are ones with substitutions in the 2,3,7, and 8 positions. There are 209 PCB congeners, of which only 13 are thought to have dioxin-like toxicity. These are PCBs with 4 or more chlorines with just 1 or no substitutions in

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the ortho position. These 30 dioxin-like compounds are often found in complex mixtures. For risk assessment purposes, a toxicity equivalency procedure was developed to describe the cumulative toxicity of these mixtures. This procedure involves assigning individual toxicity equivalency factors (TEFs) to the PCDD, PCDF and PCB congeners. These TEF values have had international endorsement (EPA/625/3-89/016, March 1989; Ahlborg, et al., Chemosphere 28(6), 1994; EPA website: www.epa.gov/ncea/dchem.htm). 2,3,7,8-TCDD is assigned a TEF of 1. All other congeners have lower TEF values ranging from 0.5 to 0.00001. Recently the World Health Organization (WHO) revised the international TEFs. A list of current WHO TEFs is presented in Table 8.1. Calculating the toxic equivalency (TEQ) of a mixture involves multiplying the concentration of individual congeners by their respective TEF. The sum of the TEQ concentrations for the individual congeners is the TEQ concentration for the mixture. The Tier 1 and Tier 2 Excel files contain a TEQ calculation worksheet to facilitate these calculations.

Table 8.1 Toxicity Equivalency Factors (TEFs) for Chlorinated Dioxins/Furans and Dioxin-Like PCBs

Compound	TEF
DIOXINS:	
2,3,7,8-Tetrachlorinated dibenzo-p-dioxin	1
1,2,3,7,8-Pentachlorinated dibenzo-p-dioxins	1
1,2,3,4,7,8-Hexachlorinated dibenzo-p-dioxins	0.1
1,2,3,6,7,8-Hexachlorinated dibenzo-p-dioxins	0.1
1,2,3,7,8,9-Hexachlorinated dibenzo-p-dioxins	0.1
1,2,3,4,6,7,8-Heptachlorinated dibenzo-p-dioxins	0.01
1,2,3,4,6,7,8-Octachlorinated dibenzo-p-dioxin	0.0001
FURANS:	
2,3,7,8-Tetrachlorinated dibenzofuran	0.1
1,2,3,7,8-Pentachlorinated dibenzofurans	0.05
2,3,4,7,8-Pentachlorinated dibenzofurans	0.5
1,2,3,4,7,8-Hexachlorinated dibenzofurans	0.1
1,2,3,6,7,8-Hexachlorinated dibenzofurans	0.1
1,2,3,7,8,9-Hexachlorinated dibenzofurans	0.1
2,3,4,6,7,8-Hexachlorinated dibenzofurans	0.1
1,2,3,4,6,7,8-Heptachlorinated dibenzofurans	0.01
1,2,3,4,7,8,9-Heptachlorinated dibenzofurans	0.01
1,2,3,4,6,7,8,9-Octachlorinated dibenzofurans	0.0001
PCBs:	
3,3',4,4'-TeCB (PCB 77)	0.0001
3,4,4',5 – TeCB (PCB 81)	0.0001
2,3,3',4,4'-PeCB (PCB 105)	0.0001
2,3,4,4',5-PeCB (PCB 114)	0.0005
2,3',4,4',5-PeCB (PCB 118)	0.0001
2',3,4,4',5-PeCB (PCB 123)	0.0001
3,3,'4,4',5-PeCB (PCB 126)	0.1
2,3,3',4,4',5-HxCB (PCB 156)	0.0005
2,3,3',4,4',5'-HxCB (PCB 157)	0.0005
2,3',4,4',5,5'-HxCB (PCB 167)	0.00001
3,3',4,4',5,5'-HxCB (PCB 169)	0.01
2,3,3',4,4',5,5'-HpCB (PCB 189)	0.0001

Source: M. Van der Berg, et al., Toxic Equivalency Factors (TEFs) for PCBs, PCDD, PCDFs for Humans and Wildlife. Env. Health Perspectives 106(12)755-792, 1998.

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8.2.4.2 Polycylic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are a class of structurally similar chemical compounds characterized by the presence of fused aromatic rings. PAHs are typically formed during the incomplete burning of organic material including coal, oil, gasoline and garbage. PAHs are also found in crude oil, coal tar, creosote and asphalt. PAHs are associated with human activities (the combustion of fossil fuels) and natural occurrences (such as forest fires), and they are considered to be ubiquitous in the environment at some level.

PAHs are often discussed as a group because they are commonly found as mixtures in the environment. It should be noted that, while PAHs are often discussed as a group, the individual chemicals are evaluated as separate chemicals in the risk characterization. There are over 100 chemicals in this family of compounds, although only a smaller number are routinely analyzed for and reported at sites. ***The PAHs which are often present at sites but are unreported may result in the underestimation of potential risks.***

Among the polycyclic aromatic hydrocarbons, the USEPA has classified seven chemicals as *probable (B2) human carcinogens*. The seven include: benzo[a]pyrene (BaP), benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene. PAHs which are considered unclassified may also contribute to carcinogenic risk (Nisbet and LaGoy, 1992).

The only cancer slope factor (CSF) published for cPAHs is for benzo[a]pyrene (B[a]P). In 1993, USEPA formally adopted provisional guidance for estimating cancer risks associated with polycyclic aromatics hydrocarbons (USEPA, EPA/600/R-93/089, July, 1993). The procedure uses information from the scientific literature to estimate the carcinogenic potency of several PAHs relative to benzo[a]pyrene. These **relative potencies** have been used to calculate B[a]P-equivalent concentrations for each of the PAHs (which would then be used with the B[a]P slope factor). This approach is similar to that used for the evaluation of dioxin-like compounds. A list of the USEPA relative potency values are presented in Table 8.2 for use in risk characterization. The Tier 1 and Tier 2 Excel files contain a B[a]P -equivalent calculation worksheet to facilitate these calculations. Relative potency values for additional carcinogenic PAHs (California EPA, 1994) are currently being evaluated.

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Table 8.2 Relative Potency Values for Individual Carcinogenic PAHs

Compound	Relative Potency
Benzo[a]pyrene	**1.0**
Benz[a]anthracene	**0.1**
Benzo[b]fluoranthene	**0.1**
Benzo[k]fluoranthene	**0.01**
Chrysene	**0.001**
Dibenz[a,h]anthracene	**1.0**
Indeno[1,2,3-cd]pyrene	**0.1**

Source: EPA Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons (EPA/600/R-93/089, July 1993).

Carcinogenic PAHs also exhibit dermal toxicity. EPA has stated that it is inappropriate to use the oral slope factor to evaluate the risks associated with dermal exposure to carcinogens which cause skin cancer through direct action at the point of application. This does not mean that the potential for systemic effects following dermal exposures need not be assessed. It is important to include the potential for systemic effects that may result after dermal exposure. Ideally since it is well established that PAHs cause point of contact tumors the dermal toxicity resulting from dermal exposure to PAHs should also be evaluated. In order to quantify the risk of dermal toxicity associated with dermal exposure to PAHs a dermal cancer slope factor would be required. However, a dermal cancer slope factor for benzo(a)pyrene, or any other PAH, has not been derived. Therefore, it is not currently possible to quantitatively evaluate dermal toxicity associated with dermal exposure to PAHs. ***The inability to include dermal toxicity may result in the <u>underestimation</u> of potential risks.***

8.2.4.3 Polychlorinated Biphenyls (PCBs).

Polychlorinated biphenyls (PCBs) is the name given to the general class of compounds in which one or more chlorine atoms are bonded to a biphenyl structure. The PCB family is comprised of 209 different variants, or **congeners**, depending upon the number of chlorine atoms present and their position on the biphenyl structure. PCBs may also be described according to *isomeric groups*, which are families of PCBs having the same number of chlorine atoms and thus the same molecular weight. For example, 2,2'-Dichlorobiphenyl is one of 209 chlorinated biphenyl congeners and one of 12 possible dichlorobiphenyls; these 12 dichlorobiphenyls are considered **isomers** of each other.

PCBs are typically found in the environment as mixtures of different PCB congeners. These mixtures (also known as ***Aroclors***, a trade name of the Monsanto Corporation) are identified by a four digit numbering code in which the first two digits (12) indicate that the parent molecule (the biphenyl) has twelve carbon atoms, and the last two digits indicate the percent chlorine by weight. Thus, Aroclor 1260 is a chlorinated biphenyl mixture with an <u>average</u> chlorine content of 60%. [The only exception to this nomenclature is Aroclor 1016, which retains the name by which it was known during development. Aroclor 1016 is a mixture which has an average chlorine percentage of 41.5%, making it very similar to Aroclor 1242.] It is important to

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note that an Aroclor mixture may contain dozens of individual PCB congeners representing several isomeric groups. Since the classification of the peaks into specific Aroclors is somewhat arbitrary it is recommended that when analytical results are reported for Aroclors the mixture be evaluated as total PCBs using the following approach:

- for evaluating human carcinogenic health effects of total PCBs - - the use of the upper-bound slope factor (2 per (mg/kg-d)) for high risk and persistent Arochlors.
- for evaluating the noncarcinogenic health effects of total PCBs - - the use of the Aroclor-specific USEPA derived chronic, oral reference dose of 2×10^{-5} mg/kg/day for Aroclor 1254 (USEPA *IRIS*, 1996). This value may also be applicable to PCB mixtures containing similarly chlorinated congeners, such as Aroclor 1260.

In situations where only one specific Aroclor has been identified the following approach maybe utilized:

- for evaluating human carcinogenic health effects of individual Aroclors - - the use of the EPA PCB Guidance for Environmental Mixtures (EPA/600/P-96/001F, September, 1996).
- for evaluating the noncarcinogenic health effects of individual Aroclors - - the use of the Aroclor-specific USEPA derived chronic, oral reference doses. For Aroclor 1016, 7×10^{-5} mg/kg/day (USEPA *IRIS*, 1996). (Note: This value may also be applicable to PCB mixtures containing similarly chlorinated congeners, such as Aroclor 1242.) For Aroclor 1254, 2×10^{-5} mg/kg/day (USEPA *IRIS*, 1996).
- the use of other Aroclor-specific USEPA derived values, as they become available.

If PCB congener specific analytical results are available the dioxin TEFs presented in Section 8.2.4.1 should be utilized for the dioxin-like congeners.

PCBs also have significant health effects following sub-chronic exposure. Sub-chronic exposures should be evaluated, particularly if they are anticipated to be higher than chronic exposures.

8.2.4.4 Total Petroleum Hydrocarbons (TPH)

(to be developed)

8.3 Exposure Assessment

The exposure assessment is a critical component of the site assessment process as it describes, both qualitatively and quantitatively, the contact between the contamination and the people who are potentially affected by the contamination. The exposure assessment must be consistent with the primary questions asked in the risk characterization process:

Given the current and foreseeable uses of the site, would the contaminant pose an unacceptable risk of harm to human health if no further remedial action were to occur?

or

If a proposed remedial alternative is implemented will a condition of acceptable risk of harm to human health be achieved given the current and foreseeable uses of the site?

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Anticipated or proposed remedial actions or institutional controls should never be incorporated into the risk characterization, as it would no longer be an evaluation of the "no action" alternative. Actions which have already occurred can be considered in a risk characterization ***only if they are considered to be permanent***.

The risk characterization must be explicit about the conditions and assumptions upon which the risk characterization is based. The risk characterization must also note that the results of the risk characterization are only valid if and when the remedial measures (including institutional or engineering controls) are carried out.

The Tier 3 exposure assessment must incorporate site conditions associated with planned (both current use and identified foreseeable) uses of the site and surrounding environment. In this context site *use* or site *activity* are indices of potential exposure to site contaminants.

There are two parts to the exposure assessment: exposure scenario and quantitative estimates of exposure. An exposure scenario describes how contact with a contaminant takes place. The quantification of exposure translates the exposure scenario into a series of exposure equations resulting in numerical estimates of exposure. These numerical estimates are subsequently used in the risk calculations.

8.3.1 Development of Exposure Scenarios

Exposure scenarios provide the description of how potential exposure takes place at the site. The exposure scenarios assist the risk assessor in identifying appropriate values for the exposure variables (such as intake rate, frequency of exposure, etc.) within the various exposure pathways.

An exposure scenario should be developed for each of the receptors identified based on planned uses of the site and surrounding environment. The number and content of the exposure profiles will vary from site-to-site, reflecting the nature and complexity of the exposures which may occur. The number of scenarios evaluated can be streamlined If for example, the current use of the site is assumed to remain unchanged into the future, then separate exposure profiles need not be developed for both the current and future receptors or a the exposure scenario can be developed for the highest exposed receptor, accompanied by the conclusion that lesser exposed receptors will also be protected.

For a property where the frequency and intensity of exposure is low or limited, it is also possible to assume that the use and activities will remain the same, ***but this assumption requires institutional controls***.

The USEPA *Guidelines for Exposure Assessment* (Federal Register, 57(104)22888 - 22938, 1992) describes exposure scenarios as containing the "*facts, data, assumptions, inferences, and sometimes professional judgment*" about how the exposures take place. Since these factors determine the magnitude of exposure (and therefore the magnitude of the risk) it is important that there be a clear description and summary of this information. The exposure scenario allows anyone concerned about the exposure to site contaminants to read and understand what was considered in the risk characterization and what was the basis for the decision on the need for remedial action.

Note that the information which goes into an exposure scenario (e.g., the receptors, exposure pathways, activities which may lead to exposure, etc.) comes from the site investigation. Thus the investigation must be designed in such a way to provide the risk assessor with information suitable for the risk characterization. Actively soliciting input from the local community regarding activities on and around the site is

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highly recommended. The following subsections discuss the specific information which must be gathered for the risk characterization, presented in the site assessment report or the documentation of the risk characterization and summarized in the exposure scenario.

8.3.1.1 Site Information Required to Quantify Exposures

The exposure assessment begins with a description of the physical characteristics of the site and surrounding environment. This information is typically collected as part of a Phase I or Phase II site investigation, although the type of information needed and the appropriate level of detail should reflect the nature and complexity of the site as well as point in time at which the risk characterization is being performed. Relevant site information would include:

- the location of the site;
- a summary of the history of contaminant use and a description of any known and relevant releases which may have occurred;
- a detailed map and description of the soil contamination and the spatial distribution of contaminants (include off-site property locations if appropriate);
- a detailed map and description of the planned property use and activities on the site and surrounding areas (see Draft Guidance on Incorporation of Planned Property Use into Site Decisions (August 25, 1997) for further discussion);
- a summary of soil types and characteristics; and
- a summary of background concentrations of contaminants.

8.3.1.2 Identification of Potential Human Receptors

The documentation of the risk characterization should contain a description of the potentially exposed persons who live, work, play, visit, or otherwise contact the site or the surrounding environment. In identifying these receptors, the risk assessor must consider not only those individuals currently associated with the site, but also those who may frequent the site in the future, particularly if the use of the site were to change.

The human receptors are often described as subpopulations rather than specific individuals so that the results of the risk characterization can be generalized. For example "*children*", are often identified as a specific subpopulation of concern. Hypothetically a risk assessor could identify a specific (real) child who lives at the site and conduct a risk assessment based upon that child's physical characteristics and behavioral patterns, but the result of such an assessment would be valid only for that child and could not be generalized to other children who may visit the site or live there in the future. Note, that while the receptors are described in terms of "subpopulations", the product of the risk assessment is still an estimate of the risk that applies to the protection of an *individual* within that group.

For the purposes of the risk characterization the site receptors should be divided into subpopulations based upon gender, age or other factors that are indicative of a higher exposure potential or greater susceptibility to environmental contamination. Young children and women of child-bearing age are often chosen as receptors of concern in residential locations because of these factors. At industrial locations, adults

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workers may be the most highly exposed receptors. Identification of the most sensitive subpopulation should be done on a site by site basis.

To adequately evaluate the potential receptors, the risk assessor may need to look at several specific subpopulations of receptors to insure that all sensitive subpopulations are being protected. By focusing on the subpopulations experiencing the highest rates of exposure the risk assessor may conclude that all other subpopulations at the location would be subject to lower exposures and risks than those calculated. Examples of typical receptors who might be chosen to evaluate a residential exposure scenario are:

Acute Noncancer Exposure Scenario - Evaluation of a young child (e.g., 1 - 2 years old) for single event or several exposure events over a short period of time (e.g., ingestion of a bolus of soil).

Subchronic Noncancer Exposure Scenario - Evaluation of a young child for short-term (e.g., several weeks to several months) exposure due to higher exposure potential (e.g., increased soil contact during summer months).

Chronic Noncancer Exposure Scenario - Evaluation of a young child experiencing the reasonable maximum soil-related exposure in a residential setting.

Chronic Cancer Exposure Scenario - Evaluation of a individual < 1 year to 33 years old. The exposure would be age-adjusted to incorporate the different exposure experiences (e.g., higher exposure as a child).

8.3.1.3 Identification of Exposure Pathways

The route by which the contaminant travels from the source to a receptor is called the *exposure pathway*. Each exposure pathway includes a source or release from a source, a transport medium, and an exposure area/point. The exposure scenario may be relatively simple if a single receptor group is exposed at one location via one route of exposure. Exposures at sites are generally a bit more complex, however. A receptor group may be exposed to the contaminant through a number of exposure routes at several locations. The documentation of the risk characterization must describe the components of the exposure pathway(s). This information should be gathered during site investigations.

8.3.1.4 Identification of Exposure Areas or Exposure Points

For receptors to be exposed to a contaminant at or from a site, an exposure pathway must exist leading from the source of the contaminant to the receptor. The area (or point) at which the contact occurs is referred to as the *exposure area (or exposure point)*. Potential exposure areas/points may be distant from the source. The risk assessor must consider the current and future exposure pathways to identify all exposure areas/points.

Exposure to soil typically occurs within an area (e.g., play area) rather than at a specific point (e.g., drinking water well). Note, acute soil exposure may occur at a specific point. The exposure area should be an area within which the receptor has an equal likelihood of exposure. If there are areas within the site which receptors frequent at a higher rate (such as the area surrounding playground equipment within a larger recreational area or school yard) then those areas should be evaluated as separate and distinct exposure areas/points.

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In general, an exposure area for soil should be delineated by the distribution of the contaminant in the environmental medium. In other words, an exposure area should be a contaminated area within which exposure can potentially occur. The area outside the boundaries of the contamination should not be included in the exposure area, and data from those areas should not be included in the concentration estimate. There are two reasons for this recommendation:

1) There is rarely enough information on small-scale exposure patterns in the vicinity of a contaminated area, for example a residential yard, to justify assumptions about the relative amount of time spent in the area known to be contaminated.

2) The full areal extent of contamination is not always known, unfortunately, at the time of the risk characterization. Sample collection is often focused on the areas where contamination is expected and/or obvious, and other areas are not fully characterized (although those areas may be contaminated as well). The practice of treating the contaminated area as the entire exposure provides a conservative estimate of exposure.

This is why *hot spots* (see Section 5.1.1 "Sampling Plans") are identified as separate and distinct exposure areas for purposes of risk characterization. This requirement ensures that areas with high relative contamination will not simply be averaged into a wider area of lesser contamination, thus minimizing (or diluting) their potential impacts.

There may be some situations where the approach described above is not appropriate. In cases where the extent of soil contamination is well defined and clearly constitutes only a fraction of the area over which the receptor group of concern is equally likely to be exposed, the exposure area may be an area that is somewhat larger than the contaminated area. When considering whether the exposure area should cover an area larger than that which is contaminated, the scale of the contaminated area relative to the anticipated exposure pattern is an important consideration. Another important consideration is whether the foreseeable activities are likely to result in more intense or more frequent exposures in some areas than in others. For example, in play parks, exposure intensity at any location depends upon the landscaping, the pattern of open space and the layout of equipment. If a small area of surface soil located within a large park were contaminated, the risk assessor may not be able to rule out the possibility that exposures to individual children will be higher in that area than in other areas of the park. Therefore it would be more appropriate to designate the contaminated area alone as the exposure area, and not the entire park.

The burden to demonstrate that the designation of an exposure area is appropriate and conforms with the intent of this guidance rests with the responsible or voluntary party. The documentation of the risk characterization should present summary tables describing the exposure pathways identified and the exposure areas to be evaluated.

8.3.1.5 Identification of Exposure Routes

The mechanism by which the contaminant contacts or enters the receptor is called the *Exposure Route*. Typical exposure routes include:

- **Ingestion** of contaminated soil, water or food;
- **Dermal Absorption** from contaminated water, soil or sediments; and
- **Inhalation** of contaminated air or fugitive dust.

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The receptor may be exposed to contaminants at one *or more* exposure areas/points, and at each exposure area/point the receptor may be exposed via one *or more* routes. The exposure scenario for the receptor should describe such multiple exposure scenarios in a way which makes clear to the reader that the combination of exposures to the receptor is being addressed in the risk assessment.

8.3.2 Basic Approach/Assumptions

The basic approach which should be taken in an exposure assessment is to produce an assessment which is realistic and health protective. The objective of a Tier 3 risk characterization is to provide a conservative estimate of the impact that the contaminant may have on the receptors at the site and in the surrounding environment. The assessment should not be a "*worst case*" exposure assessment unless there are site-specific justifications for performing such an evaluation. Conversely, the assessment should not represent an "*average case*" which may underestimate potential risks experienced by a large portion of the exposed subpopulation, and thus would not be considered to be health protective. This section presents limited guidance on identifying receptor groups that are likely to be most susceptible to contamination at the site, and on selecting exposure parameters that will result in an appropriately conservative estimate of risk to that receptor group. It is anticipated that the individual(s) performing the risk assessment is qualified to conduct a site-specific risk characterization and are working closely with a MPCA risk assessor.

Numerous attempts have been made to define a combination of exposure assumptions which would result in a reasonable yet health-protective exposure assessment. A **Reasonable Maximum Exposure** (RME) has been defined as "*the maximum exposure that is reasonably expected to occur at a site*" (USEPA, RAGS, EPA/540/1-89/002, 1989). Standard RME default scenarios for the different property use categories have been developed by the SRS for Tier 2 risk characterizations. For the purpose of Tier 3 risk characterizations the receptor subpopulation of concern should be characterized by those individuals whose activities (described by the frequency and duration of the actions) represent a full and unlimited use of the site (considering the current *and* foreseeable uses identified) and who are most susceptible to the contamination at the site.

The receptor subpopulations evaluated in the quantitative risk characterization should represent the most susceptible individuals of all of those who are exposed to contamination at the site in question. Higher susceptibility is used here to mean a higher probability of experiencing adverse impacts as a result of exposure. Susceptibility is determined by the combination of the intensity of exposure and the sensitivity to toxic effects combined. Examples of receptor groups that are often identified as the most susceptible subpopulations include those described below:

- In typical residential or recreational areas, children are usually considered among the most susceptible receptors because (1) their activities are likely to result in more intense exposures than those of adults, (2) they are believed to intake higher amounts of soil by incidental ingestion, and (3) all other things being equal, their lower body weights result in higher normalized doses.
- In typical industrial areas (access by the public is restricted), adults who work at the site are often considered as one of the most susceptible subgroups because their exposure frequency is higher than for others who may be exposed on occasion. Occasionally, pregnant and/or nursing women may be identified as a highly susceptible subgroup. The effects of concern in these cases may be developmental effects on fetuses and babies, not necessarily effects on the mother herself.

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The term "most susceptible receptors" often reflects a higher susceptibility due to a higher exposure intensity and not necessarily a greater sensitivity to the toxin. While higher sensitivity to a toxin may be an important consideration, it is seldom addressed quantitatively in health risk assessments because the information is not available. If information regarding sensitivity to a toxin is available it should be incorporated into the risk characterization. The absence of information regarding sensitive subpopulations (e.g., no developmental toxicity studies conducted) should be discussed in the uncertainty section of the risk characterization report.

Deterministic exposure assessments should use a combination of mid-range and upper-range estimates of exposure parameters to produce a RME exposure scenario. A conservative estimate (95% UCL) of the arithmetic mean of concentrations are recommended for use as the exposure concentration. The resulting exposure estimates are considered to be protective of public health in that they are not likely to be underestimates of the "true risk" for individuals in the specified receptor subpopulation.

For exposure assessments performed using probabilistic techniques (such as Monte Carlo analysis) the 95th percentile value of the resulting exposure distribution *for the specified receptor subpopulation* should be used to calculate risk estimates. Soil contaminant concentration distributions as well as exposure parameter distributions may be utilized in the probabilistic evaluation provided sufficient distributional data exists.

8.3.3 Quantitative Estimates of Exposure

Once exposure scenarios have been developed describing the contaminants of concern, exposure area(s), exposure concentrations and the receptors of concern, the potential exposures experienced by the receptors are quantified. The daily exposure/dose(s) of each contaminant calculated for each potential receptor should be summarized in the risk characterization report in a manner which is clear and concise. Summary tables presenting the equations and the exposure assumptions used to calculate the daily dose should also be presented and well referenced.

This section of the guidance briefly describes the different types of exposures and doses which may be employed in the risk assessment, the common factors used to estimate exposure, the pathway-specific equations employed to quantify exposure, and estimation of exposure concentration. It is anticipated that the individual(s) performing the risk assessment are trained and qualified to conduct a site-specific risk characterization and therefore in depth guidance is not required. It is also the responsibility of the risk assessor to obtain approval from MPCA/SRS staff prior to conducting the risk characterization.

8.3.3.1 Exposure and Dose

The concept of exposure is complex, and the numerical value calculated by the risk assessor will depend upon the nature of the exposure pathway under investigation, the duration of the exposure, and the health effects associated with the chemicals of concern. The US EPA Exposure Assessment Group defines *exposure* as the amount of material in contact with an organism and available for absorption. This is often referred to as the potential dose and is analogous to the administered dose in the laboratory studies. The material which actually crosses the receptor's exchange boundary is defined as the absorbed dose.

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The type of potential dose used to characterize risk will depend upon the exposure pathway under evaluation and the nature of the toxicity information available for each chemical:

- Typically *respiratory* exposures are evaluated using the exposure medium concentration, as the potential dose, in combination with a published Reference Concentration or Unit Risk value.
- Oral exposures are typically estimated as a potential dose. To insure that the estimated potential dose is comparable to the Reference Dose or Cancer Slope Factor it is often modified with an *Absorption Adjustment Factor* (AAF) during the quantitative risk characterization step.
- Dermal exposures are typically estimated as an absorbed dose. To insure that the estimated dose and the Reference Dose or Cancer Slope Factor are comparable the Reference Dose or Cancer Slope Factor is modified with an *Absorption Adjustment Factor* (AAF) during the quantitative risk characterization step.

8.3.3.2 Types of Daily Doses

The equations presented in the next two sections outline the process for calculating the Average Daily Dose (ADD) or the Lifetime Average Daily Dose (LADD). The ADD can be calculated over various exposure periods. The chronic ADD is calculated for the characterization of potential noncancer risk resulting from long-term exposures. The subchronic ADD is calculated for the characterization of potential noncancer risk resulting from mid-range exposures. The acute dose is calculated for the characterization of potential noncancer risks resulting from a single or short-term exposure.

The LADD is typically calculated by taking the total intake during the exposure period and normalizing it to a lifetime. The actual exposure may occur for only a portion of the lifetime. For some contaminants or subpopulations of receptors this approach (normalizing over a lifetime) may not be health protective. Contaminant exposures are often unequally distributed throughout life. The factors that may influence cancer risk are the existence of critical periods of susceptibility during a lifetime and the intensity of exposure. These factors may warrant deviation from the traditional approach. For example, risks for infants and children may differ from the risks for adults. Infants and children may exhibit unique susceptibility to toxic chemicals because they are undergoing rapid tissue growth and development. This appears to be the case for vinyl chloride (personal communication with Bill Pepelko at USEPA). Limited evidence also exists for PCBs and PAHs.

When possible, the biological basis or mechanism by which a carcinogen acts should be used to characterize risk from the carcinogenic contaminant. If that is not possible and higher exposure occurs during a short exposure duration (i.e., *significantly* less than a lifetime), the cancer risk should be no more than 1E-6 (10 percent of the total chronic acceptable excess lifetime cancer risk).

The effect (noncarcinogenic and carcinogenic) of a contaminant also depends on the dose and the rate at which the dose is administered. A specific dose given in a short-period of time may not produce the same effect when given over a longer period of time. In the development of generic Tier 1 and 2 SRVs the risk of noncancer health effects from subchronic and acute exposure were evaluated for this reason. It was found that in general (for exceptions see the Tier 1 or 2 SRV table) the chronic exposure scenario was adequately protective of higher exposures which occurred during shorter exposure periods. For numerous contaminants the level of protection was small (e.g., the chronic SRV was approximately equal to the subchronic SRV). If the chronic default exposure parameters are not utilized the risk assessor must evaluate subchronic and acute exposure scenarios.

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8.3.3.3 Soil-Related Exposure Equations

The following equations, are provided to assist the risk assessor in quantifying a receptor's potential dose to contaminants at site and surrounding properties. The default values for these variables are provided in Appendix 1.

Incidental Ingestion of Contaminated Soil:
The Average Daily Dose due to the *chronic* incidental ingestion of contaminated soil ($ADD_{ingestion}$) may be calculated:

$$\text{LADD or ADD}_{soil\ ingestion} = \frac{C_{soil} * IR * CF * FI * EF * ED}{BW * AT}$$

Where:

LADD/ADD$_{ing}$	=	Average daily potential dose of contaminant received through the ingestion of soil, during the period of exposure (mg/kg-day).
C$_{soil}$	=	Representative exposure concentration of the contaminant in soil (mg/kg).
IR	=	Annual daily soil ingestion rate during the exposure period (mg/day).
CF	=	Conversion Factor (1E-6 kg/mg).
FI	=	Fraction of ingested soil which is from contaminated soil (unitless).
EF	=	Number of exposure days during the exposure period (days/year).
ED	=	Duration of the exposure period (years).
BW	=	Body weight of the receptor of concern during the exposure period (kg).
AT	=	Averaging Time (days) (AT = ED x 365 days for noncarcinogens; AT = 70 yrs x 365 days/yr for carcinogens).

The Average Daily Dose during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated:

$$ADD_{soil\ ingestion} = \frac{C_{soil} * IR * CF * FI * EF}{BW * AT}$$

Where:

ADD$_{ing}$	=	Average daily potential dose of contaminant received through the ingestion of soil, during the period of exposure (mg/kg-day).
C$_{soil}$	=	Representative exposure concentration of the contaminant in soil (mg/kg).
IR	=	Daily soil ingestion rate during the exposure period (mg/day).
CF	=	Conversion Factor (1E-6 kg/mg).
FI	=	Fraction of ingested soil which is from contaminated soil (unitless).
EF	=	Number of exposure days during exposure period(days).
BW	=	Body weight of the receptor of concern during the exposure period (kg).
AT	=	Averaging Time (number of days in exposure period).

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The Acute Dose due to the incidental ingestion of a bolus of contaminated soil ($AD_{ingestion}$) may be calculated:

$$AD_{soil\ ingestion} = \frac{C_{soil} * IR * CF * EF}{BW}$$

Where:

AD_{ing}	=	Acute potential dose of contaminant received through the ingestion of soil, during a short exposure (e.g. , 1 day) (mg/kg BW).
C_{soil}	=	Representative exposure concentration of the contaminant in soil (mg/kg).
IR	=	Acute soil ingestion rate (mg/day).
CF	=	Conversion Factor (1E-6 kg/mg).
EF	=	Exposure Frequency (1 day).
BW	=	Body weight of the receptor of concern at the time of exposure (kg).

Dermal Contact with Contaminated Soil:

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. In fact, dermal absorption from soils may be more significant than incidental ingestion for chemicals which have a percent absorption exceeding about 10% (USEPA, EPA/600/8-91/011B, January, 1992). Contaminants exhibiting percentage absorption less than 10% may also contribute significantly to cumulative risk estimates and therefore these contaminants must also be evaluated. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil (e.g., organic carbon content. The Average Daily Dose due to chronic dermal contact with contaminated soil ($ADD_{dermal\ absorption}$) may be calculated:

$$LADD \text{ or } ADD_{dermal\ absorption} = \frac{C_{soil} * CF * SA * AF * ABS * EF * ED}{BW * AT}$$

Where:

$LADD/ADD_{dermal}$	=	Average daily dose of contaminant received through dermal contact with soil, during the period of exposure (mg/kg-day).
C_{soil}	=	Representative exposure concentration of contaminant in the soil during the period of exposure (mg/kg)
CF	=	Conversion Factor (1E-6 kg/mg)
SA	=	Skin surface area in contact with the soil on days exposed (cm^2)
AF	=	Skin adherence factor of soil adhered to the unit surface area of skin exposed (mg/cm^2)
ABS	=	Absorption Factor (unitless)
EF	=	Exposure Frequency: the number of exposure events during the exposure period (days/year)
ED	=	Exposure Duration: the duration of the exposure period (years)
BW	=	Body Weight of the receptor of concern during the exposure period (kg)
AT	=	Averaging Time (days) (AT = ED x 365 days) for noncarcinogens; AT = 70 years x 365 days/yr for carcinogens)

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The Averag Daily Dose during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated:

$$ADD_{dermal\ absorption} = \frac{C_{soil} * CF * SA * AF * ABS * EF}{BW * AT}$$

Where:

ADD_{dermal}	=	Average daily dose of contaminant received through dermal contact with soil, during the period of exposure (mg/kg-day).
C_{soil}	=	Representative exposure concentration of contaminant in the soil during the period of exposure (mg/kg).
CF	=	Conversion Factor (1E-6 kg/mg).
SA	=	Skin surface area in contact with the soil on days exposed (cm^2).
AF	=	Skin adherence factor of soil adhered to the unit surface area of skin exposed (mg/cm^2).
ABS	=	Absorption Factor (unitless).
EF	=	Exposure Frequency: the number of exposure days (days).
BW	=	Body Weight of the receptor of concern during the exposure period (kg).
AT	=	Averaging Time (number of days in exposure period).

Inhalation of Vapors and Resuspended Soil/Dust:

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

Contaminants may be inhaled by the receptor of concern whenever the receptor is at or near the site. The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air.

$$\text{LADC or } ADC_{air} = \frac{C_{air} * EF * ED * CF}{AT}$$

Where:

$LADC/ADC_{air}$	=	Average daily concentration of contaminant in air, during the period of exposure (mg/m^3 or ug/m^3).
C_{air}	=	Exposure concentration of contaminant in the air during the period of exposure (mg/m^3 or ug/m^3).
EF	=	Number of exposure days during the exposure period (days/year).
ED	=	Duration of the exposure period (years).
AT	=	Averaging Time (days) (AT = ED x 365 days/yr for noncarcinogens; AT = 70 yrs x 365 days/yr for carcinogens).
CF	=	Appropriate units conversion factor if appropriate (e.g., 1000 ug/mg).

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The air concentration parameter (C_{air}) can be measured or modeled. See Appendix 1 regarding the Volatilization Factor and Particulate Emission Factor models. Monitoring may be utilized in lieu of models, provided that the monitoring is conducted under conditions that would maximize emissions.

The Average Daily Concentration during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated:

$$\text{LADC or ADC}_{air} = \frac{C_{air} * EF * CF}{AT}$$

Where:

LADC/ADC$_{air}$	=	Average daily concentration of contaminant in air, during the period of exposure (mg/m^3 or ug/m^3).
C_{air}	=	Exposure concentration of contaminant in the air during the period of exposure (mg/m^3 or ug/m^3).
EF	=	Number of exposure days during the exposure period (days/year).
AT	=	Averaging Time (number of days in exposure period).
CF	=	Appropriate units conversion factor if appropriate (e.g., 1000 ug/mg).

Ingestion of Contaminated Food:

The average daily potential dose experienced by the receptor as a result of consuming food (ADD_{food}) containing contaminants taken up from contaminated soil may be estimated using the following equation. The general form of this equation may be applied to the ingestion of contaminated fish, meat, or vegetables. The evaluation of exposure to contaminated fluids (e.g., milk) may be estimated using the general equation for drinking water exposures in combination with the appropriate exposure factors.

$$\text{LADD or ADD}_{food} = \frac{C_{food} * IR_{food} * FI * EF * ED}{BW * AT}$$

Where:

LADD/ADD$_{food}$	=	Average daily potential dose received through ingestion of contaminated food, during the period of exposure (mg/kg-day).
C_{food}	=	Representative concentration of contaminant in the food of concern during the period of exposure (mg/kg)
IR_{food}	=	Daily food ingestion rate during the exposure period (kg/day)
FI	=	Fraction of ingested food during the exposure period which is contaminated (unitless)
EF	=	Number of exposure events during the exposure period (day/year)
ED	=	Duration of the exposure period (years)
BW	=	Body weight of the receptor of concern during the exposure period (kg)
AT	=	Averaging Time (days) (AT = ED x 365 days/yr for noncarcinogens; AT = 70 yrs x 365 days/yr for carcinogens)

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8.3.3.4 Estimating Exposure Concentrations - General Considerations

To assure that site sampling efforts provide adequate data for the risk assessment, the sampling and analysis plan should be developed in consultation with the risk assessor. Analytical data is collected during the site investigation to fully characterize the nature, extent, severity and horizontal and vertical distribution of the contaminant at the site. Some or all of the data obtained may be used for the risk assessment. The data obtained or selected for the risk assessment must be representative of potential exposures and it should be compatible with the dose response value that will be used in the assessment.

The exposure point concentration should represent the arithmetic mean of the concentrations to which an individual may be exposed over the exposure period. As previously stated, the exposure concentration should be compatible with the toxicity values that will be used to characterize health risks. Chronic and subchronic reference doses are generally based on time-weighted averages of exposure concentrations used in toxicological experiments, and are expressed in terms of an allowable average daily dose. Therefore, the exposure concentrations used with those reference doses should approximate the time weighted average concentration to which the receptor may be exposed at the exposure point during the exposure period being evaluated. Cancer slope factors are also based on an average daily dose, and exposure point concentrations for evaluating cancer risks should represent the average daily dose.

Four types of exposures should be evaluated in Tier 3 site risk assessments. For non-carcinogenic effects: (1) acute (typically 24 hour exposures), (2) subchronic (several months to several years) exposures, and (3) chronic exposures (greater than several years). For carcinogenic effects lifetime exposures (typically a chronic exposure averaged over a lifetime of 70 years). For each type of exposure, the risk assessment should focus on the time-segment during which the highest dose is likely to be received. The exposure concentration should be a conservative estimate of the average exposure concentration over that period of time. For example, to evaluate three month subchronic exposure when the exposure is known to fluctuate seasonally (e.g., higher in summer months), the exposure concentration should represent the highest average to which a person could be exposed within a three month time frame. Medium concentrations may also fluctuate seasonally and the exposure concentration should represent the highest average to which a person could be exposed during that time period.

For acute exposure assessments, the exposure concentration should represent a conservative estimate of the concentration to which a receptor might be exposed over the period of a single event (e.g., ingestion of a bolus of soil) or a single day. Generally, the highest detected concentration should be employed when one-time exposure could result in adverse health effects.

<u>Using Qualified Data</u>

In estimating exposure point concentrations, it is not uncommon for the risk assessor to be presented with analytic data for a chemical at the site which includes a number of samples reported to be below the Method Detection Limit (MDL). Such results are referred to as "Non-Detects".

Non-Detect results may be classified into two general situations. First, if a chemical is truly not present at the site (virtually all the samples are reported as Non-Detect), and there is no history of a release of that chemical, then the risk assessor may conclude that the chemical should be dropped from the quantitative risk assessment. Second, if the chemical is reported at the site at concentrations ranging from Non-Detect to some site maximum, the risk assessor may conclude that the reported Non-Detects actually

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represent a distribution of concentrations between zero and the MDL. There is a third possible site situation which result in non-detect values. The spatial pattern of detected and non-detect results may indicate that contamination is localized to specific areas. This would represent a combination of the first and second situations presented above.

The Non-Detect method selection should also consider, the often high level of uncertainty which is often inherent in environmental sampling and analysis procedures. This uncertainty may result from failure to take an adequate number of samples, mistakes on the part of the sampler, the heterogeneity of the matrix being sampled, and intentional bias in the sample collection. For relatively small sites, these inherent uncertainties may overwhelm the bias introduced by using 1/2 the MDL. A more statistically oriented method may not, in such cases, significantly reduce the uncertainty. It is up to the risk assessor to judge the level of sophistication appropriate to the data set. See Section 7.4 for further discussion treatment of non-detects.

Tentatively Identified Compounds

Tentatively identified compounds (TICs) are compounds which are detected during sample analysis, but are not target compounds. TICs are often reported when gas-chromatography-mass spectrometry (GC-MS) is used to analyze organic compounds. Target compounds are those for which the instrument was calibrated, using a chemical standard, prior to analysis. The ability of the MS system to store mass spectra electronically in a "library" enables the analyst to compare the library spectra with the spectra produced by a non-target contaminant when one shows up in an environmental sample. Identification based on a "library" comparison is much more uncertain, however, than one based on calibration with a standard for the target compound.

There is no rule of thumb for whether TICs should be included in the risk assessment. Confidence in a TIC identification depends on a number of factors, including site history and the presence of similar compounds at the site. The EPA's *Guidance for Data Usability in Risk Assessment* provides the following guidance:

> Confidence in the identification of a TIC can be increased in several ways. .An analytical chemist trained in the interpretation of mass spectra and chromatograms can review TIC data and eliminate many false positive identifications. The use of retention indices or relative retention times can confirm TICs identified by the GC-MS computer (Eckel, et al. 1989). Examination of historical data, industry-specific compound lists, compound identifications from iterative sampling episodes, and analyses performed by different laboratories may also increase confidence in the identification of a TIC. The final identification step is to re-analyze the sample after calibrating the GC-MS instrument with an authentic standard of the compound that the TIC is believed to be.
>
> Many compounds that appear as TICs during broad spectrum analyses belong to compound classes. Examples of compound classes are saturated aliphatic hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). The risk assessor may be able to make a preliminary judgment of toxicity at the compound class level without a definitive identification of each compound present.

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The identification of a TIC can be confirmed definitively only by further analysis. However, depending on the analytical and historical information available, and the potential impact of the TIC on the results of the risk assessment, confirmatory analysis may not be warranted. The risk assessor should work with the project manager and an analytical chemist to make a prudent decision about the need for follow-up analysis.

Measured vs. Modeled Concentrations

Direct measurement of environmental concentrations is generally preferred, but estimation by an analytical or numerical model may be acceptable when direct measurement is impossible or extremely impractical. If a model is used, modeling methods, input parameters and assumptions, and model validation should be fully referenced and described.

The key steps in the consideration, selection and application of predictive models are summarized below.

- Characterization and modeling objectives. The study objective should be clearly defined.
- Model Selection. It is important to ensure that the selected model address the processes that are of interest or importance.
- Extent and quality of input data. Modeling can require a significant amount of site-specific data. In the absence of such data a more simplistic approach is more appropriate.
- Model accuracy, validation and verification. Some models may need to undergo a series of calibration/validation processes.
- Budget and resources availability. The costs to obtain and use the model, including costs associated with obtaining site data needed for model calibration, validation, or model input can be considerable. In addition, it is important that the persons using the model be experienced and proficient in its use and interpretation.
- Sensitivity and uncertainties analysis. Given the uncertainties that exist using any model, reasonably conservative input values should be used wherever appropriate. A sensitivity or uncertainty analysis should be considered. Input parameters should be varied in order to determine variations in the predicted results. This information can then be used to determine which input parameters require accurate determination and which input parameters may be approximated with little loss in model accuracy. In situations where an accurate determination of sensitive input parameters cannot be obtained, such an analysis can be used to define the range of possible model outputs.
- Model interpretation. A conceptualization of the modeled system and understanding of the processes being simulated is necessary to avoid making mistakes related to blind acceptance of predicted results. Predicted results which are inconsistent with technical insight or intuitively inconsistent with real-world situations should be a cause for concern and re-evaluation.

Use of predictive models in characterizing risk must meet the following criteria:

- The selected model must be scientifically valid and sufficiently documented.
- The model will be selected, used and applied in a manner that leads to a reasonably conservative and protective estimate of exposure concentrations.

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- All modeling and site-specific assumptions and conditions are clearly stated and documented.
- Data inputs to the model are of sufficient quantity and quality to allow for meaningful use, interpretation, and confirmation of modeling outputs given the sensitivity and uncertainty of the modeling parameters and the intended application of the modeling results.
- All results are clearly documented

8.3.3.5 Exposure Concentrations

Direct contact with soil can result from such diverse activities as work, play and gardening on residential properties; recreational activities on public and private land; outdoor work on industrial properties; grading or excavation of soil for construction or utility repair; landscaping on a variety of properties and; agricultural work. Exposure occurs primarily by incidental ingestion of contaminated soil, dermal absorption of contaminants from soil and inhalation of resuspended contaminated soil and dust or inhalation of vapors from contaminated soil. To calculate an exposure concentration for a particular exposure scenario, the selected samples should be representative of the area and depth within which the potential exposure occurs. See Section 7.4 for additional discussion on determination of exposure areas and exposure concentrations.

Generally, the arithmetic mean soil concentration in an exposure area may be used as the exposure concentration estimate. The accuracy of this method depends on three underlying assumptions (EPA OSWER Memorandum, May 1992):

- Over time, soil concentrations remain constant;
- The detected concentrations represent a uniform or random distribution of soil samples over the exposure area; and
- Over time, exposure is equally likely at any location within the exposure area.

If these assumptions hold true, the arithmetic mean concentration in the exposure area will represent the arithmetic mean concentrations with which a person comes into contact over time. In other words, the spatial average may be used as a surrogate for the temporal average.

The first assumption stated above is consistent with current MPCA/SRS practice. Laboratory derived degradation rates often are not observed in the field, and the conservative assumption that concentrations will not decrease over the time of the exposure period is encouraged unless site-specific degradation rates are available.

There are cases, however, when the second and/or third assumptions do not hold true. Sampling locations are not always distributed evenly over the site, and exposure frequencies are often higher in some areas than others. In these cases, a weighted average of the detected concentrations should be used *if* detailed site-specific information regarding exposure patterns are known. Knowledge of foreseeable exposure patterns is particularly problematic.

In situations where the sampling points are not evenly distributed over the area of concern, an area weighted average exposure concentration can be considered to be a representative estimate of the exposures within the area of concern if exposures are equally likely throughout the area under consideration. In this method, the sample values should be weighted according to the relative area each represents.

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In situations where the sampling locations are distributed evenly, but exposure occurs more frequently in one portion of the area of concern than another a time-weighted average should be estimated. The time-weighted average should account for different exposure frequencies in different portions of the area under consideration as long as similar levels of exposure occur on the different portions. For example, if 75% of the exposure time takes place on half of the area of concern and the remaining 25% of the exposure takes place on the other half the average concentration of each half should be calculated separately and then weighted to obtain a time-weighted average. If different exposure levels occur within the different portions of the area a time-weighted average should not be utilized. Note that there may be situations in which weighting for both exposure time and area are appropriate.

These examples represent simple approaches to obtaining a weighted average. More refined techniques for weighting soil data to estimate an areal average are available. Those that appear to be best suited for exposure assessment are polygon techniques. In general, these procedures involve construction of a polygon around each data point so that each polygon contains the locations that are closer to the data point at its center than any other data point. Such methods are useful for deriving area weighted average soil concentrations which may be used as surrogates for time-weighted exposure concentrations. Other approaches often suggested in risk assessment literature and guidance are oriented toward estimating the most likely concentrations at locations between data points. Kriging and triangulation are examples of such methods. The problem of determining concentrations between data points is related to but different from the problem of estimating the average concentration over an exposure area.

The inhalation pathway is evaluated somewhat differently than the ingestion and dermal pathways. The inhalation pathway involves the estimation of an air contaminant concentration. Calculation of the air exposure concentration (mass of contaminant/volume air) was presented in Section 8.3.3.3. . To estimate air concentrations resulting from contaminated soil a particulate emission factor or a volatilization factor must be calculated.

The particulate emission factor (PEF) relates the concentration of contaminant in soil with the concentration of dust particles in the air. The following discussion addresses dust generated from open sources, termed “fugitive” because the dust is not discharged into the atmosphere in a confined flow stream. The following equation is utilized to calculate the PEF:

$$PEF\,(m^3/kg) = Q/C \times \frac{3{,}600\,s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Where:

PEF	=	Particulate emission factor (m^3/kg)
Q/C	=	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)
V	=	Fraction of vegetative cover
U_m	=	Mean annual windspeed (m/s)
U_t	=	Equivalent threshold value of windspeed at 7 meters (m/s)
F(x)	=	Function dependent on U_m/U_t derived using Cowherd et al. (1985)

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The emission and dispersion portion of the PEF equation have been updated since EPA's Risk Assessment Guidance for Superfund (RAGS, 1989) (EPA Soil Screening Guidance: Technical Background Document, 1996 (EPA/540/R-95/128)). For further discussion on the PEF model see Appendix 1.

It is generally assumed that the concentration of the contaminant in the particulate is equal to the concentration of the contaminant in soil. This assumption may underestimate the concentration of contaminant in the inhalable fraction (i.e., PM10 fraction), since smaller particulate fractions sometimes contain contaminant concentrations that are enriched relative to larger fractions. However, the data needed to derive more accurate concentration estimates are typically not available.

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). Activities likely to disturb soil occur during construction and utility work activities. These activities are typically of short-term duration. To assess site risks, short-term as well as chronic exposure scenarios should be evaluated. The above model is only applicable for estimating chronic particulate emissions. To assess short-term (e.g., subchronic) exposures utilization of default particulate concentration values may be necessary. For exposure during construction or utility work, a PM10 value of at least 150 $\mu g/m^3$ should be used to estimate concentrations. This value is the average 24 hour PM10 standard. A contribution factor of 100% should be used to estimate the portion of particulate level contributed by the construction activities.

There are a number of uncertainties associated with use of the default PM10 values, including: 1) the published 24 hour averages may underestimate PM10 concentrations attained during the work day; and 2) the sampling locations are not necessarily located near construction activities or large areas of sparsely vegetated soil. Therefore, these PM10 values are acceptable for use only in the absence of more representative data.

For evaluation of volatile contaminants the soil-to-air volatilization factor model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. The following equation is utilized to calculate the VF:

$$VF\,(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}\,(m^2/cm^2)$$

Where:

VF	=	Volatilization factor (m^3/kg).
Q/C	=	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3).
D_A	=	Apparent Diffusivity (cm^2/s).
T	=	Exposure interval (s).
ρ_b	=	Dry soil bulk density.

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The VF equation is based on the volatilization model developed by Jury et al. (1984) for infinite sources and Jury et al. (1990) for finite sources. This equation represents an update of EPA's Risk Assessment Guidance for Superfund (RAGS, 1989) (EPA Soil Screening Guidance: Technical Background Document, 1996 (EPA/540/R-95/128)). As discussed in Section 6.5 there are several site situations for which the VF model is not applicable. In particular, if the soil contaminant concentration is above saturation the VF model can not be utilized. For further discussion on the VF model see Appendix 1.

For volatile contaminants volatilization to ambient air may not be the only inhalation pathway of concern. At site situations where soil beneath a building is contaminated with very volatile organic compounds and the soil is considered highly porous, the potential for exposure to soil vapors migrating indoors must also be considered in the human health risk assessment. Organic compounds can accumulate in indoor air by migrating from soil, through the soil gas in the overlying unsaturated soil and into buildings through pores, cracks or openings in the foundation.

Exposure point concentrations in the air in any particular building are dependent upon a combination of conditions:

- The Henry's Law coefficients of the contaminant of concern, which provides an indication of their tendency to partition from the groundwater to the air spaces in the overlying soil;
- the concentrations of contaminant in the soil and location relative to the building;
- the physical characteristics (e.g., permeability) of the soil at the location of concern;
- the structure of the building; and
- the heating and ventilation features of the building which affect the rate at which soil gas will enter the building.

Based on sensitivity evaluation conducted by EPA (EPA Soil Screening Guidance, May 1996) the four most important factors affecting the average long-term building concentration are: 1) building ventilation rate; 2) source-building separation; 3) soil permeability to vapor flow; and 4) source depth. A variety of transport models exist to assess this pathways. It is important to keep in mind that utility lines, sumps, etc. can also provide a conduit for vapor migration. Guidance on how to evaluate this pathway is currently under development.

Indirect Exposure Pathways:

In addition to the direct exposure pathways discussed above exposure can also occur from indirect exposure pathways such as consumption of contaminated food. Consumers of homegrown food products may be of particular concern because exposure resulting from local contamination will be higher. According to data reported in the EPA Exposure Factors Handbook (EPA 1997) an estimated fifty (50) percent of the household in the Midwest maintain vegetable gardens. In households that raise animals or farm nearly sixty (60) percent consume home-produced meats. Consumption of homegrown food products will result in exposure if the plant or animal takes up a portion of contaminant from the soil. Ideally, food concentrations should be measured directly. However, sometimes concentration data cannot be obtained (e.g., future exposure is a concern) and must therefore be estimated from soil concentration data. Methodology for evaluating the risk resulting from ingestion of contaminated food is under development.

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8.4 Risk Characterization

Risk Characterization is the final step in the risk assessment process. In this step, the results of the Hazard Identification, Dose-Response Assessment and Exposure Assessment are integrated to yield quantitative measures of cancer and noncancer risk. The Risk Characterization can be thought of as providing a link between risk assessment and risk management because it presents the numerical estimates of risk posed by the site in a context that can be used by risk managers to make decisions about remediation.

A critical component in the presentation of risk estimates is the discussion of major assumptions, scientific judgments and uncertainties inherent in the numerical risk estimates. The importance of this component cannot be overstated. The discussion of uncertainties should place the numerical estimates of risk and hazard in the overall context of what is known about the site and what is uncertain. The numerical risk estimates should never be interpreted as a characterization of absolute risk but should always be interpreted in the context of the uncertainties.

The numerical estimates of risk in the Risk Characterization should present chemical-specific and medium-specific estimates of risk. These risk estimates should also be combined to yield Cumulative Site Cancer and Noncancer Risks for each Receptor. The Cumulative Site Risks are then compared with specific target risk levels. The result of these comparisons determine whether a condition of Acceptable Risk of harm to human health exists at the site.

This Section of the *Guidance* describes methods for characterizing cancer and noncancer risks and discusses the interpretation of Risk Characterization results including how uncertainties should be addressed.

8.4.1 Absorption Adjustment Factors (AAFs)

The Absorption Adjustment Factor (AAF) is used to account for differences in the absorption of a contaminant under assumed exposure conditions at the site (exposure route and matrix) relative to the absorption of the contaminant under the experimental conditions upon which the dose-response value is based. AAFs are used *in lieu of absorption efficiencies* to ensure that the exposures evaluated at the site are comparable to the toxicity information identified in the literature. The AAF relates the exposure and absorption estimated for the exposure pathway under evaluation to the exposure and absorption in the toxicological study on which the dose-response information is based. The AAF is dimensionless and is chemical and pathway specific. When the toxicity value represents an *administered* dose or concentration, the AAF is calculated as the ratio of the absorption efficiency of the route and medium of the exposure route and medium under consideration and the absorption efficiency of the route and medium of the study used as the basis of the toxicity value. In the case of the dermal exposure pathway the exposure is expressed as an absorbed dose. If the toxicity value is based on absorbed dose no adjustment is necessary. If the toxicity value is based on administered dose it must be adjusted for absorption so that it is consistent with the absorbed dose estimate for the dermal contact exposure pathway.

The reference doses, reference concentrations, slope factors and unit risks used in quantitative risk assessment are typically based upon controlled laboratory experiments in which animal test species are exposed in some manner to the chemical under study. Many important features vary from study to study: the test animal may vary (e.g., mice, rats, rabbits or even humans may be used); the chemical may be administered orally, dermally, via inhalation or injected; and the material may be administered in different

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matrices (e.g., neat, dissolved in oil or mixed with food). At sites, the exposures of concern also vary widely and rarely correspond to the exact conditions under which the toxicity information was derived. Typical site-related exposure pathways include the incidental ingestion of contaminated soil by children and the dermal absorption of a contaminant as a result of contact with contaminated soil.

The AAF is used to adjust the calculated dose (e.g., the potential soil ingestion dose to a child) in such a way that it is comparable to the toxicity information (e.g., derived from a study in which rats were administered by gavage a chemical dissolved in olive oil). Ideally, a AAF should be determined or estimated for a contaminant for each combination of toxicity value and route of exposure. This means that multiple AAFs may be required in order to conduct the quantitative risk assessment. To estimate an AAF, two factors must be identified:

- the absorption efficiency for the contaminant via the route and medium of exposure being evaluated for the site, and
- the absorption efficiency for the route and medium of exposure in the experimental study which is the basis of the dose-response value for the contaminant in question.

Thus, the absorption adjustment is based on these two absorption efficiencies. Typically, two different types of adjustments are done. One involves adjusting the site exposure for differences in absorption efficiency between the route and medium at the site and the route and medium utilized in the toxicity study. The second adjustment involves adjusting the toxicity value based on administered dose for absorbed dose when assessing risk from a dermally absorbed dose.

Typically, the exposure from incidental ingestion of soil, ingestion of food and inhalation of contaminants in soil estimates a potential dose. The potential dose is analogous to an administered dose in a toxicity study. If the absorption efficiency for the contaminant via the route and medium of exposure at the site differs from the absorption efficiency for the contaminant in the toxicity study an absorption adjustment should be made. Likewise, the toxicity value is typically based on an administered dose but the dermal exposure pathway evaluation results in an estimate of *absorbed* dose. The toxicity value based on administered dose must be adjusted for absorption before it can be utilized to calculate risk posed by the dermal exposure pathway dose.

The risk assessor is reminded that it is very important to determine whether the toxicity value is based on an absorbed or administered dose. An example of the absorption adjustment calculations is presented in Table 8.3.

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Table 8.3 Example of Absorption Adjustment

The oral reference dose for Contaminant X is 0.003 mg/kg-day. The oral slope factor for Contaminant X is 20 per mg/kg-day. The toxicity values are based on administration of contaminated drinking water to rats. Based on laboratory studies the oral absorption from drinking water has been estimated to be approximately 80%. Bioavailability studies have indicated that the oral absorption efficiency of Contaminant X in soil is approximately 40% (i.e., half of the oral absorption efficiency in water).

Non-Cancer Risk Evaluation:
Incidental Soil Ingestion Exposure - To incorporate this information into the risk estimate the incidental soil ingestion exposure (mg/kg-day) should be multiplied by 0.5 (i.e., 40%/80%) before it is utilized in estimating the hazard quotient for ingestion of soil for Contaminant X. *Note: in the absence of absorption efficiency information no adjustment for efficiency differences is made.*

Dermal Exposure - To incorporate this information into the risk estimate for dermal exposure the toxicity value (i.e., the reference dose) must be multiplied by 0.8 (i.e., 80%) to adjust the reference dose for absorption. The adjusted reference dose is then utilized in estimating the hazard quotient for dermal exposure to Contaminant X. *Note: in the absence of absorption efficiency information a default absorption efficiency of 90% is used to adjust the oral reference dose. If the actual absorption efficiency is significantly lower the default will underestimate the risk.*

Cancer Risk Evaluation:
Incidental Soil Ingestion Exposure - To incorporate this information into the risk estimate the incidental soil ingestion exposure (mg/kg-day) should be multiplied by 0.5 (i.e., 40%/80%) before it is utilized in estimating the excess cancer risk from ingestion of soil for Contaminant X. *Note: in the absence of absorption efficiency information no adjustment for efficiency differences is made.*

Dermal Exposure - To incorporate this information into the risk estimate for dermal exposure the toxicity value (i.e., the oral slope factor) must be divided by 0.8 (i.e., 80%) to adjust the slope factor for absorption. The adjusted slope factor is then utilized in estimating the excess cancer risk from dermal exposure to Contaminant X. *Note: in the absence of absorption efficiency information a default absorption efficiency of 90% is used to adjust the oral slope factor. If the actual absorption efficiency is significantly lower the default will underestimate the risk.*

8.4.2 Noncancer Risk

The measure used to describe the potential for noncarcinogenic health effects from an individual contaminant is a Hazard Quotient (HQ). The HQ is the ratio of a receptor's dose level to the *"acceptable"* (or "safe") dose level. A Hazard Quotient of 1 or less indicates that the receptor's exposure is equal to or less than the allowable exposure level. A HQ of greater than 1 indicates that noncancer health effects could occur, and cannot be ruled out. It does not mean that noncancer effects *will* occur. Uncertainty inherent in most RfDs/RfCs precludes identifying a specific dose above which adverse effects are likely *and* below which effects are unlikely. Accordingly, the probability of an effect cannot be quantified from a HQ, however, the likelihood of an effect increases as the exposure level (and therefore the HQ) increases. The chronic target noncancer risk level is a Hazard Quotient of 0.2 for individual contaminants. Over the course of a chronic exposure period multiple other sources of exposure exist and therefore the risk posed by a single contaminant in a single media (soil) at a single site is allowed to account for only a fraction of the total safe dose. The subchronic and acute target risk level is a Hazard Quotient of 1. The subchronic HQ is not conservative . The severity and reversibility of the toxic effect, the nature of the site exposure, and the potential for non-site related exposure should be considered to determine if the default subchronic HQ is adequately protective.

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The uncertainty inherent in RfDs/RfCs for different contaminants differs both qualitatively and quantitatively. Therefore, for different substances, the probability of an effect increases at different rates. The actual shape of the dose-response curve is often not known or not available from the toxicity databases commonly utilized. A HQ of 20 for one substance may indicate a very high probability of an effect, but may represent only a moderate probability of an effect for another chemical. In interpreting the HQ, one must consider the appropriateness of the exposure assumptions and the basis of the toxicity information used to develop the RfD (e.g., data gaps, severity of effect). As a general rule, the greater the HQ is above 1, the greater the level of concern.

In its most general form, the Hazard Quotient associated with a contaminant via a given route of exposure is calculated as:

$$HQ = \frac{ADD}{RfD}$$

or, for inhalation exposures,

$$HQ = \frac{ADC_{air}}{RfC}$$

Where:

HQ	=	The Hazard Quotient associated with exposure to the contaminant via the specified route of exposure.
ADD	=	The estimated Average Daily Dose of the chemical via the specified exposure route (mg/kg/day). (Note: the oral dose must be modified, if appropriate, for absorption efficiency differences between the site media and the toxicity study media)
RfD	=	The oral Reference Dose or appropriate substitute toxicity value identified for the chemical of concern (mg/kg/day). (Note: this must be modified, if appropriate, for absorbed dose when evaluating ADD from dermal exposure)
ADC	=	The estimated Average Daily Concentration of the contaminant in air (mg/m^3 or $\mu g/m^3$)
RfC	=	The Reference Concentration or substitute toxicity value identified for the contaminant of concern (mg/m^3)

The ADD/ADC parameter in the equations above are calculated from the Exposure Concentration using exposure assumptions consistent with the Exposure Scenarios developed for each receptor being evaluated. Section 8.3.3 describes the process for calculating a receptor's ADD and ADC. If the exposure calculations are being performed using a probabilistic analysis, the risk assessor must identify the dose or concentration associated with the 95th percentile estimate of exposure. This dose or concentration should be compared with the toxicity value (e.g., RfD) identified following the methodology presented in Section 8.2 Toxicity (Dose-Response) Assessment. The RfD, RfC or other measure of allowable dose or exposure (denominators in above equations) will typically be the EPA Reference Dose (RfD) for most exposure routes or the EPA Reference Concentration (RfC) for air exposures.

If any of the contaminant-specific HQs exceeds the acceptable target risk level, then the Risk Characterization must conclude that the site contaminant poses a potentially unacceptable risk of harm to human health based on the risk of noncancer health effects. It is important to calculate separate HQs for acute, subchronic or chronic exposures if these have been identified as exposure periods of concern in the development of exposure scenarios.

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At sites it is common to have situations where a receptor may be exposed to a contaminant through multiple exposure pathways, such as ingesting contaminated soil, absorbing the material following dermal contact with contaminated soil, and ingestion of contaminated ground water. In such cases, the doses of a contaminant received via different routes of exposure are assumed to be additive unless there is evidence otherwise. The Hazard Index (HI) is the measure of the cumulative noncarcinogenic impact that the site has on a particular receptor group. The HI accounts for exposures that a receptor may receive from multiple contaminants which affect similar target endpoints (i.e., organ system impacted by adverse health effects) and multiple exposure routes. The HI is typically calculated by assuming the effects of multiple contaminants will be additive. This may result in an under- or overestimation of noncancer risk. Dichlorobenzenes have been shown to alter the hepatoxicity of each other (Mumtaz, et al., 1993). Acetone, isopropanol, ethanol and chlordecone are known to increase the severity of liver injury induced by carbon tetrachloride. PCBs are enzyme-inducing agents which can increase the hepatoxicity of other chemicals. If adequate information regarding antagonistic or synergistic effects of multiple contaminants is available it must be included in the risk characterization. The impact of possible interactions between multiple contaminants must be discussed in the uncertainty section.

The procedure for segregating HIs by target endpoint may not be simple and should be performed by a toxicologist. If the segregation is done improperly, an under- or overestimate of the true hazard could result. Segregation of HIs requires identification of the major health endpoints of each contaminant, including effects observed at higher doses than the critical effect on which the toxicity value is based. This is because the additive impacts could be important for other health endpoints that are only expected at higher doses.

Each target endpoint-specific HI should be compared with the Cumulative Noncancer Target Risk which is a HI equal to 1. If any of the target endpoint-specific HIs exceeds one, then the Risk Characterization must conclude that the site poses a potentially unacceptable risk of harm to human health based on the risk of noncancer health effects. Keep in mind that there may be multiple target endpoints associated with exposure to a given contaminant.

Separate HIs should be calculated for acute, subchronic or chronic exposures that have been identified as exposure period of concern for the site. As shown by the following two equations, the cumulative HI for each target endpoint can be calculated by summing all contaminant-specific HQs across all exposure pathways of concern.

$$HI_{\text{target endpoint specific}} = \sum \sum HQ_{\text{(contaminant specific, pathway-specific)}}$$

Initially, the risk assessor may choose to calculate a *Screening Hazard Index* for a given receptor group based on all contaminants of concern at the site for all relevant exposure pathways regardless of toxicity target endpoint. A HI calculated in this way will provide a quick, conservative estimate of the true HI because it treats as additive, different toxic effects from multiple contaminants acting on different organ systems by different mechanisms of action. If the screening hazard index is less than 1 there is no need to conduct a target endpoint specific evaluation.

If the screening HI exceeds 1, the risk assessor should then calculate separate HIs for contaminants with similar target endpoints. Separate screening HIs should be calculated for different exposure periods (i.e., chronic, subchronic, acute). The documentation of the Risk Characterization must clearly present all mathematical equations used to calculate Cumulative Excess Cancer Risks.

8.4.3 Cancer Risk

The potential for carcinogenic (i.e., nonthreshold) health effects is characterized as the Excess Lifetime Cancer Risk (ELCR). The ELCR represents the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. For a given contaminant, the estimated ELCR is the product of the receptor's quantified dose and a measure of carcinogenic potency. The typical measures of carcinogenic potency are the EPA Cancer Slope Factor (SF) for most exposure routes and the Unit Risk (UR) for inhalation.

In its basic form, the ELCR associated with exposure to a given chemical via a particular exposure pathway is estimated as follows:

$$ELCR = LADD \times SF$$

or, for inhalation exposures,

$$ELCR = LADC \times UR$$

Where:

ELCR	=	The Excess Lifetime Cancer Risk associated with exposure to the chemical via the specified route of exposure.
LADD	=	The estimated Lifetime Average Daily Dose of the chemical via the specified exposure route (mg/kg-day). (Note: the oral dose must be modified, if appropriate, for absorption efficiency differences between the site media and the toxicity study media).
SF	=	The Cancer Slope Factor identified for the chemical, appropriate to the specific exposure pathway ($(mg/kg/day)^{-1}$) (Note: this must be modified, if appropriate, for absorbed dose when evaluating ADD from dermal exposure).
LADC	=	The estimated Lifetime Average Daily Concentration of the contaminant in air (ug/m^3).
UR	=	The Unit Risk for the particular chemical of concern ($(ug/m^3)^{-1}$).

The LADD or LADC parameters in the equation above are calculated from the Exposure Concentration using exposure assumptions consistent with the exposure scenarios developed for each receptor being evaluated. Section 8.3.3 describes the process for calculating a receptor's LADD or LADC.

If the risk calculations are being performed using a probabilistic analysis, the risk assessor must identify the dose or concentration associated with the 95th percentile estimate of exposure. This dose or concentration should be compared with the toxicity value identified following the dose/response section. This ELCR is then compared with the Chronic Cancer Risk Limit of 1×10^{-5} or Subchronic Cancer Risk Limit of 1×10^{-6} in order to determine whether the site poses an unacceptable risk of harm to human health based on the risk of cancer health effects.

At sites it is common to have situations where a receptor may be exposed to a contaminant through multiple exposure pathways, such as ingesting contaminated soil, absorbing the material following dermal contact with contaminated soil, and ingestion of contaminated ground water. In such cases, the doses of a contaminant received via different routes of exposure are assumed to be additive unless there is evidence otherwise. The cumulative cancer risk must be estimated for all Class A and B carcinogens (i.e., chemicals classified by EPA as being known human carcinogens and probable human carcinogens). For Class C Carcinogens (i.e., those classified by EPA as being possible human carcinogens), the available toxicity data may

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be insufficient to quantify cancer risks. If a cancer potency factor exists for a Class C carcinogen the cancer risk should be quantified in the same manner at Class A or B carcinogens. If a cancer potency factor does not exist for a Class C carcinogen the risk is calculated based on the noncancer risk methodology with the addition of an extra uncertainty factor. This approach is consistent with EPA and MDH methodology utilized for determining drinking water criteria for Class C carcinogens.

The cumulative excess lifetime cancer risk is typically calculated by assuming simple additivity. This may result in an under- or overestimation of cancer risk. If adequate information regarding antagonistic or synergistic effects of multiple contaminants is available it must be included in the risk characterization. The impact of possible interactions between multiple contaminants must be discussed in the uncertainty section.

The cumulative ELCR represents the cumulative carcinogenic impact that the site has on a particular receptor group. The cumulative ELCR should account for exposures that a receptor may receive from multiple contaminants and multiple exposure pathways. As shown by the following equations, the cumulative ELCR can be calculated by summing all contaminant-specific ELCRs across all exposure pathways of concern. This is represented by the following equations:

$$\textit{Cumulative ELCR} = \Sigma\,\Sigma\, ELCR_{\textit{(contaminant specific, pathway-specific)}}$$

The Cumulative ELCR should be compared with the Cumulative Chronic Target Cancer Risk (an ELCR equal to one-in-one hundred thousand or 1×10^{-5}) or the Cumulative Subchronic Target Cancer Risk (an ELCR of 1×10^{-6}). If the Cumulative Excess Lifetime Cancer Risk exceeds the target risk then the Risk Characterization must conclude that the site poses a potential unacceptable risk of harm to human health based on the risk of cancer health effects. The documentation of the Risk Characterization must clearly present all mathematical equations used to calculate Cumulative Excess Cancer Risks.

8.4.4 Non-Soil Related Exposure and Risk Characterization

The overall characterization of risk of harm to human health should include an evaluation of all appropriate exposure pathways. Completed exposure pathways that are not dealt with by this draft Guidance document (e.g., drinking water, indoor air, etc.) should be evaluated. See Draft Guidance documents for appropriate methodology.

8.4.5 Combinations of Tiers for Risk Characterization of Portions of Sites

The ability to apply different tier-based remedial actions for portions of a site may allow the expedited cleanup of areas which are more readily addressed while problems which are more complex or difficult to assess/remediate can be dealt with on a different schedule. Remedial actions for a portion of a site may also be an attractive option in situations where the site includes more than one property. Different tier-based remedial actions submitted for a *portion* of a site may be problematic, as the risk criteria are expressed as limits on cumulative risk (i.e., the risk to a receptor received from all applicable exposure pathways and contaminants). Therefore, by breaking up a site into discrete areas and assessing them separately, the *cumulative* impact of the contamination may not be adequately addressed.

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If Tier 3 SRVs are used to characterize risk at one or more portions of the site particular attention must be paid to how the Tier 3 SRV assessment is conducted and how the results are interpreted in order to insure that the Cumulative Risk Limits are met for the entire site. In other words, Tier 3 risk characterizations conducted in support of a remedial action for a portion of a site must still address the issue of Cumulative Risk. Specifically, each Tier 3 SRV risk characterization should either:

1. evaluate all potential exposure pathways for each identified receptor of concern, even those exposures occurring at points beyond this portion of the site.; or
2. demonstrate that the risks from the exposure pathways evaluated are sufficiently below the Cumulative Risk Limits that the exposures associated with *this* portion of the site would not be significant *even if* the same receptor were exposed to contamination at other portions of the same site. If the potential risks associated with this portion of the site are notable then the additional exposures experienced by that receptor must be evaluated using the cumulative risk approach.

This approach for characterizing risk to support a remedial action for a portion of a site allows different risk characterization methods to be used for the different portions of the site, it eliminates the need for a final "comprehensive" risk characterization of the site after all the remedial actions for the different portions have been submitted, and this approach addresses the requirement to meet the cumulative risk limits.

8.4.6 Risk Characterization Conclusions

The documentation of the Tier 3 SRV Human Health Risk Characterization must contain a clear statement of whether or not a condition of Acceptable Risk of harm to human health exists. A condition of Acceptable Risk of harm to human health exists at the site if:

- no Exposure Concentration of contaminant is greater than an applicable risk-based criteria; *AND*
- no Cumulative Lifetime Cancer Risk calculated is greater than the Cumulative Lifetime Cancer Target Risk (1×10^{-5} for chronic exposure and 1×10^{-6} for subchronic exposure); *AND*
- no Individual Contaminant-specific Noncancer risk is greater than the individual receptor noncancer target risk limit (e.g., 0.2 for chronic exposure); *AND*
- no Cumulative Noncancer Target Endpoint risk is greater than the Cumulative Receptor Noncancer Target Risk Limit (i.e., HI less than or equal to 1 per target endpoint).

Note that all criteria must be met in order for a conclusion to be reached that the site does poses an Acceptable Risk of harm to human health. If the condition of Acceptable Risk has been achieved through implicit or explicit assumptions that the use of the property is such that exposure to contaminated soil is limited this must be clearly articulated in the risk characterization documentation. Institutional controls are recommended to ensure that the site situation (e.g., limited exposure) does not change without an accompanying evaluation of risk. If institutional controls (including engineering controls, monitoring and maintenance) are utilized to limit or interrupt exposure an evaluation of the potential for the control to fail should be considered. The magnitude of the potential risk posed as a result of control failure should be evaluated and considered in the remedial response action decision.

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8.5 Uncertainty Analysis

The Uncertainty Analysis is a critical component of the Risk Characterization. The Uncertainty Analysis should contain a narrative section which places the numerical risk estimates in the overall context of what is known and what is not known about the site and in the context of decisions that the site manager will make about remediation. The Uncertainty Analysis does not modify the risk characterization conclusions themselves. However, a Risk Characterization is not considered complete unless the numerical risk estimates are accompanied by an explanation which interprets and qualifies the risk results.

Inherent in all risk assessments are many assumptions, scientific judgments and a wide variety of uncertainties, which can be introduced at each step in the risk assessment process. The numerical risk estimates calculated in the Risk Characterization should never be interpreted as absolute estimates of the risk of harm to health.

General sources of uncertainty in the risk assessment which should be discussed in the Uncertainty Analysis include, but are not limited to:

- Identification of all site-related contaminants in sampling of the environmental media at the site.
- Development of exposure scenarios and selection of exposure assumptions used in dose calculations.
- Determination of exposure areas and estimates of exposure concentrations.
- Quantitative toxicological data (or lack of data) used to develop cancer and noncancer toxicity values.

Although the Uncertainty Analysis may be a qualitative evaluation of uncertainties affecting the risk estimates, the risk assessor should attempt to describe the magnitude and direction of effect that a particular area of uncertainty is likely to have on the numerical risk estimates.

Probabilistic analysis can be a powerful tool for expressing the uncertainties in risk assessments. The MPCA/SRS staff are currently evaluating the use of probabilistic methods as tools in sensitivity and uncertainty evaluations. Adequate distributional data must exist before application of these methods can be considered.

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Tier 3 Attachment - - Tier 3 Risk Characterization Scope of Work Framework

This framework is designed to emphasis the importance of planning when using Method 3 to characterize risk at a site. The Tier 3 approach uses site specific information to characterize risk. As a result, each Tier 3 risk characterization will be somewhat unique. It is most efficient to discuss the planned approach at the front end of the process prior to actually doing the risk characterization. Placing the emphasis on planning, including involvement of SRS staff, early in the process should aid in providing higher quality risk characterizations and be less costly and more time efficient.

The Scope of Work should seek to provide as much information as possible. The Scope should clearly identify certain activities such as categorizing soil and identifying current and reasonably foreseeable property use and activities at the site and the surrounding area. Whenever it is possible to provide information up front it should be done. There may be some activities which will only be discussed in the Scope of Work, and not actually performed until the risk assessment itself is done. These proposed activities include such things activities as providing toxicity profiles or actually conducting the risk characterization. The planned approach for those activities should be clearly described and approved.

The following is designed to be an outline and should be used in conjunction with current accepted risk assessment practices.

1. PRELIMINARY STEPS

A. Identify Planned Use of the Site and the Surrounding Area.

The Scope of Work should identify the current and reasonably foreseeable uses of the site and the surrounding area. If the use of an Institutional Control is planned to maintain the property use this should be discussed. It is important to remember that Institutional Controls can not always be utilized to limit exposures, therefore, the Scope should clearly indicate which exposure scenarios (current or future) are affected by the Institutional Control. If institutional controls (including engineering controls, monitoring and maintenance) are utilized to limit or interrupt exposure an evaluation of the potential for the control to fail should be considered. The magnitude of the potential risk posed as a result of control failure should be clearly articulated. Note that property owners concurrence may be required to implement an institutional control on the property.

B. Establish Background.

The Scope of Work should identify how background values will be established for the site. This will include actual environmental data collected in the vicinity or the site. See Section 7.3 “Comparing Site Concentrations to Background Levels”.

2. Hazard Identification

Identify Contaminants of Potential Concern (COPCs).

The Scope of Work should contain a list of COPCs. The Scope should identify any contaminants at the site which will <u>not</u> be carried through the risk assessment process and include the rationale for eliminating these contaminants. If the final list is not yet available, the Scope should include a tentative list which includes all the contaminants detected at the site. See Section 5.2 “Selection of Contaminants of Potential Concern”.

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3. Toxicity (Dose-Response) Assessment

The toxicity (dose-response) assessment is the portion of the report which discusses the observed effects in humans and animals associated with exposures to the COPC. Toxicity Profiles should be prepared for each COPC identified at the site. The toxicity profiles of the Scope should discuss both threshold (non-cancer) and non-threshold (cancer) effects. The Scope should clearly state what sources will be used to identify toxicity information. The primary sources for this information are the Minnesota Department of Health, the Integrated Risk Information System (IRIS) and the Health Effects Assessment Summary Tables (HEAST). These sources should be utilized when the information needed is available there, otherwise the Scope should identify all sources which will be accessed. In the case where a Tier 1 or 2 SRV exists for the contaminant, it is not necessary to prepare a full toxicity profile. A descriptive summary of the health effects is sufficient if the same toxicity value is utilized. The Scope of Work should identify which contaminants will require toxicity profiles and which will be discussed through the use of descriptive summaries. See Section 8.2.3 "

4. Exposure Assessment

A. Exposure Profiles

An exposure profile identifies how exposures may occur. See Section 8.3.1. The Scope of Work should contain a narrative description of each exposure profile for the site and surrounding area if appropriate. In addition, the information in the narrative should be summarized in tables for easy reference. The exposure profiles should clearly identify all potential:

1. human receptors;
2. exposure points/areas for each receptor
3. exposure routes
4. exposure pathways

B. Exposure Assumptions

The Scope of Work should identify the exposure assumptions which will be made in the risk assessment. The exposure assumptions made should be realistic and health protective, based upon current and reasonably foreseeable conditions.

C. Quantitative Estimates of Exposure

After the Scope of Work has described the exposure profiles for the site, the potential exposures to the receptors must be quantified. The Scope should identify the exposure duration and exposure factors which will be used to estimate the dose of contaminant experienced by a potential receptor. Exposure factors include but are not limited to:

* Concentration of the contaminant
* Contact Rates (e.g., ingestion rates, surface area exposed, etc.)
* Body Weight

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* Frequency of Exposure
* Duration of the Exposure Period
* Absorption Adjustment Factors
* Averaging Time
* Units Conversion Factors

The equations to be used to calculate average daily exposures from contamination in air and average daily doses from contamination in all other media should be provided in the Scope. See Section 8.3.3.

D. Exposure Concentrations

The Scope of Work should identify how exposure concentrations will be calculated. If exposure concentrations are presented in the Scope, sufficient detail should be provided so that it is clear as to how the specific exposure concentrations were calculated. See Sections 8.3.3.4 and 8.3.3.5.

5. Risk Characterization

See Section 8.4 for discussion.

A. Non-Cancer Risk

The Scope of Work should state that for each human receptor non-cancer risks shall be calculated and compared to the individual acceptable Hazard Quotient (0.2 for chronic exposure and 1 for subchronic and acute) and the cumulative Hazard Index of 1 per target endpoint.

B. Cancer Risk

The Scope of Work should state that for each human receptor identified cumulative cancer risks shall be calculated and compared to a cumulative cancer risk limit of one-in-one hundred thousand (i.e., 1E-5) for chronic exposure and one-in-a-million (i.e., 1E-6) for subchronic exposure.

C. Applicable Criteria

The Scope should identify any applicable criteria which exposure concentrations will be compared to.

D. Summary Tables

The Scope must should state that a clear summary of all non-cancer and cancer risks each receptor group for both current and reasonably foreseeable uses will be presented in the Risk Assessment Report.

6. Uncertainty Analysis

The Scope of Work should identify the uncertainties in the risk assessment which will be discussed. See Section 8.5. The types of uncertainties to be discussed should be identified. Some typical areas of uncertainty encountered in the risk assessment process include:

* adequacy of the site characterization
* adequacy of the sampling plan
* quality of the analytical data

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* accuracy of any modeling
* accuracy of the assumptions concerning frequency, duration and magnitude of exposures
* availability and accuracy of the toxicity data
* treatment of available analytical data
* accuracy of any probabilistic analysis used

7. Characterization of Risk to Safety

The Scope of Work should state that the risk of harm to safety will be characterized. The Scope should identify any applicable or suitably analogous safety standards.

8. Public Welfare Risk Characterization

The Scope of Work should state that the risk of harm to public welfare posed by the site will be evaluated. The Scope may contain such factors as deemed appropriate to evaluate this potential harm, such as the presence of nuisance conditions.

9. Conclusions

The Scope of Work should state that the risk assessment report will contain a section concluding whether or not an acceptable risk of harm to human health, safety, or public welfare exists.

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GLOSSARY

Absorption Adjustment Factor (AAF)	factor which adjusts the dose estimate in consideration of the absorption efficiencies of the study which is the basis of the toxicity information and the absorption efficiency of the route of exposure of concern. It is not itself an absorption efficiency.
Acute exposure	One dose or multiple doses occurring within a short period of time (typically 24 hours or less)
Adherence Factor (AF)	Fraction of soil adhered to the skin.
Agricultural property use	Use of property for farming. Specific uses could include: cultivating of soil; growing and harvesting of any agricultural, horticultural, or floricultural commodity; dairying; raising of livestock, bees, fish, fur-bearing animals, or poultry; and turf and tree farming. Agricultural property use does not include property used for commercial storage, processing, distribution, marketing, or shipping operations.
Air diffusivity	A constant used to describe diffusion of chemical in air.
Air-filled porosity	The fraction of soil porosity filled by air.
ADC	Average daily concentration (mg/m^3 or $\mu g/m^3$) during the exposure period.
ADD	Average daily dose (mg/kg-day) during the exposure period.
Background	Environmental contaminant conditions representative of an area which has not been impacted by contamination from the site, and which represent natural, ambient conditions.
Bioavailability	The degree to which a material in environmental media may be absorbed or incorporated by an organism.
Bioconcentration	process by which there is a net accumulation of a chemical directly from an exposure medium into an organism
Bulk density	ratio of the dried mass of the soil/sediment sample to its field volume.
Carcinogen	An agent capable of inducing a cancer response
Chronic exposure	Multiple exposures occurring over an extended period of time or a significant fraction of an individuals lifetime.

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Commercial property use Use of property which is characterized by extremely varied and broad commercial use, encompassing everything from day care centers and schools to gas stations and warehouses. The physical setting of commercial properties and the activities which workers and the general public engage in at these sites are also extremely variable. This property use designation has been divided into unrestricted and restricted subcategories based on exposure potential.

Unrestricted commercial property use Use of property for any commercial use including to house, educate, or provide care for children, the elderly, the infirm, or other sensitive subpopulations. Unrestricted commercial use allows for a higher exposure potential which approximates a residential setting. This subcategory of commercial property use is usually, but not always, located in or near residential areas and, therefore, may be used by other populations for purposes other than the intended commercial use (e.g., recreational). Specific uses could include, but are not limited to: day care centers; any form of educational facility; churches; social centers; hospitals; elder care facilities; and nursing homes.

Restricted commercial property use Commercial use of property where access or occupancy by non-employees is less frequent or is restricted, including a wide variety of uses, ranging from no public access and both outdoor and indoor activities (e.g., large-scale warehouse operations), to limited public access and indoor office worker activities (e.g., bank, dentist office). The on-site worker represents the most heavily exposed human receptor. In general, restricted commercial property use excludes the kinds of facilities specifically listed under unrestricted commercial use.

Contaminant see "pollutant."

Contaminant of Potential Concern A material detected at a hazardous waste site which has the potential to adversely affect receptors due to its concentration, distribution, and/or mode of toxicity.

Cumulative Site Cancer Risk The sum of the estimated excess lifetime cancer risks resulting from exposure to all contaminants at or from a site, at all exposure points identified. Usually expressed in terms of risk for a given receptor.

Cumulative Site Non-Cancer Risk A calculation of the possibility of non-cancer health effects associated with exposure to all contaminants at or from a site at all exposure points identified. Usually expressed in terms of a risk for a given receptor. The HI is a measure of the Cumulative Site Non-cancer Risk.

Dose-response relationship A relationship between the amount of an agent (either administered or absorbed) and changes in certain aspects of the biological system (usually toxic effects), apparently in response to that agent.

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Engineering controls Physical actions, structures or improvements (e.g., caps, vaults, fences, ground water gradient, methane gas capture/venting systems) that reduce, control or interrupt exposure and/or migration of contamination.

Excess Lifetime Cancer Risk(ELCR) The product of exposure and carcinogenic potency. The resulting risk estimate is an upper-bound probability that an individual's average lifetime to a contaminant could result in cancer.

Exposure Pathway The course a chemical or physical agent takes from a source to an exposed organism. If the exposure point differs from the source, transport/exposure media (i.e., air, water) are also included.

Exposure Area/Point Location of potential contact between a human or environmental receptor and a release of contaminants. An exposure may occur within an area or at a single discrete point.

Exposure Concentration The concentration of contaminants in a specific medium which a human or environmental receptor may contact at an exposure area/point.

Exposure Route A mechanism by which a contaminant comes into contact with a receptor, including, but not limited to, ingestion, inhalation, dermal absorption and transpiration.

Facility A facility as defined in Minn. Stat. § 115B.02, subd. 5, and includes any site or area where a hazardous substance, or a pollutant or contaminant, has been deposited, stored, disposed of, or placed, or otherwise came to be located.

Fraction of organic carbon (f_{oc}) Fraction of organic carbon to the total weight of the soil sample, expressed as a decimal. See *soil-organic carbon partition coefficient (k_{oc})* and *total organic carbon (TOC).*

Hazard Index (HI) calculation of the possibility of non-cancer health effects as the result of exposure to contaminants. The calculation consists of summing the HQs for multiple substances with the same or similar toxic endpoints. The HI = HQ1 + HQ2 + ...+ HQn

Hazard Quotient (HQ) ratio of a single substance exposure level to a reference dose for that substance derived from a similar exposure period (e.g., D1/RfD1, where D is the daily dose (or air concentration) for a particular contaminant, and the RfD is the reference dose (or air reference concentration, RfC)). Also see: *target risk level*.

HEAST U.S. EPA's Health Effects Assessment Summary Tables.

Hot Spot discrete area of a hazardous waste site characterized by contaminant levels substantially higher than those of the surrounding area of the site.

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Industrial property use Use of property for industrial purposes. MPCA may consider property use to be considered "industrial" for risk characterization where property use will not allow public access to areas where residual contamination may be present in soil. In risk evaluation scenarios, potential occupational exposure assumptions are used in the calculation of cleanup levels. Industrial property uses generally include, but are not limited to, the following types of uses: public utility services, rail and freight services, raw storage facilities, refined material storage facilities, and manufacturing facilities engaged in the mechanical or chemical transformation of materials or substances into new products.

Institutional control As defined by Minn. Stat. § 115B.02, subd. 9a. Legally enforceable restrictions, conditions or controls on the use of real property, ground water or surface water located at or adjacent to a facility where response actions are taken that are reasonably required to assure that the response actions are protective of public health or welfare or the environment; includes *real property notification/affidavit*. Examples include zoning restrictions and well advisories.

IRIS US EPA's Integrated Risk Information System.

Kd See *soil-water partition coefficient*.

Koc See *soil-organic carbon partition coefficient*.

LADC Lifetime average daily concentration (mg/m^3 or $\mu g/m^3$).

LADD Average daily dose (mg/kg-day).

Lowest Observed Adverse Effect Level (LOAEL) Lowest exposure level at which there are statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

Lowest Observed Effect Concentration (LOEC) Lowest concentration of a chemical in a toxicity test that causes an effect that is statistically or biologically significantly different from the controls

Method Detection Limit (MDL) Minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, and is determined from the analysis of a sample in a given matrix type containing the analyte. (40CFR Part 136 App. B)

Modifying Factor (MF) uncertainty factor which is greater than zero and less than or equal to ten; the magnitude of the MF depends upon the professional assessment of scientific uncertainties of the study and database not explicitly treated with the standard uncertainty factors (e.g., the completeness of the overall database and the number of species tested); the default value for the MF is 1.

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NAPL

Non- Aqueous Phase Liquid NAPL. The free product, or non-dissolved, portion of the contaminants. A dense non-aqueous phase liquid (DNAPL) is denser than water and tends to sink through saturated porous media. A light non-aqueous phase liquid (LNAPL) is less dense than water and tends to float at the water table.

No Observed Effect Concentration (NOEC)

The highest concentration of a chemical in a toxicity test that causes effects that are not statistically significantly different from the controls

No observed adverse effect level (NOAEL)

The exposure level at which there are not statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control group.

Planned use of the property

means the current use of the property, if that use (or reuse) will be continued for a foreseeable period of time, or a new use involving activities that will continue for the foreseeable future. In most cases the term "planned use of the property" implies a long-term commitment or expectation about how the property will be used as determined by current or future owners or actions of local units of government, government agencies or other organizations representing the community where the property is located, such as property use or economic development plans or zoning ordinances. A foreseeable period of time means the period of time during which requirements to maintain the necessary institutional controls, engineering controls as part of the remedy and/or other requirements such as compliance monitoring are necessary to protect public health and the environment. In some cases, the term planned future use may also encompass short-term development or redevelopment activities such as demolition, excavation and construction.

The concept of planned use generally refers to human use of the property, except where the use is specifically for ecological or environmental purposes, such as a nature preserve or a wildlife management area. Where habitat exists, exposures to ecological receptors are likely to be similar regardless of use (i.e., there is no residential or industrial exposure scenario for ecological receptors). Property use will influence ecological exposure primarily by affecting the presence or amount of habitat on a site. Therefore, ecological risk or protectiveness of remedies for the environment must be evaluated on a site-specific basis, independent of human property use scenarios.

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Pollutant — as defined in Minn. Stat. § 115B.02, subd. 13, any element, substance, compound, mixture, or agent, other than a hazardous substance, which after release from a facility and upon exposure of, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in the organisms or their offspring. Pollutant does not include natural gas, natural gas liquids, liquefied natural gas, synthetic gas usable for fuel, or mixtures of such synthetic gas and natural gas.

Practical Quantitation Limit (PQL) — the smallest concentration of an analyte for which quantitative results may be obtained with a specified degree of confidence. Considered the lowest level achievable among laboratories within specified limits during routine laboratory operations. Also called reporting limit (RL).

Property — real property, land, buildings and fixtures and improvements attached to land and buildings and associated legal rights.

Reasonable Maximum Exposure (RME) — the maximum exposure that is reasonably expected to occur. An element of the *risk characterization* procedure.

Receptor — 1) human or non-human organism (or population, community, or ecosystem) that has or has the potential to experience adverse effects from direct or indirect exposure to contaminated media; or 2) location of media point of exposure for a given receptor, as in “drinking water well” or “ground water receptor”.

Recreational property use — use of property for recreational purposes which is characterized by unrestricted access by the public. In site risk characterization, an exposure frequency lower than the residential setting and potential recreational exposure assumptions are used in the calculation of cleanup levels. Recreational property uses generally include, but are not limited to, the following: parks, playing fields, beaches, green spaces, open areas, wildlife management areas, and nature preserves.

Reference Concentration (RfC) — an estimate (with uncertainty of perhaps an order of magnitude or greater) of a continuous inhalation exposure to a human population that is likely to be without an appreciable risk of deleterious noncancer effects.

Reference Dose (RfD) — an estimate (with uncertainty of perhaps an order of magnitude or greater) of a daily exposure level for the human population, that is likely not to result in appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound.

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Release — a release, as defined in Minn. Stat. § 115B.02, subd. 15, and subject to the exceptions set forth therein, and includes any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment which occurred at a point in time or which continues to occur.

Remedy or remedial action — as defined in Minn. Stat. § 115B.02, subd. 16, and subject to the inclusions and exclusions set forth therein, and includes those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance, or a pollutant or contaminant, into the environment. Conducted to prevent, minimize or eliminate the release to protect the public health, or welfare or the environment. See *response action.*

Remove or removal — as defined in Minn. Stat. § 115B.02, subd. 17. Generally includes short-term actions to remove or control a release of a hazardous substance, or pollutant or contaminant in order to reduce risk to public health or the environment.

Residential property use — use of property characterized by use for homes or residences. As used relative to *risk characterization* this property use scenario generally assumes potential residential exposure in the calculation of cleanup levels. Residential property use can be characterized by single-family and/or multiple-family dwellings.

Residual contamination — contamination remaining on site after implementation of a remedial action has been completed.

Response Action — includes removal action and remedial action. See Minn. Stat. § 115B.02, subd. 18.

Responsible party — a person(s) responsible for a release or threatened release of a hazardous substance, or a pollutant or contaminant, as defined in Minn. Stat. § 115B.03. A responsible party who enters a site in the Voluntary Investigation and Cleanup (VIC) Program is also a voluntary party.

Risk characterization — An element of conventional risk assessment procedure. A systematic, scientific assessment of potential adverse health effects resulting from exposure to hazardous agents or situations which uses information from the site characterization.

Risk-based Site Evaluation — RBSE, a process of applying a tiered evaluation scheme based on site specific characteristics and property or surface water use. It extends beyond a risk characterization to include statutory, engineering, economic, social and political factors in making site decisions.

Short-term Hazard — A hazard which would pose a significant risk of harm to health or safety if it were present for even a short period of time.

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Site

1) physical property where a release has occured or the source is located, as well as where remediation may be needed; 2) property or portion of property evaluated for potential environmental impact relative to technical assistance or liability assurance. See *facility* and *release*.

Slope factor

slope of the cancer dose-response curve in the low-dose region. The units of the slope factor are usually expressed as 1/(mg/kg-day). The slope factor represents a plausible upper-bound estimate of the probability of an adverse health-related response per unit intake of a chemical over a lifetime.

Soil bulk density

the ratio of the dried mass of the soil/sediment sample to its field volume.

Soil-organic carbon partition coefficient (Koc)

Koc predicts the degree to which a chemical will bind to the organic carbon fraction in the soil (L/kg). The Koc may be thought of as the soil-water partition coefficient normalized for organic carbon. For organic compounds the Koc may be estimated by dividing the Kd by the fraction of organic carbon in soil (foc). Thus Koc = Kd/foc.

Soil-water partition coefficient (Kd)

Kd is an experimentally derived physical constant that expresses the ratio of the amount of chemical adsorbed to the soil solids to the amount dissolved in the water (L/kg). Kd is a valid prediction of the partitioning between liquid and solid only if the reactions that cause the partitioning are assumed to be fast and reversible. The reversibility of partitioning equilibrium is thought to decrease significantly with older spills. Also known as distribution coefficient.

Soil saturation level (Csat)

The concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached.

Solubility

A physical property of a compound, normally expressed in milligrams per liter, that determines how much of a solute (the contaminant) that the solvent (water) can carry in dissolved form per unit volume.

Subchronic exposure

Multiple exposures occurring over a small fraction of an individual's lifetime (e.g., a period of several months to several years)

Total organic carbon (TOC)

The carbon fraction of the total organic matter of soil. It is the portion of the sample that comes from biologically derived compounds composed primarily of nitrogen, carbon, oxygen, and phosphorous. It may be estimated by multiplying the organic matter concentration by 0.6. See *fraction of organic carbon (foc).*

Total porosity

The ratio of the volume of void spaces in a soil or sediment to the total volume of the sample.

Toxicity Threshold

The dose or exposure below which a significant adverse effect is not expected. Carcinogens are thought to be non-threshold chemicals, to which no exposure can be presumed to be without some risk of adverse effect.

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Toxicity Endpoint — the endpoint of cancer for carcinogens or the organ or physiological system(s) affected by exposure to noncarcinogens.

Uncertainty factor (UF) — One of several, generally 10-fold factors, used in operationally deriving the Reference Dose (RfD) or Reference Concentration (RfC) from experimental data. UFs are intended to account for: (1) variation in sensitivity among the members of the human population; (2) the uncertainty in extrapolating animal data to humans; (3) the uncertainty in extrapolating from data obtained in a study that is of less-than-lifetime exposure; and (4) the uncertainty in using LOAEL data rather than NOAEL data.

Unit Risk — The upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 μg/L in water or 1 $\mu g/m^3$ in air.

Volatile Organic Compounds (VOCs) — Generally, an organic compound with a Henry's Law constant greater than 10^{-5} (atm-m^3/mol), a boiling point less than 180° C, and a molecular weight less than 200 g/mole.

Volatility — A physical property of any compound that indicates its tendency to change to a gas state. It is expressed as vapor pressure (mm Hg) for pure compounds. Henry's Law is used to determine volatility of dissolved compounds.

Volatilization — The conversion of all or part of a liquid or solid into vapor or gas.

Voluntary party — a person who has entered into the MPCA Voluntary Investigation and Cleanup Program. A voluntary party may be either a responsible person or a non-responsible person.

Water Diffusivity — a constant used to describe diffusion of chemical in water.

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APPENDIX 1 EXPOSURE EQUATIONS AND DEFAULT VALUES

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1.0 INTRODUCTION

This Appendix contains the exposure equations and default exposure assumptions used in the exposure assessment to calculate dose. In the absence of site specific, or otherwise justifiable exposure information, the use of default values will result in realistic yet adequately conservative dose estimates. The selection of all exposure assumptions should be described in narrative form, accompanied by a referenced summary table.

It is important to differentiate between site-specific information which can be appropriately used to modify site-specific parameters and professional judgment about the scientific evidence which supports generic assumptions. Modification of MPCA/SRS default exposure assumptions in a site-specific risk assessment will not be allowed unless there is a reasonable basis for site-specific differences. Default values will be revised as new information becomes available.

Most exposure parameters have a range of values. Exposure parameters were chosen with the intent that the combination of variables for a given pathway would result in an estimate of the Reasonable Maximum Exposure (RME). Under this approach some exposure variables represent average values, but when combined with other variables, which are set at an more conservative value, will result in an RME estimate. If the default exposure variables set at the more conservative value are modified downward, other variables would need to be adjusted to a more conservative value to maintain an RME evaluation.

Contact rate, exposure frequency and exposure duration are believed to be the most sensitive parameters in each equation (RAGS, EPA 1989). When adequate distributional data were available the 90th or 95th percentile values were selected for exposure duration. When adequate distributional data were not available for exposure frequency estimates an upper-end estimate was made using available data and professional judgment. Central-tendency or average values were typically utilized for contact rates. As indicated above, if the exposure frequency or duration are adjusted to represent a central-tendency value the contact rate may need to be increased to maintain a RME estimate.

2.0 RESIDENTIAL PROPERTY USE - DIRECT SOIL EXPOSURE PATHWAY EVALUATION

2.1 Residential - Chronic Exposure

2.1.1 General Exposure Factors

There are five exposure factors which recur throughout the equations used to estimate the dose of contaminant experienced by a potential receptor:

- C_{soil}, Contaminant Concentration
- CF, Units Conversion Factors
- ED, Exposure Duration
- BW, Body Weight
- AT, Averaging Time

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These factors are generally used in the same manner regardless of the exposure pathway under investigation, so it is useful to discuss them separately.

2.1.1.1 C_{soil}, Contaminant Concentration

The concentration of the contaminant used to quantify exposure is the Exposure Concentration. The exposure concentration is expressed in terms of mass of the material per unit mass (or volume) of the exposure medium (e.g., mg contaminant/kg soil). The exposure point concentration should *not* be adjusted for receptor exposure frequency, duration, etc. as those factors are generally addressed in the exposure calculations. See Sections 7.4 and 8.3.3.5 of the main text for additional discussion.

2.1.1.2 CF, Units Conversion Factors

The exposure factors and analytical data used for a given calculation may come in several forms. Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units (e.g., mg/kg/day). Use of a units conversion factors (CF) is equivalent to multiplication by one. The numerator and denominator of the factor must be an equivalent quantity expressed in different terms.

2.1.1.3 ED, Exposure Duration

The exposure duration (ED) describes the length of time over which the receptor comes into contact with the contaminant. The exposure duration depends upon the type of activities which lead a receptor to be exposed. Remember that the receptor may be exposed continuously, at regular intervals, or sporadically, depending upon the activity being modeled, so the exposure duration would be the length of time between the first exposure experienced and the last.

As discussed previously, exposure duration is believed to be one of the more sensitive parameters in the exposure equation. In keeping with the RME approach the upper-end estimate was utilized as the default for the duration of chronic exposure. National statistics are available for residential occupancy (US Bureau of Census data). The 90th percentile value for years lived in the current home for the Minneapolis/St. Paul metropolitan area was determined to be 33 years. No statistical data on childhood residential occupancy time are available. For the purpose of calculating the SRVs, children (defined here as infants to 6 years old) are assumed to reside at a single residence (i.e., exposure duration for children is 6 years). This does not appear to be an upper-end estimate for young children (Johnson and Capel, 1992 as cited in Exposure Factors Handbook, EPA 1997).

2.1.1.4 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). When each receptor of concern is identified, the receptor is often described in terms of occupation (resident, construction worker), age (a child age 1 to 6 years) and sometimes gender. The receptor's body weight is dependent upon its age and gender. Since body weight is easily measured, there are numerous summaries of age and gender-specific body

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weights. Table A1.1 provides age-specific body weights for children and adults. The body weights are 50th percentile values for males and females and are presented annually for children and at longer intervals for adults (EPA Exposure Factors Handbook, 1997).

TABLE A1.1 AGE-SPECIFIC BODY WEIGHTS FOR CHILDREN AND ADULTS

AGE (Years)	Mean BW for Females (kg)	Mean BW for Males (kg)	Default BW Recommended (kg)
< 1	8.8	9.4	
1 < 2	10.8	11.8	1 - 2 years: 11 kg
2 < 3	13.0	13.6	
3 < 4	14.9	15.7	
4 < 5	17.0	17.8	
5 < 6	19.6	19.8	≤ 6 years: 15 kg
6 < 7	22.1	23.0	
7 < 8	24.7	25.1	
8 < 9	27.9	28.2	
9 < 10	31.9	31.1	
10 < 11	36.1	36.4	
11 < 12	41.8	40.3	
12 < 13	46.4	44.2	
13 < 14	50.9	49.9	
14 < 15	54.8	57.1	
15 < 16	55.1	61.0	
16 < 17	58.1	67.1	
17 < 18	59.6	66.7	> 6 - 18 years: 43 kg
18 < 25	60.6	73.8	> 6 - 33 years : 58 kg
25 < 34	64.2	78.7	> 18 - 33 years: 70 kg

The receptor body weight (BW, typically expressed in kilograms, kg) must be matched to the age and gender identified in the exposure profile. Since exposure is often assumed to occur over a period of several years, the changes in body weight which might occur during the period of exposure must also be considered. An average body weight is estimated across the age group under consideration. Within a given age/sex combination, there is some variability of body weight for that subpopulation. This variation is well defined, and the distribution of body weights for this subpopulation of concern may be used as part of a probabilistic assessment of exposure. For deterministic evaluations (i.e., evaluations using a point estimate of body weight) the 50th percentile body weigh for the subpopulation under consideration is recommended, unless there is strong evidence that the potentially exposed subpopulation is biased in some manner.

Because body weights changes with age it is necessary to calculate an age-adjusted body weight when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor

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throughout the exposure period or in the case of cancer evaluation a lifetime. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. The results of utilizing a simple age-weighted averaging approach to calculate age-adjusted body weight is shown below:

$$BW_{age-adjusted} = \frac{(15\text{ kg x 6 yrs}) + (43\text{ kg x 12 yrs}) + (70\text{ kg x 15 yrs})}{33\text{ yrs}} = 51\text{ kg}$$

2.1.1.5 AT, Averaging Time

The averaging time (AT) is the time over which the total intake is normalized. For the evaluation of *noncancer risk*, the Average Daily Dose (ADD) calculated should be representative of the exposure received while exposure is on-going (i.e., during the exposure period). Thus the values for exposure period duration (ED) and the averaging time (AT) are equivalent.

The Lifetime Average Daily Dose (LADD) is calculated for the evaluation of *cancer risk*. While the duration of the exposure period (ED) might range from one day to an entire lifetime, the total intake during that exposure is traditionally normalized to a lifetime. The averaging time for assessment of cancer risk is therefore typically set at 70 years. For exposures lasting less than a lifetime, the values for ED and AT will be different. As stated in Section 8.3.3.2, for some contaminants or subpopulations of receptors this approach (normalizing over a lifetime) may not be health protective (e.g., vinyl chloride exposure to children). The existence of critical periods of susceptibility during a lifetime and the intensity of exposure may influence cancer risk. These factors may warrant deviation from the traditional approach. When possible, the biological basis or mechanism by which a carcinogen acts should be used to characterize risk from the carcinogenic contaminant.

2.1.2 Incidental Soil Ingestion Pathway

The Average Daily Dose due to the *chronic* incidental ingestion of contaminated soil ($ADD_{soil\ ingestion}$) may be calculated utilizing the equation presented in Table A1.2.

2.1.2.1 C_{soil}, Contaminant Concentration

See Section 2.1.1.1.

2.1.2.2 IR, Soil Ingestion Rate

Soil ingestion is assumed to occur incidentally, from hand-to-mouth contact, during outdoor activities in the warmer months of the year and through the inhalation of larger particles. Soil from outdoors can also be brought indoors (e.g., on clothing, shoes and tools) or can enter the house as windblown dust. Therefore, some incidental soil/dust ingestion can also occur indoors.

Soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period.

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Table A1.2. Residential - Chronic Incidental Ingestion of Soil.

$$\text{LADD or ADD}_{soil\ ingestion} = \frac{Csoil \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or $ADD_{soil\ ingestion}$	Average daily potential dose of contaminant received through the ingestion of soil (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
IR	Annual daily soil ingestion rate (mg/day)	100 (< 6 yr) 75 (> 6 - 18 yr) 50 (> 18 - 33 yrs) 68 (age-adjusted)	C	EPA 1997, Stanek & Calabrese, 1995.
CF	Conversion Factor	1E-6 kg/mg		
FI	Fraction of ingested soil which is from contaminated soil	1	NA	
EF	Number of exposure days during the exposure period (days/year).	350	C	Utilized with annual average daily soil ingestion rate.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
BW	Body weight of the receptor of concern during the exposure period (kg).	15 (< 6 yr) 43 (> 6 - 18 yrs) 70 (> 18 - 33 yr) 51 (age-adjusted)	C C C	EPA 1997 Exposure Factors Handbook
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr LADD calculation: AT = 70 yrs x 365 days/yr

C = Central Tendency Value (e.g., average)
U = Upper Tendency Value

Several studies have been conducted to estimate the amount of soil incidentally ingested by children. The studies upon which the incidental soil ingestion rate was estimated utilized mass balance equations and tracer levels in soil and dust (indoor as well as outdoor) and in feces. Children were monitored for several days and an average daily rate was calculated. It is inappropriate to "limit" exposure time to outdoor time since the estimated incidental ingestion rate includes indoor as well as outdoor sources.

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The central tendency value of 100 - 200 mg/day is recommended by EPA (EPA, 1997) for young children. Stanek and Calabrese's (1995) have utilized previously obtained data to estimate an annual average median daily soil ingestion of 75 mg/day. The middle value of 100 mg/day was selected as the default annual daily ingestion rate for a young child in a residential setting. Since the annual daily soil ingestion rate was, in part, based on data derived by averaging the median soil ingestion rates over 365 days the default exposure frequency must be set at a minimum of 350 days per year. The use of an average daily ingestion rate for chronic exposure is believed to be consistent with the RME approach when combined with conservative estimates for exposure duration.

Older children and adults may incidentally ingestion soil that adhere to food or their hands or through the inhalation of larger particles. Information on soil ingestion among adults is very limited. An annual average daily ingestion rate of 50 mg/day for soil and household dust is recommended as the default for older children and adults in a residential setting or working indoors. Since the 50 mg/day ingestion rate was based on adult volunteers, this value may underestimate the soil ingestion rate for older children (> 6 - 18 yrs). In the absence of information a soil ingestion rate of 75 mg/day (i.e., midway between rate for young children and adults) is assumed for older children.

Because soil ingestion rates differ for children, older children and adults, it is necessary to calculate an age-adjusted soil ingestion rate when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. Therefore, the age-adjusted exposure should be calculated in a way that does not "dilute" the higher exposure rates experienced by young children with lower exposure rates experienced by older children and adults.

There are a number of averaging methods that can be used to calculate a ADD that reflects the higher exposure rates experienced by young children. One method which can be used to calculate the age-adjusted average daily dose is a simple age-weighted averaging approach. In the case of the incidental soil ingestion pathway this simple averaging approach would result in calculating a weighted total daily dose for the three age groups evaluated. The weighted total daily dose then calculated as the sum of the three doses averaged over the exposure period. For example, the calculation for the soil ingestion rate would be:

$$IR_{age-adjusted} = \frac{(100 \text{ mg / d x 6 yrs}) + (75 \text{ mg / d x 12 yrs}) + (50 \text{ mg / d x 15 yrs})}{33 \text{ yrs}} = 68 \text{ mg / d}$$

2.1.2.3 CF, Units Conversion Factors

See Section 2.1.1.2 for discussion of CF parameter.

2.1.2.4 FI, Fraction of Ingested Soil

Since soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period. It is assumed that the daily ingestion occurs within the exposure area.

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2.1.2.5 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. Contact rates which are on the scale of days are the most common. The ingestion pathway is typical of this case. While estimates have been published on the amount of soil ingested during a *day*, there can be no reliable estimate of average *hourly* ingestion rates as incidental ingestion of soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures (including soil ingestion and dermal contact) EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant.

Frequency of exposure is site- and activity-specific. The exposure frequency selected must be appropriate for the duration and contact rate chosen Since long-term contact rates are assumed for all exposure pathways, a daily exposure frequency (350 days/year for residential) to contaminants is assumed. For children this value does not represents an upper-end estimate since the ingestion rate represents an annual daily average.

2.1.2.6 ED, Exposure Duration

See Section 2.1.1.3 for discussion of ED parameter.

2.1.2.7 BW, Body Weight

See Section 2.1.1.4 for discussion of the BW parameter.

2.1.2.8 AT, Averaging Time

See Section 2.1.1.5 for discussion of AT parameter.

2.1.3 Dermal Contact Pathway

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. In fact, dermal absorption from soils may be more significant than incidental ingestion for chemicals which have a percent absorption exceeding about 10% (USEPA, EPA/600/8-91/011B, January, 1992). Contaminants exhibiting percentage absorption less than 10% also contribute to cumulative risk estimates and therefore these contaminants must also be evaluated. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil. The Average Daily Dose due to chronic dermal contact with contaminated soil ($ADD_{dermal\ absorption}$) may be calculated as shown in Table A1.3.

2.1.3.1 C_{soil}, Contaminant Concentration

See Section 2.1.1.1 for discussion of C_{soil} parameter.

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2.1.3.2 CF, Units Conversion Factors

See Section 2.1.1.2 for discussion of CF parameter.

Table A1.3 Residential - Chronic Dermal Contact with Soil

$$\text{LADD or ADD}_{dermal\ absorption} = \frac{Csoil \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or ADD_{dermal}	Average daily dose absorbed through dermal contact (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
CF	Conversion Factor	1E-6 kg/mg		
SA	Skin surface area (cm^2)	2000 (< 6 yr) 3300 (> 6 - 18 yrs) 4500 (> 6 - 33 yr) 3609 (age-adjusted)	 C	28 - 25% of the average total body SA (EPA, 1992 and EPA, 1997)
AF	Skin adherence factor (mg/cm^2)	0.2 (< 18 yrs) 0.13 (> 18 - 33 yrs) 0.17 (age-adjusted)	 C	Kissel et. al., (as cited in EPA, 1997)and EPA, 1992
ABS	Absorption factor	Chemical specific		
EF	Number of exposure days during the exposure period (days/year).	150 (< 6 yr) 100 (> 6 - 18 yr) 74 (>18 - 33 yr) 97 (age-adjusted)	NA	5 d/wk for warmer 7 mons. 2 d/wk for 4 mo + 5 d/wk for 3 mo. 2 d/wk for 4 mo + 3 d/wk for 3 mo
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey, 1993. 33 years = 90th percentile resident tenure.
BW	Body weight of the receptor of concern during the exposure period (kg).	15 (< 6 yr) 43 (>6 - 18 yrs) 70 (> 18 - 33 yr) 51 (age-adjusted)	C C C	EPA 1997
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 -18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr LADD: AT = 70 yrs x 365 days/yr

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

2.1.3.3 SA, Skin Surface Area

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The surface area parameter (SA) describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends on the receptor and the exposure scenario. Clothing is expected to limit the extent of the exposed surface area for most activities. All SA estimates used 50th percentile values in order to correlate with the average body weights used for exposure estimations. This is done to prevent inconsistent parameter combinations since body weight and surface area are not independent variables. The age-specific 50th percentile total body surface areas are shown in Table A1.4.

TABLE A1.4 AGE-SPECIFIC TOTAL BODY SURFACE AREA

AGE (Years)	Mean SA for Females (cm^2)	Mean SA for Males (cm^2)	Default Total Body Surface Area (cm^2)
< 1 (a)	4271	4487	
1 < 2 (a)	4980	5324	
2 < 3	5790	6030	
3 < 4	6490	6640	
4 < 5	7060	7310	
5 < 6	7790	7930	≤ 6 years: 7000 cm^2
6 < 7	8430	8660	
7 < 8	9170	9360	
8 < 9	10000	10000	
9 < 10	10600	10700	
10 < 11	11700	11800	
11 < 12	13000	12300	
12 < 13	14000	13400	
13 < 14	14800	14700	
14 < 15	15500	16100	
15 < 16	15700	17000	
16 < 17	16000	17600	
17 < 18	16300	18000	> 6 - < 18 years: 13120 cm^2
> 18	16900	19400	> 18 - 33 years: 18150 cm^2

(a) Utilized formula developed by Costeff (as cited in Exposure Factors Handbook,1997): SA = (4BW + 7)/(BW + 90).

The exposure frequency for dermal exposure is limited to the warmer months of the year. For the purpose of calculating the dermal dose it was assumed that the forearms, lower legs, hands, and feet were exposed. The age-specific percentage of total body surface area by body part are shown in Table A1.5. This exposed area constitutes approximately 28% in the < 6 year young child receptor and 25% in the > 6 - 18 older child and > 18 - 33 year adult receptor. Surface areas of 2,000, 3300 and 4,500 cm^2 were calculated by incorporating data from the EPA Exposure Factors Handbook (EPA 1997) as presented in Tables A1.4 and A1.5. Since some studies have suggested that exposure can occur under clothing (EPA, 1992, Dermal Guidance) this scenario is not considered to be unduly conservative.

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TABLE A1.5. Age-Specific Percentage of Total Body Surface by Body Part

AGE (Years)	Mean Total Body Surface Area (cm^2)	Mean Percentage of Total Body Surface Area by Part					
		Head	Trunk	Arms	Hands	Legs	Feet
<1	4379	18.2	35.7	13.7	5.3	20.6	6.5
1<2	5152	16.5	35.5	13	5.7	23	6.3
2<3	5910	14.2	38.5	11.8	5.3	23.2	7.1
3<4	6565	13.6	31.9	14.4	6.1	26.8	7.2
4<5	7185	13.8	31.5	14	5.7	27.8	7.3
5<6	7860	NA	NA	NA	NA	NA	NA
6<7	8545	13.1	35.1	13.1	4.71	27.1	6.9
7<8	9265	NA	NA	NA	NA	NA	NA
8<9	10000	NA	NA	NA	NA	NA	NA
9<10	10650	12	34.2	12.3	5.3	28.7	7.58
10<11	11750	NA	NA	NA	NA	NA	NA
11<12	12650	NA	NA	NA	NA	NA	NA
12<13	13700	8.74	34.7	13.7	5.4	30.5	7.03
13<14	14750	9.97	32.7	12.1	5.11	32.0	8.02
14<15	15800	NA	NA	NA	NA	NA	NA
15<16	16350	NA	NA	NA	NA	NA	NA
16<17	16800	7.96	32.7	13.1	5.68	33.6	6.93
17<18	17150	7.58	31.7	17.5	5.13	30.8	7.28
> 18	18150	7.5	35.4	14	5.2	31.8	6.8

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Because body surface area changes with age it is necessary to calculate an age-adjusted skin surface area when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period. The results of utilizing a simple age-weighted averaging approach to calculating age-adjusted surface area is shown below:

$$SA_{age-adjusted} = \frac{(2000\ cm^2 \times 6\ yrs) + (3300\ cm^2 \times 12\ yrs) + (4500\ cm^2 \times 15\ yrs)}{33\ years} = 3600\ cm^2$$

2.1.3.4 AF, Soil Adherence Factor

The adherence factor (AF) describes the amount of soil that adheres to the skin. The EPA Exposure Factors Handbook (EPA 1997) recommends utilizing the Kissel, et al., study for estimating soil adherence. The results of this study showed that generally soil adherence could be directly correlated with soil moisture and activity and inversely correlated with particle size. The default AFs are based on the central tendency value recommended in EPA's Dermal Guidance (EPA 1992) and a review of the body-part-specific and activity-specific adherence factors reported by Kissel et al., 1996 (as cited in the EPA Exposure Factors Handbook, 1997).

The data available for young children (< 6 years) is very limited. The studies by Kissel et al., for this age group evaluated adherence in an indoor setting. The exposure frequency utilized in the dermal exposure pathway is based on outdoor activity. Kissel et al., also studied older children, age 9 to 14 years. Unfortunately, the setting was playing in mud at the shore of a lake. This scenario is not likely to be representative of a residential setting. In the absence of appropriate data a default AF of 0.2 mg/cm2 is recommended for individuals less than 18 years old. Given the limited data and the variability in the existing data this is not considered to be unduly conservative.

For the adult resident (> 18 - 33 years) the gardening scenario was utilized as the most likely residential activity. This activity included weeding, pruning, and digging. The weighted adherence factor for the adult resident was calculated utilizing the equation below:

$$\text{Weighted AF} = \frac{(SA1 \times AF1) + (SA2 \times AF2) + \ldots + (SAi \times AFi)}{(SA1 + SA2 + \ldots + SAi)}$$

where:

SAi = surface area for body part "i", cm^2
AFi = soil-to-skin adherence factor for body part "i", mg/cm^2-event

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The body part specific surface area information can be found in Table A1.6. Kissel, et al. presented the body part specific AFs for two subsets of gardeners. The highest geometric mean value of the two subsets was utilized when calculating the weighted AF. The selection of the highest mean AF is not unduly conservative considering that the value represents a central tendency value, the reported high variability, and the clothing worn by the study participants (e.g., 75% wore long pants, intermittent use of gloves). The calculation of the adult resident AF is shown below:

$$\text{Weighted AF} = \frac{(1000 \times 0.054) + (900 \times 0.2) + (1700 \times 0.072) + (900 \times 0.26)}{(4500)} = 0.13$$

TABLE A1.6 DEFAULT MEAN EXPOSED SURFACE AREA BY BODY PART

Age (years)	Total SA Exposed (cm^2)	Surface Area Exposed (cm^2)			
		Lower Arms	Hands	Lower Legs	Feet
< 6	2000 (28%)	400 (6%)	400 (5.6%)	700 (10%)	500 (7%)
> 6 - < 18	3300 (25%)	700 (5.5%)	650 (5%)	1300 (10%)	650 (5%)
> 18 - 33	4500 (25%)	1000 (6%)	900 (5%)	1700 (9.5%)	900 (5%)

( ) represents percent of total body surface area. Default total body surface area of < 6 years, > 6 - < 18 years and > 18 - 33 years are 7000, 13120 and 18150 cm^2 (see Table A1.4). It was assumed that the forearm constituted 45% of the total arm and the lower leg constituted 40% of the total leg based on data from adult males (EPA Exposure Factors Handbook 1997, Table 6-5)

Because the AF changes with age it is necessary to calculate an age-adjusted AF when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period. The results of utilizing a simple age-weighted averaging approach is shown below:

$$AF_{age-adjusted} = \frac{(0.2\ mg/cm^2 \times 18\ yrs) + (0.13\ mg/cm^2 \times 15\ yrs)}{33\ years} = 0.17\ mg/cm^2$$

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2.1.3.5 ABS, Absorption Factor

The dermal absorption factor (ABS) is the fraction of the contaminant contacting the skin that is absorbed. At this time only limited information is available to derive soil ABS values. In the absence of contaminant specific information default ABS values have been incorporated. The recommended default values are:

- 1 - 10% for volatile organic contaminants, depending on volatility. It is assumed that volatilization will be a competing process;
- 10% for semi-volatile and non-volatile organic contaminants; and
- 0.1 - 1% for inorganic compounds, depending on qualitative evidence of absorption. Note: The default ABS was set such that dermal absorption would not be greater than 10% of oral absorption.

The default values are based on the EPA Dermal Workgroup recommendations and professional judgment. The recommended ABS values are listed in Table A.2.1 of Appendix 2.

2.1.3.6 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. Contact rates which are on the scale of days are the most common. The event duration in the AF studies varied from several minutes to over 8 hours. There can be no reliable estimate of an average *hourly* rate since contact with soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures EF is by definition 1 day/event.

Frequency of exposure is site- and activity-specific. The exposure frequency selected must be appropriate for the duration and contact rate chosen. Dermal contact with contaminated soil is assumed to occur mainly during outdoor activities. For young children this is assumed to be an average of 5 days a week during the warmer 7 months of the year (April - October) for a total of 150 days per year. For school-age individuals the exposure frequency is assumed to be an average of 2 days a week in the spring and fall increasing to an average of 5 days a week during the 3 months of summer. The resulting exposure frequency is 100 days per year. For adults the exposure frequency is assumed to be an average of 2 days per week in the spring and fall increasing to an average of 3 days a week during the 3 months of summer. The resulting exposure frequency for adults is 74 days per year.

Because the EF changes with age it is necessary to calculate an age-adjusted EF when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period or in the case of cancer evaluation a lifetime. The results of utilizing a simple age-weighted averaging approach is shown below:

$$EF_{age-adjusted} = \frac{(150 \text{ days x } 6 \text{ yrs}) + (100 \text{ days x } 12 \text{ yrs}) + (74 \text{ days x } 15 \text{ yrs})}{33 \text{ years}} = 97 \text{ days}$$

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2.1.3.7 ED, Exposure Duration

See Section 2.1.1.3 for discussion of ED parameter.

2.1.3.8 BW, Body Weight

See Section 2.1.1.4 for discussion of BW parameter.

2.1.3.9 AT, Averaging Time

See Section 2.1.1.5 for discussion of AT parameter.

2.1.4 Inhalation of Vapors or Resuspended Particulate Pathway

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air. The Average Daily Concentration (ADC_{air}) may be calculated as shown in Table A1.7.

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Table A1.7 Residential - Chronic Inhalation of Vapors or Particulate from Soil

$$\text{LADC or ADC}_{air} = \frac{Cair \times EF \times ED \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{aie}	Average daily concentration in air (mg/m^3 or ug/m^3).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) = C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg		Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period (days/year).	350	C	1/PEF and 1/VF are based on annual estimates.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr LADC calculation AT = 70 yrs x 365 days/yr

C = Central Tendency Value
U = Upper Tendency Value

2.1.4.1 C_{air}, Air Concentration

To calculate an average daily air concentration, the particulate emission factor and volatilization factor must be calculated. Separate Particulate Emission Factor-based (PEF) and Volatilization Factor-based (VF) equations were developed by EPA (EPA Soil Screening Guidance: Technical Background Document, 1996). The derivations of PEF and VF have been updated since RAGS, part B was published and are discussed fully in Sections 2.4.2 and 2.4.5, respectively, of the EPA Soil Screening Guidance (EPA 1996).

The particulate emission factor (PEF) relates the concentration of contaminant in soil with the concentration of dust particles in the air. The PEF equation is based on the "unlimited reservoir" model from Cowherd et al. (1985) developed to estimate particulate emissions due to wind erosion. Unlike volatile contaminants, meteorological conditions (i.e., the intensity and frequency of wind) affect both the dispersion and emissions of particulate matter. Table A1.8 presents the PEF equation and the default input values.

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Table A1.8 Residential - Calculation of Chronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600 s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	7.7E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0.5	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.92	Based on climatic data for Minneapolis/St. Paul metropolitan area (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

Table 3 of the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996) provides the estimated annual Q/C values for 0.5, 1, 2, 5, 10 and 30 acre source areas for the city of Minneapolis. An intermediate source size of 5 acres was selected for the default source size. A linear inverse relationship exists between the log of the source size and the log of the annual Q/C as shown in Figure A1.1. This relationship can be utilized to estimate the annual Q/C for source sizes which are not included in Table 3 of the EPA Soil Screening Guidance.

The Q/C value, is used in the determination of both PEF and VF. For a detailed site-specific assessment of the inhalation pathway, a site-specific Q/C can be determined using the Industrial Source Complex Model platform in the short-term mode (ISCST3). The ISCST3 model will output an air concentration when the concentration model option is selected. Numerous site-specific input parameters must be determined, e.g., the surface area of the contaminated soil source, contaminant area emission rate (g/m2-s), hourly meteorological data, etc.

The fraction of vegetation will vary from site to site. A default value of 0.5 (50% of source area is vegetated) was selected.

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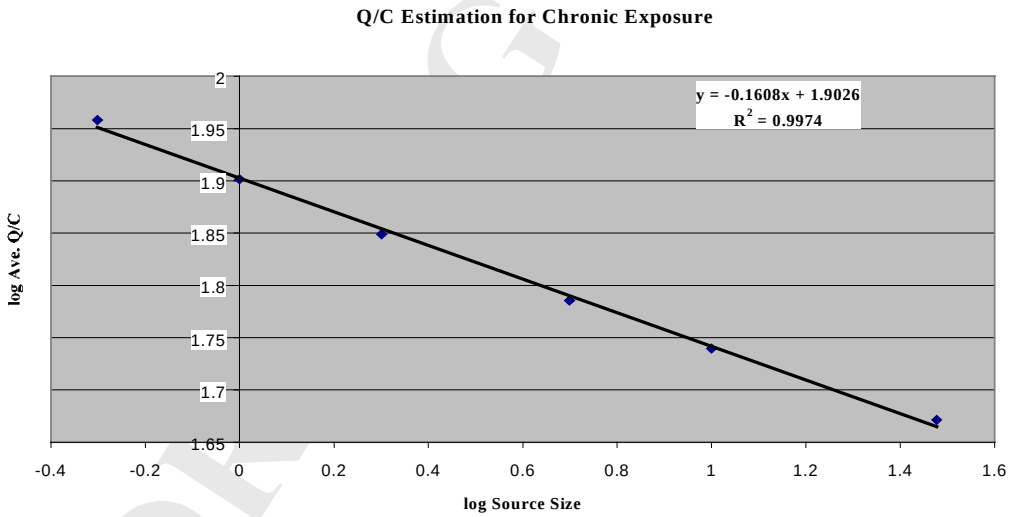
Figure A1.1 Estimation of Chronic Q/C

Source Size (acres) [log]	Annual Minneapolis Ave. Q/C (g/m2s per kg/m3) [log]
0.5 [-0.3]	90.8 [1.96]
1 [0]	79.68 [1.90]
2 [0.3]	70.64 [1.85]
5 [0.7]	61.03 [1.79]
10 [1]	54.9 [1.74]
30 [1.5]	46.92 [1.67]

From Table 3 (EPA 1996)



It is generally assumed that the concentration of the contaminant in the particulate is equal to the concentration of the contaminant in soil. This assumption may underestimate the concentration of contaminant in the inhalable fraction (i.e., PM10 fraction), since smaller particulate fractions sometimes contain contaminant concentrations that are enriched relative to larger fractions. However, the data

needed to derive more accurate concentration estimates are typically not available. To calculate the airborne particulate contaminant concentration simply multiple the soil concentration by the inverse of the particulate emission factor (e.g., 3.1E-3 mg/m^3)

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). Activities likely to disturb soil in a residential setting are typically infrequent and of short-term duration. The above model is applicable for estimating chronic particulate emissions. To assess short-term (e.g., subchronic) exposures utilization of default particulate concentration values may be necessary.

For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. Table A1.9 presents the VF equation and default values. The VF equation is based on the volatilization model developed by Jury et al. (1984) for infinite sources and Jury et al. (1990) for finite sources and represents an update of EPA's Risk Assessment Guidance for Superfund (RAGS, 1989) (EPA, 1996).

Table A1.9 Residential - Calculation of Chronic Volatilization Factor

$$VF(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4} (m^2/cm^2)$$

Variable	Definition	Default Value	Reference
VF	Volatilization Factor (m^3/kg)	Contaminant Specific	
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA 1996). (Use site specific information if available).
Da	Apparent diffusivity (cm^2/s)	Contaminant Specific	See Table A1.10.
T	Exposure interval (s)	1.89E+08 (< 6 yrs) 3.8E+08 (> 6 - 18 yrs) 4.7E+08 (> 18 - 33 yrs) 1.0E+09 (age-adjusted)	
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996). (Use site data to develop site-specific value)

Other than initial soil concentration, air-filled soil porosity is the most significant soil parameter affecting the final steady-state flux of volatile contaminants from soil. In other words, the higher the air-filled soil porosity, the greater the emission flux of volatile constituents. Air-filled porosity is calculated the total soil porosity (n) minus the water-filled soil porosity (θ_w). The total soil porosity is based on the dry soil bulk density (ρ_b) and the soil particle density (ρ_s). Of these parameters, water-filled soil porosity (θ_w) has the most significant effect on air-filled soil porosity and hence volatile contaminant emissions.

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Table A1.10 Residential - Calculation of Apparent Diffusivity (Da)

$$D_a\,(cm^2/s) = \frac{\left[(\theta_a^{10/3} \times D_i \times H') + (\theta_w^{10/3} \times D_w) / n^2\right]}{\left[(\rho_b \times K_d) + \theta_w + (\theta_a \times H')\right]}$$

Variable	Definition	Default Value	Reference
Da	Apparent Diffusivity (cm^2/s)	Contaminant Specific	
θ_a	Air filled soil porosity (= n - θ_w)	0.28	Calculated
n	Total soil porosity (= 1 - (ρ_b/ρ_s))	0.43	Calculated
θ_w	Water filled soil porosity (= f_m x ρ_b)	0.15	Calculated
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996. Mode of the range for US soils). (Use site data to develop site-specific value)
ρ_s	Soil particle density (g/cm^3)	2.65	Default (EPA, 1996). (Use site data to develop site-specific value)
f_m	Average soil moisture content (cm^3 water per gram soil)	0.1	Default. (Use site data to develop site-specific value)
D_i	Diffusivity in air (cm^2/s)	Contaminant Specific	
H	Henry's constant (atm-m^3/mol)	Contaminant Specific	
H'	Dimensionless Henry's constant (= H x 41)	Contaminant Specific	
D_w	Diffusivity in water (cm^2/s)	Contaminant Specific	
K_d	Soil-water partition coefficient (cm^3/g) (= K_{oc} x f_{oc})	Contaminant Specific	
K_{oc}	Organic carbon partition coefficient (cm^3/g)	Contaminant Specific	
f_{oc}	Organic carbon content of soil	0.005	Default. (Use site data to develop site-specific value)

The VF equation given above represents a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The equation incorporates a number of conservative, simplifying assumptions, e.g., infinite source, steady state conditions. Part 3 of the Soil Screening Guidance: Technical Background Document (EPA 1996) includes information on models for a more detailed evaluation. These models can accommodate finite contaminant sources and fractionate contaminants between pathways and predict the subsequent impact on ambient air. However, caution should be used when employing a finite source model, the uncertainties inherent in site-specific estimates of subsurface contaminant distributions should be recognized and conservative estimates of source size and concentrations should be used to allow for such uncertainties. In addition, model predictions should be validated against actual site conditions to the extent possible. See Section 8.3.3.4 regarding the use of predictive models. If contaminant concentrations vary significantly over the exposure period a short-term as well as chronic exposure assessment should be conducted.

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There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. The determination of Csat is important as it sets the upper concentration limit at which the soil-to-air volatilization model is valid. The Henry's Law constant used in the VF model is invalid above the saturation limit. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When a calculated SRV exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. Table A1.11 presents the Csat equation and default values.

Table A1.11 Residential - Calculation of Soil Saturation Limit (Csat)

$$Csat(mg/kg) = (S/\rho_b) \times \left[(Kd \times \rho_b) + \theta_w + (H' \times \theta_a)\right]$$

Variable	Definition	Default Value	Reference
C_{sat}	Soil Saturation Concentration (mg/kg)	Calculated	
S	Solubility in water (mg/L)	Contaminant Specific	
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996. Mode of the range for US soils). (Use site data to develop site-specific value)
K_d	Soil-water partition coefficient (cm^3/g) (= K_{oc} x f_{oc})	Contaminant Specific	
K_{oc}	Organic carbon partition coefficient (cm^3/g)	Contaminant Specific	
f_{oc}	Organic carbon content of soil	0.005	Default. (Use site data to develop site-specific value)
θ_w	Water filled soil porosity (= f_m x ρ_b)	0.15	Calculated
f_m	Average soil moisture content (cm^3 water per gram soil)	0.1	Default. (Use site data to develop site-specific value)
H	Henry's constant (atm-m^3/mol)	Contaminant Specific	
H'	Dimensionless Henry's constant (= H x 41)	Contaminant Specific	
θ_a	Air filled soil porosity = n - θ_w	0.28	Calculated
n	Total soil porosity = 1 - (ρ_b/ρ_s)	0.43	Calculated
ρ_s	Soil particle density (g/cm^3)	2.65	Default (EPA, 1996). (Use site data to develop site-specific value)

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2.1.4.2 CF, Units Conversion Factors

See Section 2.1.1.2 for discussion of the CF parameter.

2.1.4.3 EF, Exposure Frequency

The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. Contact rates which are on the scale of days are the most common. Frequency of exposure is site- and activity-specific. The exposure frequency selected must be appropriate for the duration and contact rate chosen Since long-term contact rates are assumed for all chronic exposure pathways, a daily exposure frequency (350 days/year) to contaminants is assumed.

2.1.4.4 ED, Exposure Duration

See Section 2.1.1.3 for additional discussion of ED parameter.

2.1.4.5 AT, Averaging Time

See Section 2.1.1.5 for discussion of AT parameter.

2.1.5 Indirect Exposure Pathways

Contaminated soil can also be a source of indirect exposure to contaminants. Exposure can occur through the ingestion of food products (e.g., meat, produce, milk) contaminated via transfer from soil to plants and/or animals. Methods for the evaluation of food related exposure pathways are under development. See Section 6.

2.2 Residential Subchronic Exposure

The effect (noncarcinogenic and carcinogenic) of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short-period of time may not produce the same effect when given over a longer period of time. To adequately evaluate the potential receptors, the risk assessor may need to look at several specific subpopulations of receptors which may experience higher rates of exposure. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. A young child (< 6 years) was chosen as the receptor for the subchronic exposure scenario. The exposure time selected was the summer months due to higher exposure potential, i.e., higher potential contact with soil. See Section 8.3.3.4 of main text for further discussion.

2.2.1 General Exposure Factors

There are five exposure factors which recur throughout the equations used to estimate the dose of contaminant experienced by a potential receptor:

- C_{soil}, Contaminant Concentration
- CF, Units Conversion Factors

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- EF, Exposure Frequency
- BW, Body Weight
- AT, Averaging Time

These factors are generally used in the same manner regardless of the exposure pathway under investigation, so it is useful to discuss them separately.

2.2.1.1 C_{soil}, Contaminant Concentration

The concentration of the contaminant used to quantify exposure is the Exposure Concentration. The exposure concentration is expressed in terms of mass of the material per unit mass (or volume) of the exposure medium (e.g., mg contaminant/kg soil). The exposure point concentration should *not* be adjusted for receptor exposure frequency, duration, etc. as those factors are generally addressed in the exposure calculations. See Sections 7.4 and 8.3.3.5 of the main text for additional discussion.

2.2.1.2 CF, Units Conversion Factors

The exposure factors and analytical data used for a given calculation may come in several forms. Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units (e.g., mg/kg/day). Use of a units conversion factors (CF) is equivalent to multiplication by one. The numerator and denominator of the factor must be an equivalent quantity expressed in different terms.

2.2.1.3 EF, Exposure Frequency

The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. While estimates have been published on the amount of soil ingested during a *day*, there can be no reliable estimate of average *hourly* ingestion rates as incidental ingestion of soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures (including soil ingestion and dermal contact) EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant. Frequency of exposure is site- and activity-specific. The exposure frequency selected for subchronic exposure is an average of 5 days per week during the 3 summer months (i.e., 65 days).

2.2.1.4 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). See Appendix Section 2.1.17 for additional discussion of BW parameter. Age-specific body weights are summarized in Table A1.1. The body weights are 50th percentile values (EPA Exposure Factors Handbook, 1997).

2.2.1.5 AT, Averaging Time

The averaging time (AT) is the time over which the total intake is normalized. For the evaluation of *noncancer risk*, the Average Daily Dose calculated should be representative of the exposure received while exposure is on-going (i.e., during the exposure period). The exposure period evaluated for the

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subchronic exposure scenario is 90 days (i.e., 3 summer months). The averaging time (AT) is equivalent to the exposure period, i.e., 3 months.

The Lifetime Average Daily Dose (LADD) is calculated for the evaluation of *cancer risk*. While the duration of the exposure period might range from one day to an entire lifetime, the total intake during that exposure is traditionally normalized to a lifetime. The averaging time for assessment of cancer risk is therefore typically set at 70 years. See Appendix 1 Section 2.1.1.8 for additional discussion. Note that for the evaluation of cancer risks resulting from subchronic exposure the target risk is 1 in 1,000,000. See Section 8.3.3 of main text.

2.2.2 Incidental Soil Ingestion Pathway

The Average Daily Dose during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated utilizing the equation presented in Table A1.12.

Table A1.12 Residential - Subchronic Incidental Ingestion of Soil By Child

$$\text{LADD or ADD}_{\text{ingestion}} = \frac{Csoil \times IR \times CF \times FI \times EF}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or $ADD_{soil\ ingestion}$	Average daily potential dose of contaminant received through the ingestion of soil (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
IR	Daily soil ingestion rate (mg/day)	300 (< 6 yr)	C	Stanek & Calabrese, 1995. 40 days at 500 mg/day and 50 days at 100 mg/day.
CF	Conversion Factor	1E-6 kg/mg		
FI	Fraction of ingested soil which is from contaminated soil	1	NA	
EF	Number of exposure days during the exposure period	65	C	3 summer months, average of 5 d/wk.
BW	Body weight during the exposure period (kg).	15 (< 6 yr)	C	EPA, 1997
AT	Averaging Time (days)	90 25550		Noncancer AT = 3 months Cancer AT = 70 yrs x 365 days/yr

C = Central Tendency Value (e.g., average)
U = Upper Tendency Value

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2.2.2.1 C_{soil}, Contaminant Concentration

See Section 2.2.1.1 for discussion of the C_{soil} parameter.

2.2.2.2 IR, Soil Ingestion Rate

Soil ingestion is assumed to occur incidentally, from hand-to-mouth contact, during outdoor activities in the warmer months of the year and through the inhalation of larger particles. Soil from outdoors can also be brought indoors (e.g., on clothing, shoes and tools) or can enter the house as windblown dust. Soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period.

Several studies have been conducted to estimate the amount of soil incidentally ingested by children. Stanek and Calabrese's (1995) have estimated that 31% of children will ingest greater than 500 mg/day on 35 to 40 days per year. The exposure period selected for the subchronic evaluation is the three summer months, approximately 90 days. Assuming an incidental soil ingestion rate of 500 mg/day for 40 days and an incidental soil ingestion rate of 100 mg/day for the remaining 50 days a simple time-weighted average of approximately 300 mg/day is calculated. Given that 500 mg/day represents a lower limit of ingestion for 31% of the children as well as the limited data and the variability in the existing data the value of 300 mg/day is not considered to be unduly conservative.

2.2.2.3 CF, Units Conversion Factors

See Section 2.2.1.2 for discussion of the CF parameter.

2.2.2.4 FI, Fraction of Ingested Soil

Since soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period. It is assumed that the daily ingestion occurs within the exposure area.

2.2.2.5 EF, Exposure Frequency

See Section 2.2.1.3 for discussion of the EF parameter.

2.2.2.6 BW, Body Weight

See Section 2.2.1.4 for discussion of the BW parameter.

2.2.2.7 AT, Averaging Time

See Section 2.2.1.5 for discussion of the AT parameter.

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2.2.3 Dermal Contact Pathway

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil (e.g., organic carbon content). The Average Daily Dose during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated as shown in Table A1.13.

2.2.3.1 C_{soil}, Contaminant Concentration

See Section 2.2.1.1 for discussion of the C_{soil} parameter.

Table A1.13 Residential - Subchronic Dermal Contact with Soil

$$\text{LADD or ADD}_{\text{dermal absorption}} = \frac{Csoil \times CF \times SA \times AF \times ABS \times EF}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or ADD_{dermal}	Average daily dose absorbed through dermal contact (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
CF	Conversion Factor	1E-6 kg/mg		
SA	Skin surface area (cm^2)	2000	C	28% of the average total body SA per exposure event (EPA, 1997)
AF	Skin adherence factor (mg/cm^2)	0.35	C	Kissel et. al., (as cited in EPA, 1997) and EPA, 1992
ABS	Absorption factor	Chemical specific		
EF	Number of exposure days during the exposure period	65	NA	3 summer months, average of 5 d/wk.
BW	Body weight during the exposure period (kg).	15 (< 6 yr)	C	EPA, 1997
AT	Averaging Time (days)	90 25550		Noncancer AT = 3 months Cancer AT = 70 yrs x 365 days/yr.

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

2.2.3.2 CF, Units Conversion Factors

See Section 2.2.1.2 for discussion of the CF parameter.

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2.2.3.3 SA, Skin Surface Area

The surface area parameter (SA) describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends on the receptor and the exposure scenario. Clothing is expected to limit the extent of the exposed surface area for most activities. All SA estimates used 50th percentile values in order to correlate with the average body weights used for exposure estimations. This is done to prevent inconsistent parameter combinations since body weight and surface area are not independent variables. The age-specific 50th percentile total body surface areas are shown in Table A1.4.

The subchronic exposure frequency for dermal exposure is limited to the summer months. For the purpose of calculating the dermal dose it was assumed that the forearms, lower legs, hands, and feet were exposed. The age-specific percentage of total body surface area by body part are shown in Table A1.5. This exposed area constitutes approximately 28% in the < 6 year young child receptor. A surface area of 2,000 cm^2 was calculated by incorporating data from the EPA Exposure Factors Handbook (EPA 1997) as presented in Tables A1.4 and A1.5. Since some studies have suggested that exposure can occur under clothing (EPA, 1992) and the exposure period is limited to the summer months this scenario is not considered to be unduly conservative.

2.2.3.4 AF, Soil Adherence Factor

The adherence factor (AF) describes the amount of soil that adheres to the skin. The EPA Exposure Factors Handbook (EPA 1997) recommends utilizing the Kissel, et al., study for estimating soil adherence. The results of this study showed that generally soil adherence could be directly correlated with soil moisture and activity and inversely correlated with particle size. The default AFs are based on the central tendency value recommended in EPA's Dermal Guidance (EPA 1992) and a review of the body-part-specific and activity-specific adherence factors reported by Kissel et al., 1996 (as cited in the EPA Exposure Factors Handbook, 1997).

The data available for young children (< 6 years) is very limited. The studies by Kissel et al., for this age group evaluated adherence in an indoor setting. The exposure frequency utilized in the dermal exposure pathway is based on outdoor activity. Kissel et al., also studied older children, age 9 to 14 years. Unfortunately, the setting was playing in mud at the shore of a lake. This scenario is not likely to be representative of outdoor soil contact in a residential setting. In the absence of appropriate data for young children the data from adult rugby players was utilized. The conditions included recreational activities on a field of grass and bare soil. The weighted adherence factor was calculated utilizing the equation below:

$$\text{Weighted AF} = \frac{(SA1 \times AF1) + (SA2 \times AF2) + \ldots + (SAi \times AFi)}{(SA1 + SA2 + \ldots + SAi)}$$

where:

SAi = surface area for body part "i", cm^2
AFi = soil-to-skin adherence factor for body part "i", mg/cm^2-event

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The body part specific surface area information can be found in Table A1.6. Kissel, et al. presented the body part specific AFs for three subsets of rugby players. The highest geometric mean values were utilized when calculating the weighted AF. The AF reported for legs was utilized for feet. The selection of the highest mean AF is not considered unduly conservative since the value represents a central tendency value and given the reported high variability. The calculation of the AF is shown below.

$$\text{Weighted AF} = \frac{(400 \times 0.27) + (400 \times 0.4) + (700 \times 0.36) + (500 \times 0.36)}{(2000)} = 0.35$$

2.2.3.5 ABS, Absorption Factor

The dermal absorption factor (ABS) is the fraction of the contaminant contacting the skin that is absorbed. At this time only limited information is available to derive soil ABS values. In the absence of contaminant specific information default ABS values have been incorporated. The recommended default values are discussed in Section 2.1.3.5. The recommended default ABS values are listed in Table A.2.1 of Appendix 2.

2.2.3.6 EF, Exposure Frequency

See Section 2.2.1.3 for discussion of the EF parameter.

2.2.3.7 BW, Body Weight

See Section 2.2.1.4 for discussion of the BW parameter.

2.2.3.8 AT, Averaging Time

See Section 2.2.1.5 for discussion of the AT parameter.

2.2.4 Inhalation of Vapors or Resuspended Particulate Pathway

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

Contaminants may be inhaled by the receptor of concern whenever the receptor is at or near the site. The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air. The Average Daily Concentration (ADC_{air}) for exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated as shown in Table A1.14.

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Table A1.14 Residential - Subchronic Inhalation of Vapors or Particulate from Soil

$$\text{LADC or ADC}_{air} = \frac{C_{air} \times EF \times CF}{AT}$$

Variable	Definition	Default Value	Reference
LADC or ADC_{aie}	Average daily concentration in air (mg/m^3 or ug/m^3).		See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) = C_{soil} x (1/PEF + 1/VF)	Measured/Modeled Concentration	See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg	Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period	65	3 summer months, average of 5 d/wk.
AT	Averaging Time (days)	90 25550	Noncancer AT = 3 months Cancer AT = 70 year lifetime.

2.2.4.1 C_{air}, Air Concentration

To calculate an average daily air concentration, the particulate emission factor (PEF) and volatilization factor (VF) must be calculated. See Section 2.1.4.1 for a more detailed discussion of the PEF and VF equations. Table A1.15 presents the PEF equation and the default input values for subchronic exposure.

Table A1.15 Residential - Calculation of Subchronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600 s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	3.8E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	45.93	Annual estimate Q/C value for Los Angeles for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0.25	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.92	Based on climatic data for Minneapolis/St. Paul metropolitan area. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

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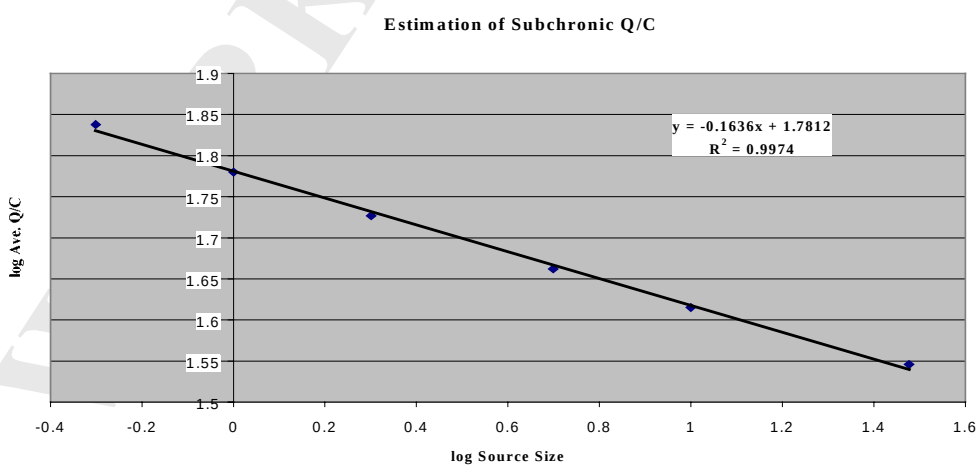
Table 3 of the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996) provides the estimated annual Q/C values for various locations (i.e., city and climatic zone) and source area sizes. Since the subchronic exposure evaluation is based on exposure during the summer months the location which best approximated the 90th percentile of the annual Q/C values (based on the 29 locations evaluated) was selected instead of the annual Q/C value for Minneapolis. An intermediate source size of 5 acres was selected for the default source size. A linear inverse relationship exists between the log of the source size and the log of the annual Q/C as shown in Figure A1.2. This relationship can be utilized to estimate the annual Q/C for source sizes which are not included in Table 3 of the EPA Soil Screening Guidance. The Q/C value, is used in the determination of both PEF and VF. The fraction of vegetation will vary from site to site. The exposure area for the subchronic evaluation is assumed to be a playarea which is only partially vegetated. A default value of 0.25 was selected.

Figure A1.2 Estimation of Subchronic Q/C

Source Size (acres) [log]	Annual Los Angeles Ave. Q/C (g/m2-s per kg/m3) [log]
0.5 [-0.3]	68.81 [1.84]
1 [0]	60.24 [1.78]
2 [0.3]	53.3 [1.73]
5 [0.7]	45.93 [1.66]
10 [1]	41.24 [1.62]
30 [1.5]	35.15 [1.55]
From Table 3 (EPA 1996)	



Minnesota Pollution Control Agency
Policy and Planning Division
Regular Facilities/Remediation Section
520 Lafayette Road
St. Paul, Minnesota 55155-4194

It is generally assumed that the concentration of the contaminant in the particulate is equal to the concentration of the contaminant in soil. This assumption may underestimate the concentration of contaminant in the inhalable fraction (i.e., PM10 fraction), since smaller particulate fractions sometimes contain contaminant concentrations that are enriched relative to larger fractions. However, the data needed to derive more accurate concentration estimates are typically not available. To calculate the airborne particulate contaminant concentration simply multiple the soil concentration by the inverse of the particulate emission factor (3E-3 mg/m^3).

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). The above model addresses mainly wind erosion. If activities likely to physically disturb soil occur with regular frequency the default PEF may not be protective.

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). The above model addresses mainly wind erosion. If activities likely to physically disturb soil occur with regular frequency the default PEF may not be protective.

For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. Table A1.16 presents the VF equation and default values for subchronic exposure.

Table A1.16 Residential - Calculation of Subchronic Volatilization Factor

$$VF\,(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}\,(m^2/cm^2)$$

Variable	Definition	Default Value	Reference
VF	Volatilization Factor (m^3/kg)	Contaminant Specific	
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	45.93	Annual estimate Q/C value for Los Angeles for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
Da	Apparent diffusivity (cm^2/s)	Contaminant Specific	See Table A1.10 and Appendix Section 2.1.3.1.
T	Exposure interval (s)	7.8E+06	Assumes 90 day exposure period.
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996). (Use site data to develop site-specific value)

The VF equation given above represents a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The equation incorporates a number of conservative, simplifying assumptions, e.g., infinite source, steady state conditions. Part 3 of the Soil Screening Guidance: Technical Background Document (EPA 1996) includes information on models for a more detailed evaluation.

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There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When a calculated SRV exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. Table A1.11 presents the Csat equation and default values.

2.2.4.2 CF, Units Conversion Factors

See Section 2.2.1.1 for discussion of the CF parameter.

2.2.4.3 EF, Exposure Frequency

See Section 2.2.1.3 for discussion of the EF parameter.

2.2.4.4 AT, Averaging Time

See Section 2.2.1.5 for discussion of the AT parameter.

2.3 Residential Acute Exposure

The presence of acutely toxic contaminants in accessible soil could pose a significant health risk from a “one-time” exposure. With acutely toxic contaminants, the risk estimate for a “one time” exposure may exceed the risks from long term exposures when the magnitude of exposure during the acute episode is very high. Acute (i.e., “one time”) risk estimates are based on the highest concentration detected. The Acute Dose due to the incidental ingestion of a bolus of contaminated soil ($AD_{ingestion}$) may be calculated utilizing the equation presented in Table A1.17.

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Table A1.17 Residential - Acute Incidental Ingestion of Soil

$$AD_{soil\ ingestion} = \frac{Csoil \times IR \times CF}{BW}$$

Variable	Definition	Default Value	Reference
$AD_{soil\ ingestion}$	Acute dose of ingested contaminant (mg/kg-d).		
C_{soil}	Soil Concentration (mg/kg)	Maximum concentration	See Section 8.3.3.5 and Section 7.4.
IR	Annual daily soil ingestion rate (mg/day)	10,000	Stanek & Calabrese, 1995.
CF	Conversion Factor (kg/mg)	1E-6	
BW	Mean Body weight (kg).	11	Mean BW for 1 - 2 year olds (EPA 1997).

2.3.1 C_{soil}, Contaminant Concentration

For acute exposure assessments, the exposure concentration should represent a conservative estimate of the concentration to which a receptor might be exposed over the period of a single event (e.g., ingestion of a bolus of soil) or a single day. Generally, the highest detected concentration should be employed when one-time exposure could result in adverse health effects.

2.3.2 IR, Soil Ingestion Rate

Based on results reported by Stanek and Calabrese's (1995) the ingestion of a bolus of soil is common among young children. These authors estimated that approximately 33% of children will ingest greater than 10,000 mg of soil on 1 to 2 days per year. Because of their low body weight young children could potentially receive a large dose per unit body weight as a result of ingesting a bolus of soil. A toddler (1 - 2 years of age) ingesting a bolus of soil is the recommended receptor for assessing acute exposure to soil contaminants. Given that 10,000 mg/day represents a lower limit of ingestion as well as the limited data and the magnitude of variability the recommended default ingestion rate is not considered to be unduly conservative.

2.3.3 CF, Units Conversion Factors

Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units (e.g., mg/kg/day). Use of the units conversion factors (CF) (1E-6 kg per mg) is equivalent to multiplication by one.

2.3.4 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). See Appendix Section 2.1.17 for additional discussion of BW parameter. Age-specific body weights are summarized in Table A1.2. The body weights are 50th percentile values for males and females age 1 - 2 years old (EPA Exposure Factors Handbook, 1997).

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3.0 RECREATIONAL PROPERTY USE - DIRECT SOIL EXPOSURE PATHWAY EVALUATION

3.1 Recreational - Chronic Exposure

3.1.1 General Exposure Factors

There are six exposure factors which recur throughout the equations used to estimate the dose of contaminant experienced by a potential receptor:

- C_{soil}, Contaminant Concentration
- CF, Units Conversion Factors
- EF Exposure Frequency
- ED, Exposure Duration
- BW, Body Weight
- AT, Averaging Time

These factors are generally used in the same manner regardless of the exposure pathway under investigation, so it is useful to discuss them separately.

3.1.1.1 C_{soil}, Contaminant Concentration

The concentration of the contaminant used to quantify exposure is the Exposure Concentration. The exposure concentration is expressed in terms of mass of the material per unit mass (or volume) of the exposure medium (e.g., mg contaminant/kg soil). The exposure point concentration should *not* be adjusted for receptor exposure frequency, duration, etc. as those factors are generally addressed in the exposure calculations. See Sections 7.4 and 8.3.3.5 of the main text for additional discussion.

3.1.1.2 CF, Units Conversion Factors

Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units. Use of a CF (1E-6 kg/mg or 1E+3 ug/mg) is equivalent to multiplication by one. The numerator and denominator of the factor must be an equivalent quantity expressed in different terms.

3.1.1.3 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. While estimates have been published on the amount of soil ingested during a *day*, there can be no reliable estimate of average *hourly* ingestion rates as incidental ingestion of soil is a sporadic

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event depending upon human behavior (e.g., activities, habits). For such exposures (including soil ingestion and dermal contact) EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant.

Frequency of exposure is site- and activity-specific. The exposure frequency selected must be appropriate for the duration and contact rate chosen Since recreational activities at a non-residential location (e.g., playground, ballfield, park, etc.) it is assumed that the exposure duration is more limited than the residential exposure scenario. The exposure frequency for young children (< 6 years) and older children (> 6 - 18 years) was assumed to be 106 days, corresponding to approximately 2 days/week during the four spring and fall months and 5 days/week during the three summer months. The exposure frequency for adults was assumed to be 75 days, corresponding to approximately 2 days/week during the four spring and fall months and 3 days/week during the three summer months. Exposure to soil during the 5 colder months of the year (November - March) is assumed to be negligible.

Because the EF changes with age it is necessary to calculate an age-adjusted EF when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period or in the case of cancer evaluation a lifetime. The results of utilizing a simple age-weighted averaging approach is shown below.

$$EF_{age-adjusted} = \frac{(106 \text{ days x } 6 \text{ yrs}) + (106 \text{ days x } 12 \text{ yrs}) + (75 \text{ days x } 15 \text{ yrs}}{33 \text{ yrs}} = 92 \text{ days}$$

31.1.4 ED, Exposure Duration

The exposure duration (ED) describes the length of time over which the receptor comes into contact with the contaminant. The exposure duration depends upon the type of activities which lead a receptor to be exposed. Remember that the receptor may be exposed continuously, at regular intervals, or sporadically, depending upon the activity being modeled, so the exposure period would be the length of time between the first exposure experienced and the last.

As discussed previously, exposure duration is believed to be one of the more sensitive parameters in the exposure equation. In keeping with the RME approach what is believed to be an the upper-end estimate was utilized as the default for the duration of exposure. This value is based on the national statistics for residential occupancy (US Bureau of Census data). This may underestimate the exposure duration since a receptor may reside within a given community for a longer period than at a single resident. The 90th percentile value for years lived in the current home for the Minneapolis/St. Paul metropolitan area (33 years) was utilized as the total exposure duration period. No statistical data on childhood residential occupancy time are available. For the purpose of calculating the SRVs, children (defined here as infants to 6 years old) are assumed to reside at a single residence (i.e., exposure duration for children is 6 years). This does not appear to be an upper-end estimate for young children (Johnson and Capel, 1992 as cited in Exposure Factors Handbook, EPA 1997).

3.1.1.5 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). The receptor's body weight is dependent upon its age and gender. Since body weight is easily measured, there are numerous summaries of

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age and gender-specific body weights. Table A1.1 provided age-specific body weights for children and adults. The body weights are 50th percentile values for males and females and are presented annually for children and at longer intervals for adults (EPA Exposure Factors Handbook, 1997).

The receptor body weight (BW, typically expressed in kilograms, kg) must be matched to the age and gender identified in the exposure profile. Since exposure is often assumed to occur over a period of several years, the changes in body weight which might occur during the period of exposure must also be considered. An average body weight is estimated across the age group under consideration. For deterministic evaluations (i.e., evaluations using a point estimate of body weight) the 50th percentile body weigh for the subpopulation under consideration is recommended, unless there is strong evidence that the potentially exposed subpopulation is biased in some manner. The body weights utilized are 15, 43, and 70 kg for young children (< 6 years), older children (> 6 - 18 years) and adults (> 18), respectively.

Because body weights changes with age it is necessary to calculate an age-adjusted body weight when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period or in the case of cancer evaluation a lifetime. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. The results of utilizing a simple age-weighted averaging approach to calculate age-adjusted body weight is shown below.

$$BW_{age-adjusted} = \frac{(15\text{ kg x 6 years}) + (43\text{ kg} \times 12) + (70\text{ kg x 15 years})}{33\text{ years}} = 51\text{ kg}$$

3.1.1.6 AT, Averaging Time

The averaging time (AT) is the time over which the total intake is normalized. For the evaluation of <u>*noncancer risk*</u>, the Average Daily Dose calculated should be representative of the exposure received while exposure is on-going (i.e., during the exposure period). Thus the values for exposure period duration (ED) and the averaging time (AT) are equivalent.

The Lifetime Average Daily Dose (LADD) is calculated for the evaluation of <u>*cancer risk*</u>. While the duration of the exposure period (ED) might range from one day to an entire lifetime, the total intake during that exposure is traditionally normalized to a lifetime. The averaging time for assessment of cancer risk is therefore typically set at 70 years. For exposures lasting less than a lifetime, the values for ED and AT will be different. As stated in Section 7.3.3.2, for some contaminants or subpopulations of receptors this approach (normalizing over a lifetime) may not be health protective (e.g., vinyl chloride exposure to children). The existence of critical periods of susceptibility during a lifetime and the intensity of exposure may influence cancer risk. These factors may warrant deviation from the traditional approach. When possible, the biological basis or mechanism by which a carcinogen acts should be used to characterize risk from the carcinogenic contaminant.

3.1.2 Incidental Soil Ingestion Pathway

The Average Daily Dose due to the *chronic* incidental ingestion of contaminated soil ($ADD_{soil\ ingestion}$) may be calculated utilizing the equation presented in Table A1.18.

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Table A1.18. Recreational - Chronic Incidental Ingestion of Soil.

$$\text{LADD or ADD}_{soil\ ingestion} = \frac{Csoil \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or $ADD_{soil\ ingestion}$	Average daily potential dose received through the ingestion of soil (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
IR	Daily soil ingestion rate (mg/day)	250 (< 6 yr) 175 (>6 - 18 yr) 100 (> 6 - 33 yr) 155 (age-adjusted)		Stanek & Calabrese, 1995. Includes higher intake in young children. Assume recreational activity results in disturbance and direct contact with soil.
CF	Conversion Factor	1E-6 kg/mg		
FI	Fraction of ingested soil which is from contaminated soil	1	NA	
EF	Number of exposure days during the exposure period (days/year).	106 (< 6 yr) 106 (> 6 - 18 yr) 74 (> 18 - 33 yr) 92 (age-adjusted)		Approximately 2 d/wk for 4 months and 5 d/wk for 3 months. Approximately 2 d/wk for 4 months and 3 d/wk for 3 months.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
BW	Body weight of the receptor of concern during the exposure period (kg).	15 (< 6 yr) 43 (> 6 - 18 yrs) 70 (>18 - 33 yr) 51 (age-adjusted)	C C C	EPA, 1997
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

C = Central Tendency Value (e.g., average)
U = Upper Tendency Value

3.1.2.1 C_{soil}, Contaminant Concentration

See Section 3.1.1.1 for discussion of the C_{soil}, parameter.

3.1.2.2 IR, Soil Ingestion Rate

Soil ingestion is assumed to occur incidentally, from hand-to-mouth contact, during outdoor activities in the warmer months of the year and through the inhalation of larger particles. Soil from outdoors can also be brought indoors (e.g., on clothing, shoes and tools) or can enter the house as

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windblown dust. Although some incidental soil/dust ingestion can also occur indoors it is assumed to be negligible under the recreational exposure setting.

Soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period.

Several studies have been conducted to estimate the amount of soil incidentally ingested by children. The central tendency value of 100 mg/day is recommended by EPA (Exposure Factors Handbook, 1997) as a daily average ingestion rate for the child receptor under the residential exposure scenario. Stanek and Calabrese's (1995) have estimated that 31% of children will ingest greater than 500 mg/day on 35 to 40 days per year. Recreational exposure is expected to mainly occur during the warmer seven months of the year (i.e., April through October). Soil exposure is assumed to be negligible during the 5 colder months of the year (i.e., November - March). Since the receptors do not reside on the recreational property it is assumed that exposure occurs only on a portion of the days within this period. The exposure frequency for young children (< 6 years) was assumed to be 106 days, corresponding to approximately 2 days/week during the four spring and fall months and 5 days/week during the three summer months. During this time period it is assumed that an incidental soil ingestion rate of 500 mg/day for 40 days and an incidental soil ingestion rate of 100 mg/day for the remaining 66 days a simple time-weighted average of approximately 250 mg/day is calculated. Given that 500 mg/day represents a lower limit of ingestion for 31% of the children as well as the limited data and the variability in the existing data the value of 250 mg/day is not considered to be unduly conservative for recreational activities.

An exposure frequency of 106 days was also was utilized for receptors age > 6 - 18 years. The exposure frequency for adults was assumed to be 75 days, corresponding to approximately 2 days/week during the four spring and fall months and 3 days/week during the three summer months. Older children and adults may incidentally ingestion soil that adhere to food or their hands or through the inhalation of larger particles. Information on soil ingestion adults is very limited. A daily incidental ingestion rate of 100 mg/day for soil is recommended as the default for adults. Since it is assumed that recreational activities will result in disturbance of soil and direct contact with soil the default values of 100 mg/day are not considered to be unduly conservative.

In the absence of information regarding soil ingestion in older children (i.e., > 6 - 18 years of age) a value midway between the soil ingestion rates for young children and adults was selected for this age-group (i.e., 175 mg/day).

Because soil ingestion rates vary across age groups it is necessary to calculate an age-adjusted soil ingestion rate when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period or in the case of cancer evaluation a lifetime. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. Therefore, the age-adjusted exposure should be calculated in a way that does not "dilute" the higher exposure rates experienced by young children with lower exposure rates experienced by older

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children and adults. Utilizing a simple averaging approach an age-weighted average can be calculated . The age-weighted average calculation is shown below.

$$IR_{age-adjusted} = \frac{(250\ mg/d \times 6\ yrs) + (175\ mg/d \times 12\ yrs) + (100\ mg/d \times 15\ yrs)}{33\ yrs} = 155\ mg/d$$

3.1.2.3 CF, Units Conversion Factors

See Section 3.1.1.2 for discussion of the CF parameter.

3.1.2.4 FI, Fraction of Ingested Soil

Since soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period. It is assumed that the daily ingestion occurs during the recreational activity within the exposure area.

3.1.2.5 EF, Exposure Frequency

See Section 3.1.1.3 for discussion of the EF parameter.

3.1.2.6 ED, Exposure Duration

See Section 3.1.1.4 for discussion of the ED parameter.

3.1.2.7 BW, Body Weight

See Section 3.1.1.5 for discussion of the BW parameter.

3.1.2.8 AT, Averaging Time

See Section 3.1.1.6 for discussion of the AT parameter.

3.1.3 Dermal Contact Pathway

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. In fact, dermal absorption from soils may be more significant than incidental ingestion for chemicals which have a percent absorption exceeding about 10% (USEPA, EPA/600/8-91/011B, January, 1992). Contaminants exhibiting percentage absorption less than 10% also contribute to cumulative risk estimates and therefore these contaminants must also be evaluated. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil (e.g., organic carbon content). The Average Daily Dose due to chronic dermal contact with contaminated soil ($ADD_{dermal\ absorption}$) may be calculated as shown in Table A1.19.

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Table A1.19 Recreational - Chronic Dermal Contact with Soil

$$\text{LADD or ADD}_{dermal\ absorption} = \frac{Csoil \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or ADD_{dermal}	Average daily dose absorbed through dermal contact (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
CF	Conversion Factor	1E-6 kg/mg		
SA	Skin surface area (cm^2)	2000 (< 6 yr) 3300 (> 6 - 18 yr) 4500 (> 18 - 33 yr) 3609 (age-adjusted)	C	28 - 25% of the average total body SA per exposure event (EPA, 1992 and EPA, 1997)
AF	Skin adherence factor (mg/cm^2)	0.35	C	Kissel et. al., as cited in EPA, 1992 and EPA, 1992
ABS	Absorption factor	Chemical specific		
EF	Number of exposure days during the exposure period (days/year).	106 (< 6 yr) 106 (> 6 - 18 yr) 74 (>18 - 33 yr) 92 (age-adjusted)	NA	Approximately 2 d/wk for 4 months and 5 d/wk for 3 months. Approximately 2 d/wk for 4 months and 3 d/wk for 3 months.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
BW	Body weight of the receptor of concern during the exposure period (kg).	15 (< 6 yr) 45 (> 6 - 18 yrs) 70 (>18 - 33 yr) 51 (age-adjusted)	C C C	EPA 1997
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

3.1.3.1 C_{soil}, Contaminant Concentration

See Section 3.1.1.1 for discussion of the C_{soil}, parameter.

3.1.3.2 CF, Units Conversion Factors

See Section 3.1.1.2 for discussion of the CF parameter.

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3.1.3.3 SA, Skin Surface Area

The surface area parameter (SA) describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends on the receptor and the exposure scenario. Clothing is expected to limit the extent of the exposed surface area for most activities. All SA estimates used 50th percentile values in order to correlate with the average body weights used for exposure estimations. This is done to prevent inconsistent parameter combinations since body weight and surface area are not independent variables. The age-specific 50th percentile total body surface areas are shown in Table A1.4.

The exposure frequency for dermal exposure is limited to the warmer months of the year (i.e., April through October). For the purpose of calculating the dermal dose it was assumed that the forearms, lower legs, hands, and feet were exposed. The age-specific percentage of total body surface area by body part are shown in Table A1.5. This exposed area constitutes approximately 28% in the < 6 year young child receptor and 25% in the > 6 - 18 older child and > 18 - 33 year adult receptor. Surface areas of 2,000, 3300 and 4,500 cm^2 were calculated by incorporating data from the EPA Exposure Factors Handbook (EPA 1997) as presented in Tables A1.4 and A1.5. Since some studies have suggested that exposure can occur under clothing (EPA, 1992) this scenario is not considered to be unduly conservative.

Because body surface area changes with age it is necessary to calculate an age-adjusted skin surface area when exposure occurs throughout childhood and into adult years. The average daily dose (ADD) should be calculated to reflect age-related differences in exposure rates that are experienced by a receptor throughout the exposure period or in the case of cancer evaluation a lifetime. The results of utilizing a simple age-weighted averaging approach to calculating age-adjusted surface area is shown below:

$$SA_{age-adjusted} = \frac{(2000\ cm^2 \times 6\ yrs) + (3300\ cm^2 \times 12\ yrs) + (4500\ cm^2 \times 15\ yrs)}{33\ years} = 3600\ cm^2$$

3.1.3.4 AF, Soil Adherence Factor

The adherence factor (AF) describes the amount of soil that adheres to the skin. The EPA Exposure Factors Handbook (EPA 1997) recommends utilizing the Kissel, et al., study for estimating soil adherence. The results of this study showed that generally soil adherence could be directly correlated with soil moisture and activity and inversely correlated with particle size. The default AFs are based on the central tendency value recommended in EPA's Dermal Guidance (EPA 1992) and a review of the body-part-specific and activity-specific adherence factors reported by Kissel et al., 1996 (as cited in the EPA, 1997).

The data available for receptors in a recreational setting is limited. The studies by Kissel et al., (1996) evaluated soccer and rugby players. The exposure frequency utilized in the dermal exposure pathway is based on outdoor activity in a recreational setting. The data from adult rugby players was utilized for all recreational receptors. The weighted adherence factor was calculated utilizing the equation below:

$$\text{Weighted AF} = \frac{(SA1 \times AF1) + (SA2 \times AF2) + \ldots + (SAi \times AFi)}{(SA1 + SA2 + \ldots + SAi)}$$

where:

SAi = surface area for body part "i", cm^2
AFi = soil-to-skin adherence factor for body part "i", mg/cm^2-event

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The body part specific surface area information can be found in Table A1.6. Kissel, et al. presented the body part specific AFs for three subsets of rugby players. The highest geometric mean values were utilized when calculating the weighted AF. The AF reported for legs was utilized for feet. The selection of the highest mean AF is not considered unduly conservative considering that the value represents a central tendency value and the high variability. The calculation of the age-group specific AF is shown below:

$$\text{Weighted } AF_{child} = \frac{(400 \times 0.27) + (400 \times 0.4) + (700 \times 0.36) + (500 \times 0.36)}{(2000)} = 0.35$$

$$\text{Weighted } AF_{>6\text{ - }18} = \frac{(700 \times 0.27) + (650 \times 0.4) + (1300 \times 0.36) + (650 \times 0.36)}{(3300)} = 0.35$$

$$\text{Weighted } AF_{adult} = \frac{(1000 \times 0.27) + (900 \times 0.4) + (1700 \times 0.36) + (900 \times 0.36)}{(4500)} = 0.35$$

3.1.3.5 ABS, Absorption Factor

The dermal absorption factor (ABS) is the fraction of the contaminant contacting the skin that is absorbed. At this time only limited information is available to derive soil ABS values. In the absence of contaminant specific information default ABS values have been incorporated. The recommended default values are presented in Section 2.1.3.5. The default values are based on the EPA Dermal Workgroup recommendations and professional judgment. The recommended default ABS values are listed in Table A.2.1 of Appendix 2.

3.1.3.6 EF, Exposure Frequency

See Section 3.1.1.3 for discussion of the EF parameter.

3.1.3.7 ED, Exposure Duration

See Section 3.1.1.4 for discussion of the ED parameter.

3.1.3.8 BW, Body Weight

See Section 3.1.1.5 for discussion of the BW parameter.

3.1.3.9 AT, Averaging Time

See Section 3.1.1.6 for the discussion of the AT parameter.

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3.1.4 Inhalation of Vapors or Resuspended Particulate Pathway

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

Contaminants may be inhaled by the receptor of concern whenever the receptor is at or near the site. The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air. The Average Daily Concentration (ADC_{air}) for chronic recreational exposure may be calculated as shown in Table A1.20.

Table A1.20 Recreational - Chronic Inhalation of Vapors or Particulate from Soil

$$\text{LADC or } ADC_{air} = \frac{Cair \times EF \times ED \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{aie}	Average daily concentration in air (mg/m^3 or ug/m^3).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) Modeled: C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg		Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period (days/year).	106 (< 6 yr) 106 (> 6 - 18 yr) 74 (>18 - 33 yr) 92 (age-adjusted)	NA	Approximately 2 d/wk for 4 months and 5 d/wk for 3 months. Approximately 2 d/wk for 4 months and 3 d/wk for 3 months.
ED	Duration of the exposure period (years).	6 (< 6 yr) 12 (> 6 - 18 yrs) 15 (> 18 - 33 yr) 33 (age-adjusted)	C U U	American Housing Survey for the Minneapolis/St. Paul Metro Area in 1993. 33 years = 90th percentile resident tenure.
AT	Averaging Time (days)	2190 (< 6 yr) 4380 (> 6 - 18 yrs) 5475 (> 18 - 33 yr) 12045 (age-adjusted) 25550 (lifetime)		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

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3.1.4.1 C_{air}, Air Concentration

To calculate an average daily air concentration, the particulate emission factor (PEF) and volatilization factor (VF) must be calculated. See Section 2.1.4.1 for a more detailed discussion of the PEF and VF equations. Table A1.21 presents the PEF equation and the default input values for chronic recreational exposure.

Table A1.21 Recreational - Calculation of Chronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600 s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	4.42E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	45.93	Annual estimate Q/C value for Los Angeles for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0.25	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.7	Based on climatic data for Minneapolis/St. Paul metropolitan area. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

Table 3 of the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996) provides the estimated annual Q/C values for various locations (i.e., city and climatic zone) and source area sizes. Since the recreational exposure evaluation is based on exposure during the warmer months the location which best approximated the 90th percentile of the annual Q/C values (based on the 29 locations evaluated) was selected instead of the annual Q/C value for Minneapolis. An intermediate source size of 5 acres was selected for the default source size. A linear inverse relationship exists between the log of the source size and the log of the annual Q/C. This relationship can be utilized to estimate the annual Q/C for source sizes which are not included in Table 3 of the EPA Soil Screening Guidance. See Section 2.1.4.1. The Q/C value, is used in the determination of both PEF and VF.

The fraction of vegetation will vary from site to site. The exposure area for the recreational exposure evaluation is assumed to be only partially vegetated. A default value of 0.25 was selected.

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It is generally assumed that the concentration of the contaminant in the particulate is equal to the concentration of the contaminant in soil. This assumption may underestimate the concentration of contaminant in the inhalable fraction (i.e., PM10 fraction), since smaller particulate fractions sometimes contain contaminant concentrations that are enriched relative to larger fractions. However, the data needed to derive more accurate concentration estimates are typically not available. To calculate the airborne particulate contaminant concentration simply multiple the soil concentration by the inverse of the particulate emission factor (3 E-3 mg/m^3).

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). The above model addresses mainly wind erosion. If activities likely to physically disturb soil occur with regular frequency the default PEF may not be protective.

For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. Table A1.22 presents the VF equation and default values for subchronic exposure.

Table A1.22 Recreational - Calculation of Chronic Volatilization Factor

$$VF\,(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}\,(m^2/cm^2)$$

Variable	Definition	Default Value	Reference
VF	Volatilization Factor (m^3/kg)	Contaminant Specific	
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	45.93	Annual estimate Q/C value for Los Angeles for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
Da	Apparent diffusivity (cm^2/s)	Contaminant Specific	See Table A1.10 and Appendix Section 2.1.3.1.
T	Exposure interval (s)	1.89E+8 (< 6 yrs) 3.8E+8 (> 6 - 18 yrs) 4.7E+8 (> 18 - 33 yrs) 1.0E+9 (total duration)	
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996). (Use site data to develop site-specific value)

The VF equation given above represents a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The equation incorporates a number of conservative, simplifying assumptions, e.g., infinite source, steady state conditions. Part 3 of the Soil Screening Guidance: Technical Background Document (EPA 1996) includes information on models for a more detailed evaluation.

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There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When a calculated SRV for a VOC exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. Table A1.11 presented the Csat equation and default values.

3.1.4.2 CF, Units Conversion Factors

See Section 3.1.1.2 for discussion of the CF parameter.

3.1.4.3 EF, Exposure Frequency EF

See Section 3.1.1.3 for discussion of the EF parameter.

3.1.4.4 ED, Exposure Duration

See Section 3.1.1.4 for discussion of the ED parameter.

3.1.4.5 AT, Averaging Time

See Section 3.1.1.6 for discussion of the AT parameter.

3.2 Recreational Subchronic Exposure

The effect (noncarcinogenic and carcinogenic) of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short-period of time may not produce the same effect when given over a longer period of time. See Section 8.3.3.4 of main text for further discussion. Because of their low body weight and behavioral characteristics, young children receive a larger potential dose per unit body weight than older children and adults. A young child (< 6 years) was chosen as the receptor for the subchronic exposure scenario. The exposure time selected was the summer months due to higher exposure potential, i.e., higher potential contact with soil. The default values utilized to evaluate the recreational subchronic exposure scenario are identical to the residential subchronic exposure scenario. See Appendix 1 Section 2.2 for methodology.

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3.3 Recreational Acute Exposure

The presence of acutely toxic contaminants in accessible could pose a significant health risk from a "one-time" exposure. With acutely toxic contaminants, the risk estimate for a "one time" exposure may exceed the risks from long term exposures when the magnitude of exposure during the acute episode is very high. Based on results reported by Stanek and Calabrese's (1995) the ingestion of a bolus of soil is common among young children. These authors estimated that approximately 33% of children will ingest greater than 10,000 mg of soil on 1 to 2 days per year. Because of their low body weight young children could potentially receive a large dose per unit body weight as a result of ingesting a bolus of soil. A toddler (1 - 2 years of age) ingesting a bolus of soil is the recommended receptor for assessing acute exposure to soil contaminants. The default values utilized to evaluate the recreational acute exposure scenario are identical to the residential acute exposure scenario. See Appendix 1 Section 2.3 for methodology.

4.0 INDUSTRIAL PROPERTY USE - DIRECT SOIL EXPOSURE PATHWAY EVALUATION

4.1 Industrial - Chronic Exposure

4.1.1 General Exposure Factors

There are five exposure factors which recur throughout the equations used to estimate the dose of contaminant experienced by a potential receptor:

- C_{soil}, Contaminant Concentration
- CF, Units Conversion Factors
- ED, Exposure Duration
- BW, Body Weight
- AT, Averaging Time

These factors are generally used in the same manner regardless of the exposure pathway under investigation, so it is useful to discuss them separately.

4.1.1.1 C_{soil}, Contaminant Concentration

The concentration of the contaminant used to quantify exposure is the Exposure Concentration. The exposure concentration is expressed in terms of mass of the material per unit mass (or volume) of the exposure medium (e.g., mg contaminant/kg soil). The exposure point concentration should *not* be adjusted for receptor exposure frequency, duration, etc. as those factors are generally addressed in the exposure calculations. See Sections 7.4 and 8.3.3.5 of the main text for additional discussion.

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4.1.1.2 CF, Units Conversion Factors

Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units. Use of a CF (1E-6 kg/mg or 1E+3 ug/mg) is equivalent to multiplication by one. The numerator and denominator of the factor must be an equivalent quantity expressed in different terms.

4.1.1.3 ED, Exposure Duration

The exposure duration (ED) describes the length of time over which the receptor comes into contact with the contaminant. Therefore, the exposure period would be the length of time between the first exposure experienced and the last. As discussed previously, exposure duration is believed to be one of the more sensitive parameters in the exposure equation. In keeping with the RME approach the upper-end estimate was utilized as the default for the duration of exposure. National statistics are available for worker tenure (Maguire, 1993). The 95th percentile value for years worked at same location was determined to be 25 years.

4.1.1.4 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). Table A1.23 provides age-specific body weights for adults. The body weights are 50th percentile values for males and females and are presented annually for adults (Table 7-2, EPA Exposure Factors Handbook, 1997). The receptor body weight (BW, typically expressed in kilograms, kg) must be matched to the age and gender identified in the exposure profile. Since exposure is assumed to be limited to an adult worker the average body weight (70 kg) for adults (> 18 - 65 years) is recommended as the default value. Within a given age/sex combination, there is some variability of body weight. If there is strong evidence that the potentially exposed subpopulation is biased in some manner a more site specific value should be utilized.

TABLE A1.23 AGE-SPECIFIC BODY WEIGHTS FOR ADULTS

AGE (Years)	Mean BW for Females (kg)	Mean BW for Males (kg)	Default BW Recommended (kg)
18 < 25	60.6	73.8	
25 < 35	64.2	78.7	
35 < 45	67.1	80.9	
45 < 55	68.0	80.9	
55 < 65	67.9	78.8	> 18 - 65 years: 70 kg

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4.1.1.5 AT, Averaging Time

The averaging time (AT) is the time over which the total intake is normalized. For the evaluation of *noncancer risk*, the Average Daily Dose calculated should be representative of the exposure received while exposure is on-going (i.e., during the exposure period). Thus the values for exposure period duration (ED) and the averaging time (AT) are equivalent.

The Lifetime Average Daily Dose (LADD) is calculated for the evaluation of *cancer risk*. While the duration of the exposure period (ED) might range from one day to an entire lifetime, the total intake during that exposure is traditionally normalized to a lifetime. The averaging time for assessment of cancer risk is therefore typically set at 70 years. For exposures lasting less than a lifetime, the values for ED and AT will be different. As stated in Section 8.3.3.2, for some contaminants or subpopulations of receptors this approach (normalizing over a lifetime) may not be health protective. The existence of critical periods of susceptibility during a lifetime and the intensity of exposure may influence cancer risk. These factors may warrant deviation from the traditional approach. When possible, the biological basis or mechanism by which a carcinogen acts should be used to characterize risk from the carcinogenic contaminant.

4.1.2 Incidental Soil Ingestion Pathway

The Average Daily Dose due to the chronic incidental ingestion of contaminated soil ($ADD_{soil\ ingestion}$) may be calculated utilizing the equation presented in Table A1.24.

4.1.2.1 C_{soil}, Contaminant Concentration

See Section 4.1.1.1 for discussion of the C_{soil} parameter.

4.1.2.2 IR, Soil Ingestion Rate

Soil ingestion is assumed to occur incidentally, from hand-to-mouth contact and through the inhalation of larger particles during outdoor activities in the warmer months of the year. Soil from outdoors can also be brought indoors (e.g., on clothing, shoes and tools) or can enter buildings as windblown dust. Therefore, some incidental soil/dust ingestion can also occur indoors. Information on soil ingestion among adults is very limited. An annual average daily ingestion rate of 50 mg/day for soil and indoor dust has been recommended based on a study involving adult volunteers. This value is appropriate for indoor workers only (e.g., office worker). A higher incidental ingestion rate would be more appropriate for industrial workers since industrial setting could involve outdoor work activities and industrial sites are generally dustier. An annual average daily ingestion rate of 80 mg/day for soil and indoor dust is recommended as the RME default for workers in an industrial or restricted commercial setting. This value is based on a simple time-weighted average utilizing 100 mg/day as an ingestion rate during the warmer 7 months of the year and 50 mg/day for the 5 colder months of the year. Given the limited data and the potential for inadvertent ingestion (e.g., inhalation of large particles) under dusty industrial conditions the default is not considered to be unduly conservative.

$$IR_{age-adjusted} = \frac{(100\ mg/day \times 7\ months) + (50\ mg/day \times 5\ months)}{12\ months} = 80\ mg/day$$

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Table A1.24. Industrial Worker - Chronic Incidental Ingestion of Soil.

$$\text{LADD or ADD}_{soil\ ingestion} = \frac{Csoil \times IR \times CF \times FI \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or $ADD_{soil\ ingestion}$	Average daily potential dose of contaminant received through the ingestion of soil (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
IR	Annual daily soil ingestion rate (mg/day)	80	C	Recommended RME Default value. Assume 7 month at 100 mg/day and 5 months at 50 mg/day.
CF	Conversion Factor	1E-6 kg/mg		
FI	Fraction of ingested soil which is from contaminated soil	1	NA	
EF	Number of exposure days during the exposure period (days/year).	250	C	Utilized with daily average soil ingestion rate. Assumes 5 d/wk and 2 wk vacation work schedule.
ED	Duration of the exposure period (years).	25	U	95th percentile worker tenure.(Maguire, 1993).
BW	Body weight of the receptor (kg).	70	C	EPA 1997 Exposure Factors Handbook
AT	Averaging Time (days)	9125 25550		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

NA = Not Available
C = Central Tendency Value (e.g., average)
U = Upper Tendency Value

Soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period.

4.1.2.3 CF, Units Conversion Factors

See Section 4.1.1.2 for discussion of the CF parameter.

4.1.2.4 FI, Fraction of Ingested Soil

Since soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period. It is assumed that the daily ingestion occurs within the exposure area.

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4.1.2.5 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. The published estimates are based on the amount of soil ingested during a *day*, there can be no reliable estimate of average *hourly* ingestion rates as incidental ingestion of soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures (including soil ingestion and dermal contact) EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant.

Frequency of exposure is site- and activity-specific. Since long-term contact rates are assumed for all exposure pathways and the incidental ingestion rate is assumed to represent a daily average, an exposure frequency of 250 days/year (5 day/week plus 2 week vacation work schedule) is assumed.

4.1.2.6 ED, Exposure Duration

See Section 4.1.1.3 for discussion of the ED parameter.

4.1.2.7 BW, Body Weight

See Section 4.1.1.4 for discussion of the BW parameter.

4.1.2.8 AT, Averaging Time

See Section 4.1.1.5 for discussion of the AT parameter.

4.1.3 Dermal Contact Pathway

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. In fact, dermal absorption from soils may be more significant than incidental ingestion for chemicals which have a percent absorption exceeding about 10% (USEPA, EPA/600/8-91/011B, January, 1992). Contaminants exhibiting percentage absorption less than 10% also contribute to cumulative risk estimates and therefore these contaminants must also be evaluated. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil (e.g., organic carbon content). The Average Daily Dose due to chronic dermal contact with contaminated soil ($ADD_{dermal\ absorption}$) may be calculated as shown in Table A1.25.

4.1.3.1 C_{soil}, Contaminant Concentration

See Section 4.1.1.1 for discussion of the C_{soil} parameter.

4.1.3.2 CF, Units Conversion Factors

See Section 4.1.1.2 for discussion of the CF parameter.

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4.1.3.3 SA, Skin Surface Area

The surface area parameter (SA) describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends on the receptor and the exposure scenario. Clothing is expected to limit the extent of the exposed surface area for most activities. All SA estimates used 50th percentile values in order to correlate with the average body weights used for exposure estimations. This is done to prevent inconsistent parameter combinations since body weight and surface area are not independent variables. The 50th percentile total body surface areas for adults are shown in Table A1.4.

The exposure frequency for dermal exposure is limited to the warmer months of the year. For the purpose of calculating the dermal dose it was assumed that the forearms, hands, and head were exposed. The percentage of total body surface area by body part for adults are shown in Table A1.5. This exposed area constitutes approximately 20% of the total body surface area in an adult. A surface area of 3,400 cm^2 was calculated by incorporating data from the EPA Exposure Factors Handbook (EPA 1997) as presented in Tables A1.4 and A1.5. Since some studies have suggested that exposure can occur under clothing (EPA, 1992) this scenario is not considered to be unduly conservative.

Table A1.25 Industrial Worker - Chronic Dermal Contact with Soil

$$\text{LADD or ADD}_{dermal\ absorption} = \frac{Csoil \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or ADD_{dermal}	Average daily dose absorbed through dermal contact (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
CF	Conversion Factor	1E-6 kg/mg		
SA	Skin surface area (cm^2)	3400	C	Approximately 20% of the average total body SA (EPA, 1992 and EPA, 1997)
AF	Skin adherence factor (mg/cm^2)	0.13	C	Kissel et. al., (as cited in EPA, 1997) and EPA, 1992
ABS	Absorption factor	Chemical specific		
EF	Number of exposure days during the exposure period (days/year).	150	NA	Assume dermal exposure negligible during 5 months of indoor exposure.
ED	Duration of the exposure period (years).	25	U	95th percentile worker tenure. (Maguire 1993)
BW	Body weight of the receptor (kg).	70	C	EPA, 1997
AT	Averaging Time (days)	9125 25550		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

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4.1.3.4 AF, Soil Adherence Factor

The adherence factor (AF) describes the amount of soil that adheres to the skin. The EPA Exposure Factors Handbook (EPA 1997) recommends utilizing the Kissel, et al., study for estimating soil adherence. The results of this study showed that generally soil adherence could be directly correlated with soil moisture and activity and inversely correlated with particle size. The default AFs are based on the central tendency value recommended in EPA's Dermal Guidance (EPA 1992) and a review of the body-part-specific and activity-specific adherence factors reported by Kissel et al., 1996 (as cited in the EPA Exposure Factors Handbook, 1997).

A variety of work conditions were evaluated by Kissel et al. These conditions included groundskeeping, digging, surface restoration, utility work, and moving or excavation of soil. The exposure conditions under an industrial land use may vary substantially and could include a number of the above conditions. The geometric mean soil adherence values for gardening fall roughly in the middle of the range reported for the various activity categories. The recommended default AF for industrial workers is therefore, the same as for the adult residential receptor which is based on the gardening scenario, i.e., 0.13 mg/cm^2. The selected default AF is not considered unduly conservative considering that the value represents a midpoint of central tendency values reported, the high variability, and the surface area limited to only the lower arms, hands and head. Kissel et al.'s study demonstrated that exposure can occur under clothing, e.g., substantial soil loading on feet even though shoes are worn.

4.1.3.5 ABS, Absorption Factor

The dermal absorption factor (ABS) is the fraction of the contaminant contacting the skin that is absorbed. At this time only limited information is available to derive soil ABS values. In the absence of contaminant specific information default ABS values have been incorporated. The basis of the recommended default values was presented in Appendix 1 Section 2.1.3.5. The default values are based on the EPA Dermal Workgroup recommendations and professional judgment. The recommended default ABS values are listed in Table A.2.1 of Appendix 2.

4.1.3.6 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. There can be no reliable estimate of an average *hourly* rate since contact with soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant.

Frequency of exposure is site- and activity-specific. The exposure frequency selected must be appropriate for the duration and contact rate chosen. Dermal contact with contaminated soil is assumed to occur mainly during outdoor activities. Outdoor activities which would result in dermal contact are assumed to occur during the 7 warmer months of the year. It is further assumed that during this period of time the work activities that would result in dermal contact occur on average 3 days per week. The resulting exposure frequency for industrial workers is 90 days per year.

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4.1.3.7 ED, Exposure Duration

See Section 4.1.1.3 for discussion of the ED parameter.

4.1.3.8 BW, Body Weight

See Section 4.1.1.4 for discussion of the ED parameter.

4.1.3.9 AT, Averaging Time

See Section 4.1.1.5 for discussion of the AT parameter.

4.1.4 Inhalation of Vapors or Resuspended Particulate Pathway

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

Contaminants may be inhaled by the receptor of concern whenever the receptor is at or near the site. The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air. The Average Daily Concentration (ADC_{air}) for chronic industrial exposure may be calculated as shown in Table A1.26.

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Table A1.26 Industrial Worker - Chronic Inhalation of Vapors or Particulate

$$\text{LADC or ADC}_{\text{air}} = \frac{Cair \times EF \times ED \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{aie}	Average daily concentration in air (mg/m^3 or ug/m^3).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) = C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg		Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period (days/year).	250	C	PEF and VF values are based on annual estimates.
ED	Duration of the exposure period (years).	25	U	95th percentile worker tenure. (Maguire 1993)
BW	Body weight of the receptor (kg).	70	C	EPA, 1997
AT	Averaging Time (days)	9125 25550		Noncancer AT = ED x 365 days/yr Cancer AT = 70 yrs x 365 days/yr

C = Central Tendency Value
U = Upper Tendency Value

4.1.4.1 C_{air}, Air Concentration

To calculate an average daily air concentration, the particulate emission factor (PEF) and volatilization factor (VF) must be calculated. See Appendix Section 2.1.4.1 for a more detailed discussion of the PEF and VF equations. Table A1.27 presents the PEF equation and the default input values for chronic industrial exposure. Based on default input values a particulate air concentration (1/PEF) of 2.3 E-9 kg/m^3 (i.e., 2.3 ug/m^3). Since the model only addressed wind disturbance of soil the calculated particulate concentration was multiplied by a factor of approximately 2 in an attempt to account for other common sources of soil disturbance (e.g., vehicle traffic). Therefore, the particulate air concentration utilized for industrial property use is 5 ug/m3. This value is not considered to by unduly conservative given the reported particulate concentrations in industrialized areas (MPCA 1997). If physical disturbance of soil is great and occurs with regular frequency the default PEF may not be protective.

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Table A1.27 Industrial Worker - Calculation of Chronic Particulate Emission Factor

$$PEF(m^3/kg) = Q/C \times \frac{3{,}600 s/h}{(0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x))}$$

Variable	Definition	Default Value	Reference
PEF	Particulate emission factor (m^3/kg)	3.8E+08	Calculated based on default inputs.
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
V	Fraction of vegetative cover	0	Default. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_m	Mean annual windspeed (m/s)	4.9	Based on climatic data for Minneapolis/St. Paul metropolitan area. (Use Cowherd et al., 1985 and site data to develop site-specific value)
U_t	Equivalent threshold value of windspeed at 7 meters (m/s)	11.32	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)
F(x)	Function dependent upon U_m/U_t	0.194	Default (EPA, 1996). (Use Cowherd et al., 1985 and site data to develop site-specific value)

Table 3 of the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996) provides the estimated annual Q/C values for 0.5, 1, 2, 5, 10 and 30 acre source areas for the city of Minneapolis. An intermediate source size of 5 acres was selected for the default source size. A linear inverse relationship exists between the log of the source size and the log of the annual Q/C This relationship can be utilized to estimate the annual Q/C for source sizes which are not included in Table 3 of the EPA Soil Screening Guidance. See Appendix 1 Section 2.1.4.1.

The Q/C value, is used in the determination of both PEF and VF. For a detailed site-specific assessment of the inhalation pathway, a site-specific Q/C can be determined using the Industrial Source Complex Model platform in the short-term mode (ISCST3). The ISCST3 model will output an air concentration when the concentration model option is selected. Numerous site-specific input parameters must be determined, e.g., the surface area of the contaminated soil source, contaminant area emission rate (g/m2-s), hourly meteorological data, etc.

The fraction of vegetation will vary from site to site. The exposure area for the industrial exposure evaluation is assumed not to be vegetated.

It is generally assumed that the concentration of the contaminant in the particulate is equal to the concentration of the contaminant in soil. This assumption may underestimate the concentration of contaminant in the inhalable fraction (i.e., PM10 fraction), since smaller particulate fractions sometimes contain contaminant concentrations that are enriched relative to larger fractions. However, the data needed to derive more accurate concentration estimates are typically not available. To calculate the airborne

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particulate contaminant concentration simply multiple the soil concentration by the inverse of the particulate emission factor (5 E-3 mg/m^3).

For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. Table A1.28 presents the VF equation and default values for chronic exposure.

Table A1.28 Industrial Worker - Calculation of Chronic Volatilization Factor

$$VF\,(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}\,(m^2/cm^2)$$

Variable	Definition	Default Value	Reference
VF	Volatilization Factor (m^3/kg)	Contaminant Specific	
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	61.03	Annual estimate Q/C value for Minneapolis/St. Paul for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
Da	Apparent diffusivity (cm^2/s)	Contaminant Specific	See Table A1.10 and Appendix Section 2.1.3.1.
T	Exposure interval (s)	7.88E+8	Number of seconds in 25 years.
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996). (Use site data to develop site-specific value)

The VF equation given above represents a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The equation incorporates a number of conservative, simplifying assumptions, e.g., infinite source, steady state conditions. Part 3 of the Soil Screening Guidance: Technical Background Document (EPA 1996) includes information on models for a more detailed evaluation.

There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When a calculated SRV for a

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VOC exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. Table A1.11 presents the Csat equation and default values.

4.1.4.2 CF, Units Conversion Factors

See Section 4.1.1.2 for discussion of the CF parameter.

4.1.4.3 EF, Exposure Frequency

A receptor may be exposed to a contaminant continuously, at regular intervals, or in a sporadic manner. The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. Frequency of exposure is site- and activity-specific. Since long-term contact rates are assumed for all exposure pathways and the incidental ingestion rate is assumed to represent a daily average, an exposure frequency of 250 days/year (5 day/week plus 2 week vacation work schedule) is assumed.

4.1.4.4 ED, Exposure Duration

See Section 4.1.1.3 for discussion of the ED parameter.

4.1.4.5 AT, Averaging Time

See Section 4.1.1.5 for discussion of the AT parameter.

4.2 Industrial Subchronic Exposure

The effect (noncarcinogenic and carcinogenic) of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short-period of time may not produce the same effect when given over a longer period of time. To adequately evaluate the potential receptors, the risk assessor may need to look at several specific subpopulations of receptors which may experience higher rates of exposure. See Section 8.3.3.4 of main text for further discussion. To evaluate the potential impact from higher rates of exposure to a worker over a subchronic exposure period refer to Appendix Section 5.0 Short-term Worker. In situations where high short-term exposure may occur the lower of the two calculated values (i.e., chronic industrial worker scenario and short-term worker scenario) should be utilized.

4.3 Industrial Acute Exposure

It is not anticipated that there will be high soil acute exposure episodes in adult workers. Acute exposure may be of concern for the inhalation pathway. Direct air monitoring should be conducted if this pathway is of concern.

5.0 SHORT-TERM WORKER SCENARIO

The effect (noncarcinogenic and carcinogenic) of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short-period of time may not produce the same effect when given over a longer period of time. To adequately evaluate the potential receptors, the risk assessor

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may need to look at several specific subpopulations of receptors which may experience higher rates of exposure. Because of their work conditions construction/utility workers receive a larger potential dose over a shorter period of time than industrial workers.

5.1 General Exposure Factors

There are five exposure factors which recur throughout the equations used to estimate the dose of contaminant experienced by a potential receptor:

- C_{soil}, Contaminant Concentration
- CF, Units Conversion Factors
- EF, Exposure Frequency
- BW, Body Weight
- AT, Averaging Time

These factors are generally used in the same manner regardless of the exposure pathway under investigation, so it is useful to discuss them separately.

5.1.1 C_{soil}, Contaminant Concentration

The concentration of the contaminant used to quantify exposure is the Exposure Concentration. The exposure point concentration should *not* be adjusted for receptor exposure frequency, duration, etc. as those factors are generally addressed in the exposure calculations. See Sections 7.4 and 8.3.3.5 of the main text for additional discussion.

5.1.2 CF, Units Conversion Factors

Units conversion factors are necessary to insure that the result of the calculation (the dose) is expressed in the correct units (e.g., mg/kg/day). Use of the units CF (1E-6 kg per mg or 1000 ug per mg) is equivalent to multiplication by one.

5.1.3 EF, Exposure Frequency

The frequency of exposure term describes how often the exposure event or contact occurs over a given period of time. While estimates have been published on the amount of soil ingested during a *day*, there can be no reliable estimate of average *hourly* ingestion rates as incidental ingestion of soil is a sporadic event depending upon human behavior (e.g., activities, habits). For such exposures (including soil ingestion and dermal contact) EF is by definition 1 day/event. During that "1 event" the receptor is assumed to receive the daily intake of the contaminant. Frequency of exposure is site- and activity-specific. The exposure frequency selected for subchronic exposure is an average of 5 days per week during a 2 month construction project (i.e., 45 days).

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5.1.4 BW, Body Weight

A receptor's body weight is relevant throughout the dose equations since dose is expressed in terms of mass of contaminant per unit body weight per day (mg/kg/day). Table A1.23 provides age-specific body weights for adults. The body weights are 50th percentile values for males and females and are presented annually for adults (Table 7-2, EPA Exposure Factors Handbook, 1997). The receptor body weight (BW, typically expressed in kilograms, kg) must be matched to the age and gender identified in the exposure profile. Since exposure is assumed to be limited to an adult worker the average body weight (70 kg) for adults (> 18 - 65 years) is recommended as the default value. Within a given age/sex combination, there is some variability of body weight. If there is strong evidence that the potentially exposed subpopulation is biased in some manner a more site specific value should be utilized.

5.1.5 AT, Averaging Time

The averaging time (AT) is the time over which the total intake is normalized. For the evaluation of *noncancer risk*, the Average Daily Dose calculated should be representative of the exposure received while exposure is on-going (i.e., during the exposure period). The exposure period evaluated for the subchronic exposure scenario is 90 days (i.e., 3 summer months). The averaging time (AT) is equivalent to the exposure period, i.e. 3 months.

The Lifetime Average Daily Dose (LADD) is calculated for the evaluation of *cancer risk*. While the duration of the exposure period might range from one day to an entire lifetime, the total intake during that exposure is traditionally normalized to a lifetime. The averaging time for assessment of cancer risk is therefore typically set at 70 years. See Appendix Section 2.1.1.8 for additional discussion. Note that for the evaluation of cancer risks resulting from subchronic exposure the target risk is 1 in 1,000,000. See Section 8.3.3 of main text.

5.2 Incidental Soil Ingestion Pathway

The Average Daily Dose during an exposure period of less than or equal to 1 year (i.e., *subchronic*) may be calculated utilizing the equation presented in Table A1.29.

5.2.1 C_{soil}, Contaminant Concentration

See Section 5.1.1 for discussion of the C_{soil} parameter.

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Table A1.29 Short-term Worker - Subchronic Incidental Ingestion of Soil

$$\text{LADD or ADD}_{\text{ingestion}} = \frac{Csoil \times IR \times CF \times FI \times EF}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or $ADD_{soil\ ingestion}$	Average daily potential dose of contaminant received through the ingestion of soil (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Sections 7.4 and 8.3.3.5
IR	Daily soil ingestion rate (mg/day)	480	NA	EPA (1989b)
CF	Conversion Factor	1E-6 kg/mg		
FI	Fraction of ingested soil which is from contaminated soil	1	NA	
EF	Number of exposure days during the exposure period (days/year).	45	C	2 months, average of 5 d/wk.
BW	Body weight during the exposure period (kg).	70	C	EPA, 1997
AT	Averaging Time (days)	60 25550		Noncancer AT = 2 months Cancer AT = 70 yrs x 365 days/yr. Note: Subchronic target cancer risk ≤ 1E-6.

C = Central Tendency Value (e.g., average)
U = Upper Tendency Value

5.2.2 IR, Soil Ingestion Rate

Soil ingestion is assumed to occur incidentally, from hand-to-mouth contact and through the inhalation of larger particles. Soil from outdoors can also be brought indoors (e.g., on clothing, shoes and tools) or can enter buildings as windblown dust. Soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period.

Information on soil ingestion among adults is very limited. A default soil ingestion rate of 480 mg/day is recommended by EPA (EPA 1989b) for workers engaged in outdoor work activities.

5.2.3 CF, Units Conversion Factors

See Section 5.1.2 for discussion of the CF parameter.

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5.2.4 FI, Fraction of Ingested Soil

Since soil ingestion rates represent **daily** rates. It is **not** appropriate to modify the soil ingestion rate to account for an exposure which occurs for a portion of a day as the studies on which the soil ingestion rates are based do not indicate whether soil ingestion is a sporadic event or whether it occurs evenly throughout the exposure period. It is assumed that the daily ingestion occurs within the exposure area.

5.2.5 EF, Exposure Frequency

See Section 5.1.3 for discussion of the EF parameter.

5.2.6 BW, Body Weight

See Section 5.1.4 for discussion of the BW parameter.

5.2.7 AT, Averaging Time

See Section 5.1.5 for discussion of the AT parameter.

5.3 Dermal Contact Pathway

Dermal absorption of contaminants is a potentially significant route of exposure whenever direct contact with soil may occur. The absorption of contaminants from soil depends upon chemical-specific factors (e.g., lipophilicity) as well as the characteristics of the soil (e.g., organic carbon content). The Average Daily Dose for subchronic exposure may be calculated as shown in Table A1.30.

5.3.1 C_{soil}, Contaminant Concentration

See Section 5.1.1 for discussion of the C_{soil} parameter.

5.3.2 CF, Units Conversion Factors

See Section 5.1.2 for discussion of the CF parameter.

5.3.3 SA, Skin Surface Area

The surface area parameter (SA) describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends on the receptor and the exposure scenario. Clothing is expected to limit the extent of the exposed surface area for most activities. All SA estimates used 50th percentile values in order to correlate with the average body weights used for exposure estimations. This is done to prevent inconsistent parameter combinations since body weight and surface area are not independent variables. The age-specific 50th percentile total body surface areas were shown in Table A1.4.

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The subchronic exposure frequency for dermal exposure is limited to the summer months. For the purpose of calculating the dermal dose it was assumed that the forearms, hands, and head are exposed. The age-specific percentage of total body surface area by body part were shown in Table A1.5. This exposed area constitutes approximately 20 % of the total body surface area. A surface area of 3400 cm^2 was calculated by incorporating data from the EPA Exposure Factors Handbook (EPA 1997) as presented in Tables A1.4 and A1.5. Since some studies have suggested that exposure can occur under clothing (EPA, 1992) and the exposure period is limited to the summer months this scenario is not considered to be unduly conservative.

Table A1.30 Short-term Worker - Subchronic Dermal Contact with Soil

$$\text{LADD or ADD}_{\text{dermal absorption}} = \frac{Csoil \times CF \times SA \times AF \times ABS \times EF}{BW \times AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADD or ADD_{dermal}	Average daily dose absorbed through dermal contact (mg/kg-day).			See Section 8.3.3.2
C_{soil}	Soil Concentration (mg/kg)	Representative site exposure concentration		See Section 8.3.3.5 and Section 7.4.
CF	Conversion Factor	1E-6 kg/mg		
SA	Skin surface area (cm^2)	3400	C	Approximately 20% of the average total body SA (EPA, 1997)
AF	Skin adherence factor (mg/cm^2)	0.3	C	Kissel et. al., (as cited in EPA, 1997) and EPA 1992
ABS	Absorption factor	Chemical specific		
EF	Number of exposure days during the exposure period	45	NA	2 summer months, average of 5 d/wk.
BW	Body weight during the exposure period (kg).	70	C	EPA, 1997
AT	Averaging Time (days)	60 25550		Noncancer AT = 2 months Cancer AT = 70 yrs x 365 days/yr. Note: Subchronic target cancer risk $\leq$ 1E-6.

NA = Not Available
C = Central Tendency Value
U = Upper Tendency Value

5.3.4 AF, Soil Adherence Factor

The adherence factor (AF) describes the amount of soil that adheres to the skin. The EPA Exposure Factors Handbook (EPA 1997) recommends utilizing the Kissel, et al., study for estimating soil adherence. The results of this study showed that generally soil adherence could be directly correlated with soil moisture and activity and inversely correlated with particle size. The default AFs are based on the central tendency value recommended in EPA's Dermal Guidance (EPA 1992) and a review of the body-part-specific and activity-specific adherence factors reported by Kissel et al., 1996 (as cited in the EPA Exposure Factors Handbook, 1997).

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Kissel et al., evaluated construction, utility and equipment operator activities. These activities would be similar to a short-term construction/utility worker. For the short-term construction/utility worker the gardening scenario was utilized. The body part specific surface area information can be found in Table A1.6. Kissel, et al. presented the body part specific AFs. The highest geometric mean value of the construction, utility or equipment operator activity categories was utilized. The selection of the highest mean AF is not considered unduly conservative since the value represents a central tendency value, the reported high variability. The weighted adherence factor was calculated utilizing the equation below:

$$\text{Weighted AF} = \frac{(SA1 \times AF1) + (SA2 \times AF2) + \ldots + (SAi \times AFi)}{(SA1 + SA2 + \ldots + SAi)}$$

where:

SAi = surface area for body part "i", forearms, hands, and head (cm^2)
AFi = soil-to-skin adherence factor for body part "i", mg/cm^2-event

The calculation of the default AF is shown below:

$$\text{Weighted AF} = \frac{(1090 \times 0.3) + (950 \times 0.32) + (1360 \times 0.23)}{(3400)} = 0.3$$

5.3.5 ABS, Absorption Factor

The dermal absorption factor (ABS) is the fraction of the contaminant contacting the skin that is absorbed. At this time only limited information is available to derive soil ABS values. In the absence of contaminant specific information default ABS values have been incorporated. The recommended default values are discussed in Appendix Section 2.1.3.5. The recommended default ABS values are listed in Table A.2.1 of Appendix 2.

5.3.6 EF, Exposure Frequency

See Section 5.1.3 for discussion of the EF parameter.

5.3.7 BW, Body Weight

See Section 5.1.4 for discussion of the BW parameter.

5.3.8 AT, Averaging Time

See Section 5.1.5 for discussion of the AT parameter.

5.4 Inhalation of Vapors or Resuspended Particulate Pathway

The toxicity information generally used to evaluate the risk of harm to health associated with inhalation exposures, Reference Concentrations and Units Risk values, are air *concentrations*. These values are intended to be used in combination with Average Daily Concentration expressed as applied concentrations, *not* dose.

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Contaminants may be inhaled by the receptor of concern whenever the receptor is at or near the site. The Average Daily Concentration of the contaminant in air (ADC_{air}) is dependent upon the frequency and duration of the assumed exposures. Note that the equation is a simple adjustment of the exposure point concentration to account for the amount of time the receptor spends in the area with contaminated air. The Average Daily Concentration (ADC_{air}) for subchronic exposure may be calculated as shown in Table A1.31.

Table A1.31 Short-term Worker - Subchronic Inhalation of Vapors or Particulate

$$\text{LADC or } ADC_{air} = \frac{C_{air} \times EF \times CF}{AT}$$

Variable	Definition	Default Value	Percentile	Reference
LADC or ADC_{aie}	Average daily concentration in air (mg/m^3 or ug/m^3).			See Section 8.3.3.2
C_{air}	Air Concentration (mg/m^3 or ug/m^3) = C_{soil} x (1/PEF + 1/VF)	Measured or Modeled Representative site exposure concentration		See Section 8.3.3.5 and discussion below.
CF	Conversion Factor	1E+3 µg/mg		Utilized for LADC calculation since toxicity values are in ug/m^3
EF	Number of exposure days during the exposure period (days/year).	45		2 summer months, average of 5 d/wk.
AT	Averaging Time (days)	60 25550		Noncancer AT = 2 months Cancer AT = 70 yrs x 365 days/yr. Note: Subchronic target cancer risk $\leq$ 1E-6.

C = Central Tendency Value
U = Upper Tendency Value

5.4.1 C_{air}, Air Concentration

To calculate an average daily air concentration, the particulate emission factor (PEF) and volatilization factor (VF) must be determined. See Appendix Section 2.1.4.1 for a more detailed discussion of the PEF and VF equations.

Inhalation of contaminated particulate matter is of particular concern in cases where contaminated soil is likely to be disturbed (e.g., grading, excavation, vehicle traffic). These activities likely to be common place at construction sites. The PEF model utilized for other receptors is only applicable for estimating long-term particulate emissions due to wind erosion. To assess short-term exposures at sites where extensive soil disturbance occurs the utilization of default particulate concentration values may be necessary. For exposure during construction or utility work, a PM10 value of *at least* 150 µg/m^3 should be used to estimate concentrations. This value is the 24 hour average PM10 standard. A State ambient monitoring station located near an industrialized area in St. Paul has exceeded this standard on several occasions. (1997 Trend Analysis Report, MPCA). There are a number of uncertainties associated with use of the default PM10 values, including: 1) the sampling locations are not necessarily located near construction activities or large areas of sparsely vegetated soil ; and 2) the published 24 hour averages may underestimate PM10 concentrations attained during the work day. Therefore, these PM10 values are acceptable for use only in the absence of more representative data.

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For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model can be utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. Table A1.32 presents the VF equation and default values for subchronic exposure.

Table A1.32 Short-term Worker - Calculation of Subchronic Volatilization Factor

$$VF\,(m^3/kg) = Q/C \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}\,(m^2/cm^2)$$

Variable	Definition	Default Value	Reference
VF	Volatilization Factor (m^3/kg)	Contaminant Specific	
Q/C	Inverse of the mean concentration at the center of the source (g/m^2-s per kg/m^3)	45.93	Annual estimate Q/C value for Los Angeles for a 5 acre source (EPA, 1996). (Use site specific information regarding source size if available).
Da	Apparent diffusivity (cm^2/s)	Contaminant Specific	See Table A1.10 and Appendix Section 2.1.3.1.
T	Exposure interval (s)	5.2E+06	Assumes 60 day exposure period.
ρ_b	Dry soil density (g/cm^3)	1.5	Default (EPA, 1996). (Use site data to develop site-specific value)

Table 3 of the EPA Soil Screening Guidance: Technical Background Document (EPA, 1996) provides the estimated annual Q/C values for various locations (i.e., city and climatic zone) and source area sizes. Since the subchronic exposure evaluation is based on exposure during the summer months the location which best approximated the 90th percentile of the annual Q/C values (based on the 29 locations evaluated) was selected instead of the annual Q/C value for Minneapolis. An intermediate source size of 5 acres was selected for the default source size. A linear inverse relationship exists between the log of the source size and the log of the annual Q/C. This relationship can be utilized to estimate the annual Q/C for source sizes which are not included in Table 3 of the EPA Soil Screening Guidance. See Appendix 1 Section 2.1.3.1 for more details.

The VF equation given above represents a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The equation incorporates a number of conservative, simplifying assumptions, e.g., infinite source, steady state conditions. Part 3 of the Soil Screening Guidance: Technical Background Document (EPA 1996) includes information on models for a more detailed evaluation.

There are several site situations for which the VF model is not applicable:

- if municipal or sanitary wastes have been disposed with contaminants, because decomposition of solid waste would generate landfill gases which can greatly enhance volatile emission rates;
- if shallow ground water is contaminated with VOCs; and
- if the soil contaminant concentration above saturation (Csat). Note: Saturation conditions also affect the bioavailability and mobility of a contaminant.

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The soil saturation limit (Csat) represents the concentration of a contaminant in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and the saturation of soil pore air have been reached. Above the Csat concentration the soil contaminant may be present in free phase, nonaqueous phase liquids (NAPLS) for contaminants that are liquid at ambient soil temperatures and pure solid phases for contaminants that are solid at ambient soil temperatures. When a calculated SRV for a VOC exceeds Csat, the allowable SRV in soil is set at Csat to minimize the potential for NAPL. Table A1.11 presented the Csat equation and default values.

5.4.2 CF, Units Conversion Factors

See Section 5.1.2 for discussion of the CF parameter.

5.4.3 EF, Exposure Frequency

See Section 5.1.3 for discussion of the EF parameter.

5.4.4 AT, Averaging Time

See Section 5.1.5 for discussion of the AT parameter.

6.0 INDIRECT EXPOSURE PATHWAY EVALUATION i.e., homegrown produce, home-raised livestock, etc.

(under development)

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APPENDIX 2 CHEMICAL SPECIFIC INFORMATION

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1.0 ABSORPTION VALUES

The Absorption Adjustment Factor (AAF) is used to account for differences in the absorption of a contaminant under assumed exposure conditions at the site (exposure route and matrix) relative to the absorption of the contaminant under the experimental conditions upon which the dose-response value is based. AAFs are used *in lieu of absorption efficiencies* to ensure that the exposures evaluated at the site are comparable to the toxicity information identified in the literature. The AAF relates the exposure and absorption estimated for the exposure pathway under evaluation to the exposure and absorption in the toxicological study on which the dose-response information is based. The AAF is dimensionless and is chemical and pathway specific. When the toxicity value represents an *administered* dose or concentration, the AAF is calculated as the ratio of the absorption efficiency of the route and medium of the exposure route and medium under consideration and the absorption efficiency of the route and medium of the study used as the basis of the toxicity value. In the case of the dermal exposure pathway the exposure is expressed as an absorbed dose. If the toxicity value is based on absorbed dose no adjustment is necessary. If the toxicity value is based on administered dose it must be adjusted for absorption so that it is consistent with the absorbed dose estimate for the dermal contact exposure pathway.

To estimate an AAF, two factors must be identified:

- the absorption efficiency for the contaminant via the route and medium of exposure being evaluated for the site, and
- the absorption efficiency for the route and medium of exposure in the experimental study which is the basis of the dose-response value for the contaminant in question.

Thus, the absorption adjustment is based on these two absorption efficiencies. Typically, two different types of adjustments are done. One involves adjusting the site exposure for differences in absorption efficiency between the route and medium at the site and the route and medium utilized in the toxicity study. The second adjustment involves adjusting the toxicity value based on administered dose for absorbed dose when assessing risk from a dermally absorbed dose. Table A2.1 contains the dermal absorption value utilized to estimate the absorbed dermal dose, the soil/toxicity study absorption adjustment factor, and the absorption efficiency for the exposure in the toxicity study.

Typically, the exposure from incidental ingestion of soil, ingestion of food and inhalation of contaminants in soil estimates a potential dose. The potential dose is analogous to an administered dose in a toxicity study. If the absorption efficiency for the contaminant via the route and medium of exposure at the site differs from the absorption efficiency for the contaminant in the toxicity study an absorption adjustment should be made. Likewise, the toxicity value is typically based on an administered dose but the dermal exposure pathway evaluation results in an estimate of *absorbed* dose. The toxicity value based on administered dose must be adjusted for absorption before it can be utilized to calculate risk posed by the dermal exposure pathway dose.

The risk assessor is reminded that it is very important to determine whether the toxicity value is based on an absorbed or administered dose. An example of the absorption adjustment calculations was presented in Table 8.3.

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
Inorganics								
Aluminum		7429905	0.001	Default for poorly absorbed metal	1	Default	0.01	ATSDR toxicological profile information
Antimony		7440360	0.001	Default for poorly absorbed metal	1	Default	0.05	ATSDR toxicological profile information
Arsenic		7440382	0.03	Wester et al., 1993.	1	Default	0.9	ATSDR toxicological profile information
Barium		7440393	0.001	Default for poorly absorbed metal	1	Default	0.05	ATSDR toxicological profile information
Beryllium		7440417	0.001	Default for poorly absorbed metal	1	Default	0.01	ATSDR toxicological profile information
Boron		7440428	0.01	Default for metals exhibiting some absorption	1	Default	0.9	ATSDR toxicological profile information
Cadmium		7440439	0.01	Default for metals exhibiting some absorption	1	Default. Assumed absorption from soil is similar to absorption from food.	1	Toxicity value based on toxicokinetic model in which 2.5% absorption from food was assumed.
Chromium III		16065831	0.01	Default for metals exhibiting some absorption	1	Default	0.05	ATSDR toxicological profile information
Chromium VI		18540299	0.01	Default for metals exhibiting some absorption	1	Default	0.05	ATSDR toxicological profile information
Cobalt		7440484	0.01	Default for metals exhibiting some absorption	1	Default	0.5	ATSDR toxicological profile information
Copper		7440508	0.01	Default for metals exhibiting some absorption	1	Default	0.6	ATSDR toxicological profile information
Copper cyanide		544923	0.01	Default for metals exhibiting some absorption	1	Default	0.5	ATSDR toxicological profile information
Cyanide		57125	0.01	Default for metals exhibiting some absorption	1	Default	0.5	ATSDR toxicological profile information
Fluorine (soluble fluoride)		7782414	0.01	Default for inorganics exhibiting some absorption	0.7	ATSDR toxicological profile information.	0.9	ATSDR toxicological profile information on fluoride in water.
Iron		7439896	0.01	Default for inorganics exhibiting some absorption	1	Default	0.05	Based on typical level for other metals.
Lead		7439921	Soil concentrations for lead are calculated based on EPA models. These models do not address the dermal absorption pathway.					
Manganese		7439965	0.001	Default for poorly absorbed metal	1	Default	0.05	ATSDR toxicological profile information

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
Methy mercury	v	22967926	0.05	Massachusetts DEP absorption value (10/92)	1	Default	0.95	ATSDR toxicological profile information
Mercury (inorganic)		7439976	0.05	Massachusetts DEP absorption value (10/92)	1	Default	0.2	ATSDR toxicological profile information
Nickel		various	0.01	Default for metals exhibiting some absorption	1	Default	0.05	ATSDR toxicological profile information
Selenium		7782492	0.01	Default for metals exhibiting some absorption	1	Default	0.9	ATSDR toxicological profile information
Silver		7440224	0.01	Default for metals exhibiting some absorption	1	Default	0.9	ATSDR toxicological profile information
Thallium		various	0.01	Default for metals exhibiting some absorption	1	Default	0.9	ATSDR toxicological profile information
Tin		various	0.01	Default for metals exhibiting some absorption	1	Default	0.05	ATSDR toxicological profile information
Titanium		7440326	0.01	Default for metals exhibiting some absorption	1	Default	0.1	STSC memo 1998
Vanadium		7440622 1314621	0.01	Default for metals exhibiting some absorption	1	Default	0.1	ATSDR toxicological profile information
Zinc		7440666	0.01	Default for metals exhibiting some absorption	1	Default	0.3	ATSDR toxicological profile information
Volatile Organics								
Acetone	v	67641	0.1	Default for organic compounds. Considers volatility.	1	Default	0.9	ATSDR toxicological profile information
Benzene	v	71432	0.01	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Bromodichloromethane	v	75274	0.05	Level of volatility	1	Default	0.9	Default
Bromomethane *(methyl bromide)*	v	74839	0.05	Level of volatility	1	Default	0.9	Default
1,3 - Butadiene	v	106990	0.01	Level of volatility	1	Default	0.9	Default
n-Butylbenzene	v	104518	0.05	Level of volatility	1	Default	0.9	Default
sec-Butylbenzene	v	135988	0.05	Level of volatility	1	Default	0.9	Default
tert-Butylbenzene	v	98066	0.5	Level of volatility	1	Default	0.9	Default
Carbon Disulfide	v	75150	0.05	Level of volatility	1	Default	0.9	Default
Carbon Tetrachloride	v	56235	0.05	Level of volatility	1	Default	0.9	Default
Chlorobenzene	v	108907	0.05	Level of volatility	1	Default	0.9	Default
Chloroethane *(ethyl chloride)*	v	75003	0.05	Level of volatility	1	Default	0.85	ATSDR toxicological profile information

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
Chloroform (trichloromethane)	v	67663	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Chloromethane *(methyl chloride)*	v	74873	0.01	Level of volatility	1	Default	0.9	Default
2-Chlorotoluene	v	95498	0.05	Level of volatility	1	Default	0.9	Default
Cumene (isopropylbenzene)	v	98828	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,2 - Dibromoethane *(ethylene dibromide)*	v	106934	0.1	Level of volatility and ATSDR Toxicological Profile	1	Default	0.9	Default
Dibromomethane *(methylene bromide)*	v	74953	0.1	Default for organic compounds. Considers volatility.	1	Default	0.9	ATSDR toxicological profile information
Dichlorodifluoromethane *(Freon 12)*	v	75718	0.01	Level of volatility	1	Default	0.9	Default
1,1 - Dichloroethane	v	75343	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,2 - Dichloroethane	v	107062	0.05	Level of volatility	1	Default	0.9	based on 1,1 dichloroethane
1,1 - Dichloroethylene	v	75354	0.01	Level of volatility	1	Default	0.9	Default
cis - 1,2 - Dichloroethylene	v	154592	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
trans - 1,2 - Dichloroethylene	v	156605	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,2 - Dichloroethylene (mixed isomers)	v	540590	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Dichloromethane *(methylene chloride)*	v	75092	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,2 - Dichloropropane	v	78875	0.05	Level of volatility	1	Default	0.9	Default
Ethyl benzene	v	100414	0.05	Level of volatility	1	Default	0.85	ATSDR toxicological profile information
n-Hexane	v	110543	0.05	Level of volatility	1	Default	0.9	Default
Methyl ethyl ketone *(2-butanone)*	v	78933	0.1	Level of volatility	1	Default	0.9	ATSDR toxicological profile information indicates it is readily absorbed.
Methyl isobutyl ketone *(MIBK)*	v	108101	0.05	Level of volatility	1	Default	0.9	Default
Naphthalene	v	91203	0.05	Level of volatility	0.8	Based BaP	0.8	Based on benzo(a)pyrene
n-Propylbenzene		104518	0.05	Surrogate: n-Butylbenzene	1	Default	0.9	Default

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
Styrene	v	100425	0.05	Level of volatility	1	Default	0.9	Default
1,1,1,2 - Tetrachloroethane	v	630206	0.1	Level of volatility	1	Default	0.9	Default
1,1,2,2 - Tetrachloroethane	v	79345	0.1	Level of volatility	1	Default	0.7	ATSDR toxicological profile information
Tetrachloroethylene (PCE)	v	127184	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Toluene	v	108883	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,2,4 - Trichlorobenzene	v	120821	0.05	Level of volatility	1	Default	0.9	Default
1,1,1 - Trichloroethane	v	71556	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
1,1,2 - Trichloroethane	v	79005	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Trichloroethylene (TCE)	v	79016	0.05	Level of volatility	1	Default	0.9	ATSDR toxicological profile information
Trichlorofluoromethane	v	75694	0.01	Level of volatility	1	Default	0.9	Default
1,1,2-Trichloro-1,2,2-trifluoroethane *(Freon 113)*	v	76131	0.01	Level of volatility	1	Default	0.9	Default
1,2,4-Trimethylbenzene	v	95636	0.05	Level of volatility	1	Default	0.9	Default
1,3,5-Trimethylbenzene	v	108678	0.05	Level of volatility	1	Default	0.9	Default
Vinyl chloride	v	75014	0.01	Level of volatility	1	Default	0.9	Default
Xylenes (mixed)	v	1330207	0.05	Level of volatility	1	Default	0.9	Default
Non/Semi Volatile Organics								
Benzoic acid		65850	0.1	Default for organics	1	Default	0.9	Default
Benzyl alcohol		100518	0.1	Default for organics	1	Default	0.9	Default
Bis (2 - chloroethyl)ether	v	111444	0.1	Default for organic compounds. Considers volatility.	1	Default	0.9	Default
Bis (chloromethyl) ether	v	542881	0.1	Default for organic compounds. Considers volatility.	1	Default	0.9	Default
Bromoform *(tribromomethane)*		75252	0.1	Default for organic compounds.	1	Default	0.9	ATSDR toxicological profile information
Butyl benzylphthalate		85687	0.1	Default for organics	1	Default	0.9	Default
Dibenzofuran (unsubstituted)		132649	0.1	Default for organics	1	Default	0.9	Default
1,4 - Dibromobenzene		106376	0.1	Default for organics	1	Default	0.8	ATSDR toxicological profile information
Dibromochloromethane		124481	0.1	Default for organics	1	Default	0.9	Default
Dibutyl phthalate		84742	0.1	Default for organics	1	Default	0.9	Default

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
1,2 - Dichlorobenzene	v	95501	0.05	Level of volatility	1	Default	0.9	Default
1,3 - Dichlorobenzene	v	541731	0.05	Level of volatility	1	Default	0.9	Default
1,4 - Dichlorobenzene	v	106467	0.05	Level of volatility	1	Default	0.9	Default
3,3' - Dichlorobenzidine		91941	0.1	Default for organics	1	Default	0.9	Default
2,4-Dichlorophenol		120832	0.25	Pentachlorophenol and chemical characteristics.	1	Default	0.9	Default
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*		117817	0.05	ATSDR toxicological profile information	1	Default	0.7	ATSDR toxicological profile information
2,4-Dimethylphenol		105679	0.1	Default for organics	1	Default	0.9	Default
Di - n - octyl phthalate		117840	0.1	Default for organics	1	Default	0.9	Default
Ethylene glycol		107211	0.1	Default for organics	1	Default	0.9	Default
Hexachlorobenzene		118741	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Hexachloro-1,3-butadiene		87683	0.1	Default for organics	1	Default	0.9	Default
Hexachlorocyclopentadiene		77474	0.1	Default for organics	1	Default	0.9	Default
Methanol		67561	0.1	Default for organics	1	Default	0.9	Default
2 - Methylphenol *(o-cresol)*		95487	0.25	Based on pentachlorophenol.	1	Default	0.8	ATSDR toxicological profile information
3 - Methylphenol *(m-cresol)*		108394	0.25	Based on pentachlorophenol.	1	Default	0.8	ATSDR toxicological profile information
4 - Methylphenol *(p-cresol)*		106445	0.25	Based on pentachlorophenol.	1	Default	0.8	ATSDR toxicological profile information
N-Nitrosodiphenylamine		86306	0.1	Default for organics	1	Default	0.9	Default
N-Nitroso-di-n-propylamine		621647	0.1	Default for organics	1	Default	0.9	Default
Pentachlorophenol		87865	0.25	Wester et al., 1993.	1	Default	0.9	Default
Phenol		108952	0.8	ATSDR Toxicological Profile	1	Default	0.9	ATSDR Toxicological Profile
2,3,4,6-Tetrachlorophenol		58902	0.25	Pentachlorophenol and chemical characteristics.	1	Default	0.9	Default
2,4,5-Trichlorophenol		95954	0.25	Pentachlorophenol and chemical characteristics.	1	Default	0.9	Default
2,4,6-Trichlorophenol		88062	0.25	Pentachlorophenol and chemical characteristics.	1	Default	0.9	Default
PAHs (Polynuclear Aromatic Hydrocarbons)								
Acenaphthene	v	83329	0.05	Level of volatility	0.8	Based BaP	0.8	Based on benzo(a)pyrene
Anthracene	v	120127	0.1	Level of volatility	0.8	Based BaP	0.8	Based on benzo(a)pyrene

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
Benzo(a)pyrene (BaP equiv)		50328	0.13	Wester et al., 1990 & Yang et al., 1989	0.8	Based on limited studies examining relative bioavailability from diet and from soil (Goon et al., 1990, 1991).	0.8	Based on ATSDR Toxicological Profile information. 1995
Fluoranthene		206440	0.13	Based on benzo(a)pyrene	0.8	Based BaP	0.8	Based on benzo(a)pyrene
Fluorene	v	86737	0.1	Level of volatility	0.8	Based BaP	0.8	Based on benzo(a)pyrene
Naphthalene	v		See Volatiles					
Pyrene	v	129000	0.1	Level of volatility	0.8	Based BaP	0.8	Based on benzo(a)pyrene
Quinoline		91225	0.13	Based on benzo(a)pyrene	0.8	Based BaP	0.8	Based on benzo(a)pyrene
Polychlorinated Biphenyls								
PCBs (Polychlorinated Biphenyls)		1336363	0.15	Wester et al., 1993	1	Default	0.9	Default
Pesticides and Herbicides								
Aldrin		309002	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Carbazole		86748	0.1	Default for organics	1	Default	0.9	Default
Chloramben		133904	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Chlordane		57749	0.05	Default for chlorinated pesticides.	1	Default	0.8	ATSDR toxicological profile information
4, 4' - DDD		72548	0.05	Default for chlorinated pesticides.	1	Default	0.8	ATSDR toxicological profile information
4, 4' - DDE		72559	0.05	Default for chlorinated pesticides.	1	Default	0.8	ATSDR toxicological profile information
4, 4' - DDT		50293	0.05	Default for chlorinated pesticides.	1	Default	0.8	ATSDR toxicological profile information
Diazinon		333415	0.05	ATSDR toxicological profile information	1	Default	0.9	ATSDR toxicological profile information
2,4-Dichlorophenoxyacetic acid (2,4-D)		94757	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)		94826	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Dieldrin		60571	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Endosulfan		115297	0.2	ATSDR toxicological profile information	1	Default	0.8	ATSDR toxicological profile information
Endrin		72208	0.05	Default for chlorinated pesticides.	1	Default	0.8	ATSDR toxicological profile information
Heptachlor		76448	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Heptachlor epoxide		1024573	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
alpha-Hexachlorocyclohexane (alpha-BHC or alpha-HCH)		319846	0.05	Based on gamma-HCH	1	Default	0.9	Default and consistent with information in ATSDR Toxicological profile (1994)
beta-Hexachlorocyclohexane) (beta-BHC or beta-HCH)		319857	0.05	Based on gamma-HCH	1	Default	0.9	Default and consistent with information in ATSDR Toxicological profile (1994)
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)		58899	0.05	Default for chlorinated pesticides and consistent with ATSDR toxicological profile information	1	Default	0.9	ATSDR toxicological profile information
Hexachlorocyclohexane, technical grade		608731	0.05	Based on gamma-HCH	1	Default	0.9	Default and consistent with information in ATSDR Toxicological profile (1994)
Methoxychlor		72435	0.2	ATSDR toxicological profile information	1	Default	0.9	Default
2-Methyl-4-chlorophenoxyacetic acid (MCPA)		94746	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
2-(2-Methyl-4-chlorophenoxy)propionic acid (MCPP)		93652	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Metolachlor		51218452	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Picloram		1918021	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Terbufos		13071799	0.25	Default for organophosphates	1	Default	0.9	Default
Toxaphene		8001352	0.05	Default for chlorinated pesticides.	1	Default	0.9	ATSDR toxicological profile information
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)		93765	0.05	Default for chlorinated pesticides.	1	Default	0.9	Default
Dioxins/Furans								
Hexachlorodibenzo-p-dioxin, mixture		19408743	0.1	Default for organics	1	Default	0.9	Default
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)		1746016	0.03	EPA 1992 Dermal Guidance Document	0.55	Absorption from soil (20-40%, M Callahan (EPA) SRA, 1996. Dietary absorption (55%, EPA 1995)	0.55	(EPA 1995, Draft Estimating Exposure to Dioxin-like Compounds, Volume III, Chapter 2.)
Explosives								
1,3 - DNB		99650	0.25	ATSDR toxicological profile information	1	Default	0.8	ATSDR toxicological profile information
2,4 - DNT		121142	0.1	ATSDR toxicological profile information	1	Default	0.75	ATSDR toxicological profile information
2,6 - DNT		606202	0.1	ATSDR toxicological profile information	1	Default	0.75	ATSDR toxicological profile information

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Table A2.1 Chemical Absorption Value Information (1999 Version)

Chemical		CAS No.	Dermal Absorption Value		Soil/Toxicity Study Adjustment		Toxicity Study Absorption	
2,4- and 2,6 DNT Mixture			0.1	ATSDR toxicological profile information	1	Default	0.75	ATSDR toxicological profile information
HMX		2691410	0.01	ATSDR toxicological profile information	1	Default	0.1	ATSDR toxicological profile information
RDX		121824	0.1	Default based on ATSDR toxicological profile information indicating absorption does occur.	1	Default	0.1	ATSDR toxicological profile information indicating poor and slow absorption.
1,3,5 - TNB		99354	0.25	Based on 1,3-DNB	1	Default	0.8	Based on 1,3-DNB
2,4,6 - TNT		118967	0.25	ATSDR toxicological profile information	1	Default	0.8	ATSDR toxicological profile information

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2.0 CHEMICAL PROPERTY INFORMATION

For evaluation of volatile contaminants the soil-to-air volatilization factor (VF) model is utilized to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. The VF model is a simple approach that requires a limited number of easily obtained soil parameters and chemical property parameters. The chemical property parameters utilized are presented in Table A2.2. For further discussion of the VF model see Appendix 1, Section 2.1.4.

Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Inorganics									
Mercury (inorganic)	v	7439976	Yes	3.07E-02	6.30E-06	52 (Kd)	1.14E-02		EPA SSL Technical Background Document (1996)
Volatile Organics									
Acetone	v	67641	Yes	1.20E-01	1.10E-05	5.80E-01	3.90E-05	1.00E+06	EPA Region IX, PRG tables (4/98)
Benzene	v	71432	Yes	8.80E-02	9.80E-06	6.20E+01	5.60E-03	1.80E+03	EPA Region IX, PRG tables (4/98)
Bromodichloromethane	v	75274	Yes	3.00E-02	1.10E-05	1.00E+02	1.60E-03	6.70E+03	EPA Region IX, PRG tables (4/98)
Bromomethane *(methyl bromide)*	v	74839	Yes	7.30E-02	1.20E-05	9.00E-00	6.20E-03	1.50E+04	EPA Region IX, PRG tables (4/98)
1,3 - Butadiene	v	106990	Yes	9.80E-02	1.10E-05	1.20E+02	1.80E-01	7.40E+02	EPA Region IX, PRG tables (4/98)
n-Butylbenzene	v	104518	Yes	7.50E-02	7.80E-06	2.80E+03	1.30E-02	1.40E+01	EPA Region IX, PRG tables (4/98)
sec-Butylbenzene	v	135988	Yes	7.50E-02	7.80E-06	2.20E+03	1.90E-02	1.70E+01	EPA Region IX, PRG tables (4/98)
tert-Butylbenzene	v	98066	Yes	7.50E-02	7.80E-06	2.20E+03	1.30E-02	3.00E+01	EPA Region IX, PRG tables (4/98)
Carbon Disulfide	v	75150	Yes	1.00E-01	1.00E-05	4.60E+01	3.00E-02	1.20E+03	EPA Region IX, PRG tables (4/98)
Carbon Tetrachloride	v	56235	Yes	7.80E-02	8.80E-06	1.50E+02	3.00E-02	7.90E+02	EPA Region IX, PRG tables (4/98)
Chlorobenzene	v	108907	Yes	7.20E-02	8.70E-06	2.20E+02	3.70E-03	4.70E+02	EPA Region IX, PRG tables (4/98)
Chloroethane *(ethyl chloride)*	v	75003	Yes	1.00E-01	1.20E-05	1.50E+01	1.10E-02	5.70E+03	EPA Region IX, PRG tables (4/98)

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Chloroform (trichloromethane)	v	67663	Yes	1.00E-01	1.00E-05	5.30E+01	3.70E-03	7.90E+03	EPA Region IX, PRG tables (4/98)
Chloromethane *(methyl chloride)*	v	74873	Yes	1.10E-01	6.50E-06	3.50E+01	2.40E-02	8.20E+03	EPA Region IX, PRG tables (4/98)
2-Chlorotoluene	v	95498	Yes	7.20E-02	8.70E-06	1.60E+02	3.50E-03	4.70E+02	EPA Region IX, PRG tables (4/98)
Cumene (isopropylbenzene)	v	98828	Yes	7.50E-02	7.10E-06	2.20E+02	1.20E-00	6.10E+01	EPA Region IX, PRG tables (9/98)
1,2 - Dibromoethane *(ethylene dibromide)*	v	106934	Yes	7.30E-02	8.10E-06	2.80E+01	3.20E-04	3.40E+03	EPA Region IX, PRG tables (4/98)
Dibromomethane *(methylene bromide)*	v	74953	No	8.00E-02	8.00E-06	1.82E+02	8.40E-04	1.10E+04	Texas Risk Reduction Documentation. Appendix 7.
Dichlorodifluoromethane *(Freon 12)*	v	75718	Yes	8.00E-02	1.10E-05	5.80E+01	1.00E-01	2.80E+02	EPA Region IX, PRG tables (4/98)
1,1 - Dichloroethane	v	75343	Yes	7.40E-02	1.10E-05	5.30E+01	5.60E-03	5.10E+03	EPA Region IX, PRG tables (4/98)
1,2 - Dichloroethane	v	107062	Yes	1.00E-01	9.90E-06	3.80E+01	9.80E-04	8.50E+03	EPA Region IX, PRG tables (4/98)
1,1 - Dichloroethylene	v	75354	Yes	9.00E-02	1.00E-05	6.50E+01	2.60E-02	2.30E+03	EPA Region IX, PRG tables (4/98)
cis - 1,2 - Dichloroethylene	v	154592	Yes	7.40E-02	1.10E-05	3.60E+01	4.10E-03	3.50E+03	EPA Region IX, PRG tables (4/98)
trans - 1,2 - Dichloroethylene	v	156605	Yes	7.10E-02	1.20E-05	3.80E+01	9.40E-03	6.30E+03	EPA Region IX, PRG tables (4/98)
1,2 - Dichloroethylene (mixed isomers)	v	540590	Yes	7.40E-02	1.10E-05	3.60E+01	4.10E-03	3.50E+03	Based on cis-1,2-dichloroethylene
Dichloromethane *(methylene chloride)*	v	75092	Yes	1.00E-01	1.17E-05	1.00E+01	2.20E-03	1.32E+04	
1,2 - Dichloropropane	v	78875	Yes	7.80E-02	8.70E-06	4.70E+01	2.80E-03	2.80E+03	EPA Region IX, PRG tables (4/98)
Ethyl benzene	v	100414	Yes	7.50E-02	7.80E-06	2.00E+02	7.90E-03	1.70E+02	EPA Region IX, PRG tables (4/98)
n-Hexane	v	110543	Yes	2.00E-01	7.80E-06	8.90E+02	1.20E-01	1.80E+01	EPA Region IX, PRG tables (4/98)
Methyl ethyl ketone *(2-butanone)*	v	78933	Yes	9.00E-02	9.80E-06	4.50E-00	2.70E-05	2.70E+05	EPA Region IX, PRG tables (4/98)
Methyl isobutyl ketone *(MIBK)*	v	108101	Yes	7.50E-02	7.80E-06	1.30E+02	1.40E-04	1.90E+04	EPA Region IX, PRG tables (4/98)

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Naphthalene	v	91203	Yes	5.90E-02	7.50E-06	1.20E+03	4.80E-04	3.10E+01	EPA Region IX, PRG tables (4/98)
n-Propylbenzene		104518	Yes	7.50E-02	7.80E-06	2.80E+03	1.30E-02	1.40E+01	EPA Region IX Physical Chemical Value Table, 1998
Styrene	v	100425	Yes	7.10E-02	8.00E-06	9.10E+02	2.80E-03	3.10E+02	EPA Region IX, PRG tables (4/98)
1,1,1,2 - Tetrachloroethane	v	630206	Yes	7.10E-02	7.90E-06	7.90E+01	3.50E-04	3.00E+03	EPA Region IX, PRG tables (4/98)
1,1,2,2 - Tetrachloroethane	v	79345	Yes	7.10E-02	7.90E-06	7.90E+01	3.50E-04	3.00E+03	EPA Region IX, PRG tables (4/98)
Tetrachloroethylene (PCE)	v	127184	Yes	7.20E-02	8.20E-06	2.70E+02	1.80E-02	2.00E+02	EPA Region IX, PRG tables (4/98)
Toluene	v	108883	Yes	8.70E-02	8.60E-06	1.40E+02	6.60E-03	5.30E+02	EPA Region IX, PRG tables (4/98)
1,2,4 - Trichlorobenzene	v	120821	Yes	3.00E-02	8.20E-06	1.70E+03	1.40E-03	3.00E+02	EPA Region IX, PRG tables (4/98)
1,1,1 - Trichloroethane	v	71556	Yes	7.80E-02	8.80E-06	1.40E+02	1.70E-02	1.30E+03	EPA Region IX, PRG tables (4/98)
1,1,2 - Trichloroethane	v	79005	Yes	7.80E-02	8.80E-06	7.50E+01	9.10E-04	4.40E+03	EPA Region IX, PRG tables (4/98)
Trichloroethylene (TCE)	v	79016	Yes	7.90E-02	9.10E-06	9.40E+01	1.00E-02	1.10E+03	EPA Region IX, PRG tables (4/98)
Trichlorofluoromethane	v	75694	Yes	8.70E-02	1.30E-05	1.60E+02	9.70E-02	1.10E+03	EPA Region IX, PRG tables (4/98)
1,1,2-Trichloro-1,2,2-trifluoroethane *(Freon 113)*	v	76131	Yes	2.90E-02	8.10E-06	1.60E+02	5.20E-01	1.10E+03	EPA Region IX, PRG tables (4/98)
1,2,4-Trimethylbenzene	v	95636	Yes	7.50E-02	7.10E-06	3.72E+03	5.70E-03	2.60E-01	EPA Region IX, PRG tables (4/98)
1,3,5-Trimethylbenzene	v	108678	Yes	7.50E-02	7.10E-06	8.20E+02	7.70E-03	5.00E+01	EPA Region IX, PRG tables (4/98)
Vinyl chloride	v	75014	Yes	1.10E-01	1.20E-06	1.90E+01	2.70E-02	2.80E+03	EPA Region IX, PRG tables (4/98)
Xylenes (mixed)	v	1330207	Yes	7.80E-02	8.73E-06	2.50E+02	6.73E-03	1.77E+02	EPA Region IX, PRG tables (4/98)
Non/Semi Volatile Organics									
Benzoic acid		65850	No	5.36E-02	7.97E-06	6.00E-01	1.54E-06	3.50E+03	EPA SSL Technical Background Document (1996)

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Benzyl alcohol		100518	No						
Bis (2 - chloroethyl)ether	v	111444	Yes	6.90E-02	7.50E-06	7.60E+01	1.80E-05	1.70E+04	EPA Region IX, PRG tables (4/98)
Bis (chloromethyl) ether	v	542881	Yes	8.90E-02	9.40E-06	1.20E-00	2.00E-04	2.20E+04	EPA Region IX, PRG tables (4/98)
Bromoform *(tribromomethane)*		75252	No	1.49E-02	1.03E-05	1.26E+02	5.35E-04	3.10E+03	EPA SSL Technical Background Document (1996)
Butyl benzylphthalate		85687	No	1.74E-02	4.83E-06	1.37E+04	1.26E-06	2.69E-00	EPA SSL Technical Background Document (1996)
Dibenzofuran (unsubstituted)		132649	Yes	6.00E-02	1.00E-05	7.80E+03	1.30E-05	3.10E-00	EPA Region IX, PRG tables (4/98)
1,4 - Dibromobenzene		106376	No						
Dibromochloromethane		124481	No	1.96E-02	1.05E-05	6.30E+01	7.83E-04	2.60E+03	EPA SSL Technical Background Document (1996)
Dibutyl phthalate		84742	No	4.38E-02	7.86E-06	1.57E+03	9.38E-10	1.12E+01	EPA SSL Technical Background Document (1996)
1,2 - Dichlorobenzene	v	95501	Yes	6.90E-02	7.90E-06	3.80E+02	1.90E-03	1.60E+02	EPA Region IX, PRG tables (4/98)
1,3 - Dichlorobenzene	v	541731	Yes	6.90E-02	6.90E-02	3.80E+02	1.90E-03	1.60E+02	EPA Region IX, PRG tables (4/98)
1,4 - Dichlorobenzene	v	106467	Yes	1.30E-01	7.90E-06	1.20E+03	1.60E-03	7.90E+01	EPA Region IX, PRG tables (4/98)
3,3' - Dichlorobenzidine		91941	No	1.94E-02	6.74E-06	7.24E+02	4.00E-09	3.11E-00	EPA SSL Technical Background Document 1996
2,4-Dichlorophenol		120832	No	3.46E-02	8.77E-06	1.47E+02	3.16E-06	4.50E+03	EPA SSL Technical Background Document 1996
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*		117817	No	3.51E-02	3.66E-06	1.11E+05	1.02E-07	3.40E-01	EPA SSL Technical Background Document 1996
2,4-Dimethylphenol		105679	No	5.84E-02	8.69E-06	2.09E+02	2.00E-06	7.87E+03	EPA SSL Technical Background Document 1996
Di - n - octyl phthalate		117840	No	1.51E-02	3.58E-06	8.00E+07	6.68E-05	2.00E-02	EPA SSL Technical Background Document 1996
Ethylene glycol		107211	No	1.08E-01	1.22E-05	1.26E-01	6.00E-08	1.00E+06	Texas Draft Risk Reduction Program, Appendix VII, 1996
Hexachlorobenzene		118741	No	5.42E-02	5.91E-06	8.00E+04	1.32E-03	6.20E-00	EPA SSL Technical Background Document 1996

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Hexachloro-1,3-butadiene		87683	No	5.61E-02	6.16E-06	5.00E+04	8.15E-03	3.23E-00	EPA SSL Technical Background Document 1996
Hexachlorocyclopentadiene		77474	No	1.61E-02	7.21E-06	2.00E+05	2.70E-02	1.80E-00	EPA SSL Technical Background Document 1996
Methanol		67561	No	1.50E-01	1.50E-05	2.75E-00	4.40E-06	1.16E+06	Texas Draft Risk Reduction Program, Appendix VII, 1996 & Montgomery "Groundwataer Chemicals Desk Reference", 1996
2 - Methylphenol *(o-cresol)*		95487	No	7.40E-02	8.30E-06	9.10E+01	1.20E-06	2.60E+04	EPA SSL Technical Background Document 1996
3 - Methylphenol *(m-cresol)*		108394	No	7.40E-02	8.30E-06	9.10E+01	1.20E-06	2.60E+04	Based on 2-methylphenol
4 - Methylphenol *(p-cresol)*		106445	No	7.40E-02	8.30E-06	9.10E+01	1.20E-06	2.60E+04	Based on 2-methylphenol
N-Nitrosodiphenylamine		86306	No	3.12E-02	6.35E-06	1.30E+03	5.00E-06	3.51E+01	EPA SSL Technical Background Document 1996
N-Nitroso-di-n-propylamine		621647	No	5.45E-02	8.17E-06	2.40E+01	2.25E-06	9.89E+03	EPA SSL Technical Background Document 1996
Pentachlorophenol		87865	No	5.60E-02	6.10E-06	5.92E+02	2.44E-08	1.95E+03	EPA SSL Technical Background Document 1996
Phenol		108952	No	8.20E-02	9.10E-06	3.00E+01	3.97E-07	8.28E+04	EPA SSL Technical Background Document 1996
2,3,4,6-Tetrachlorophenol		58902	No	8.00E-02	8.00E-06	1.05E+02	6.10E-06	1.00E+02	Texas Draft Risk Reduction Program, Appendix VII, 1996
2,4,5-Trichlorophenol		95954	No	2.91E-02	7.03E-06	1.60E+03	4.33E-06	1.20E+03	EPA SSL Technical Background Document 1996
2,4,6-Trichlorophenol		88062	No	3.18E-02	6.25E-06	3.81E+02	7.79E-06	8.00E+02	EPA SSL Technical Background Document 1996
PAHs (Polynuclear Aromatic Hydrocarbons)									
Acenaphthene	v	83329	Yes	4.20E-02	7.70E-06	4.90E+03	1.60E-04	4.20E-00	EPA Region IX, PRG tables (4/98)
Anthracene	v	120127	Yes	3.20E-02	7.70E-06	2.40E+04	6.50E-05	4.30E-02	EPA Region IX, PRG tables (4/98)
Benzo(a)pyrene (BaP equiv)		50328	No	4.30E-02	9.00E-06	1.06E+06	1.13E-06	1.62E-03	EPA SSL Technical Background Document 1996
Fluoranthene		206440	No	3.02E-02	6.35E-06	4.91E+04	1.61E-05	2.06E-01	EPA SSL Technical Background Document 1996
Fluorene	v	86737	Yes	6.10E-02	7.90E-06	7.90E+03	7.70E-05	1.90E-00	EPA Region IX, PRG tables (4/98)

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
Naphthalene	v	91203	See Volatile Organics						
Pyrene	v	129000	Yes	2.70E-02	7.20E-06	6.80E+04	1.10E-05	1.40E-01	EPA Region IX, PRG tables (4/98)
Quinoline		91225	No						
Polychlorinated Biphenyls									
PCBs (Polychlorinated Biphenyls)		1336363	No	1.04E-01	1.00E-05	5.25E+05	4.20E-04	5.52E-03	Texas Draft Risk Reduction Program, Appendix VII, 1996
Pesticides and Herbicides									
Aldrin		309002	No	1.32E-02	4.86E-06	4.87E+04	1.70E-04	1.80E-01	EPA SSL Technical Background Document (1996)
Carbazole		86748	No	3.90E-02	7.03E-06	3.39E+03	1.53E-08	7.48E-00	EPA SSL Technical Background Document (1996)
Chloramben		133904	No						
Chlordane		57749	No	1.18E-02	4.37E-06	5.13E+04	4.86E-05	5.60E-02	EPA SSL Technical Background Document (1996)
4, 4' - DDD		72548	No	1.69E-02	4.76E-06	4.58E+04	4.00E-06	9.00E-02	EPA SSL Technical Background Document (1996)
4, 4' - DDE		72559	No	1.44E-02	5.87E-06	8.64E+04	2.10E-05	1.20E-01	EPA SSL Technical Background Document (1996)
4, 4' - DDT		50293	No	1.37E-02	4.95E-06	6.78E+05	8.10E-06	2.50E-02	EPA SSL Technical Background Document (1996)
Diazinon		333415	No						
2,4-Dichlorophenoxyacetic acid (2,4-D)		94757	No	5.90E-02	6.50E-06	8.91E+02	1.40E-10	8.90E+02	Texas Draft Risk Reduction Program, Appendix VII, 1996
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)		94826	No						
Dieldrin		60571	No	1.25E-02	4.74E-06	2.55E+04	1.51E-05	1.95E-01	EPA SSL Technical Background Document 1996
Endosulfan		115297	No	1.15E-02	4.55E-06	2.04E+03	1.12E-05	5.10E-01	EPA SSL Technical Background Document 1996
Endrin		72208	No	1.25E-02	4.74E-06	1.08E+04	7.52E-06	2.50E-01	EPA SSL Technical Background Document 1996
Heptachlor		76448	No	1.12E-02	5.69E-06	9.53E+03	5.85E-04	1.80E-01	EPA SSL Technical Background Document 1996
Heptachlor epoxide		1024573	No	1.32E-02	4.23E-06	8.00E+04	9.50E-06	2.00E-01	EPA SSL Technical Background Document 1996

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
alpha-Hexachlorocyclohexane (alpha-BHC or alpha-HCH)		319846	No	1.42E-02	7.34E-06	1.76E+03	1.06E-05	2.00E-00	EPA SSL Technical Background Document 1996
beta-Hexachlorocyclohexane) (beta-BHC or beta-HCH)		319857	No	1.42E-02	7.34E-06	2.14E+03	7.43E-07	2.40E-01	EPA SSL Technical Background Document 1996
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)		58899	No	1.42E-02	7.34E-06	1.35E+03	1.40E-05	6.80E-00	EPA SSL Technical Background Document 1996
Hexachlorocyclohexane, technical grade		608731	No	1.42E-02	7.34E-06	1.35E+03	1.40E-05	6.80E-00	Based on gamma hexachlorcyclohexane.
Methoxychlor		72435	No	1.56E-02	4.46E-06	8.00E+04	1.58E-05	4.50E-02	EPA SSL Technical Background Document 1996
2-Methyl-4-chlorophenoxyacetic acid (MCPA)		94746	No						
2-(2-Methyl-4-chlorophenoxy)propionic acid (MCPP)		93652	No						
Metolachlor		51218452	No						
Picloram		1918021	No						
Terbufos		13071799	No						
Toxaphene		8001352	No	1.16E-02	4.34E-06	9.58E+04	6.00E-06	7.40E-01	EPA SSL Technical Background Document 1996
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)		93765	No						
Dioxins/Furans									
Hexachlorodibenzo-p-dioxin, mixture		19408743	No						
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)		1746016	No	4.70E-02	8.00E-06	1.40E+07	3.55E-05	1.93E-05	Texas Draft Risk Reduction Program, Appendix VII, 1996
Explosives									
1,3 - DNB		99650	No	2.80E-01	7.60E-06	3.00E+01	1.10E-07	5.40E+02	Texas Draft Risk Reduction Program, Appendix VII, 1996
2,4 - DNT		121142	No	2.03E-01	7.06E-06	9.50E+01	9.26E-08	2.70E+02	EPA SSL Technical Background Document 1996
2,6 - DNT		606202	No	3.27E-02	7.26E-06	6.90E+01	7.47E-07	1.82E+02	EPA SSL Technical Background Document 1996
2,4- and 2,6 DNT Mixture			No	2.03E-01	7.06E-06	9.50E+01	9.26E-08	2.70E+02	Based on 2,4-DNT
HMX		2691410	No						
RDX		121824	No						
1,3,5 - TNB		99354	No	8.00E-02	8.00E-06	1.40E+01	6.90E-08	3.53E+02	Texas Draft Risk Reduction Program, Appendix VII, 1996

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Table A2.2 Chemical Property Information (1999 Version)

Chemical		CAS No.	Volatile?	Diffusivity in air	Diffusivity in water	Koc	Henry's (atm-m3/mol)	Solubility (mg/l)	Source of Information
2,4,6 - TNT		118967	No	5.41E-02	6.57E-06	3.02E+02	4.57E-07	1.30E+02	Texas Draft Risk Reduction Program, Appendix VII, 1996

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3.0 CHEMICAL TOXICITY INFORMATION

Toxicity or dose-response assessment describes the observed or potential toxic effects in humans or animals associated with a particular exposure of a contaminant. For most contaminants reported at sites the toxicity information needed to generate generic SRVs or conduct a site-specific risk characterization are found in secondary sources published by the USEPA or other government agencies. The following presents a list of sources of toxicity information in the order of preference:

1) Minnesota Department of Health (MDH) Toxicity Values
2) Integrated Risk Information System (IRIS)
3) Health Effects Assessment Summary Tables (HEAST)
4) National Center for Environmental Assessment (NCEA) Superfund Technical Support Center
5) Soil Screening Level Inhalation Benchmark Values
6) California Environmental Protection Agency (Cal/EPA)
7) Agency for Toxic Substances Disease Registry (ATSDR)
8) Calculation of a dose-response value using toxicity information from the literature.

The toxicity information may provide information associated with noncarcinogenic (toxicity threshold) effects or with carcinogenic effects. See Section 8.2 of the main document for further discussion.

3.1 Noncancer Toxicity Values

For noncarcinogenic health effects it is believed that a dose (or exposure) level exists at and below which no adverse health effects would be expected. This level is referred to as the toxicity threshold dose. Noncarcinogenic toxicity values are estimates of the daily exposure to the human population that is likely to be without appreciable risk of deleterious effects during the exposure period. The toxicity values are typically expressed as reference doses (RfD) in units of mg/kg per day or as reference concentrations (RfC) in units of mg/m^3.

The toxic effect of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short period of time may not produce the same effect when given over a longer period of time. Three exposure periods, acute, subchronic and chronic have been evaluated.

3.1.1 Acute Noncancer Toxicity Values

The acute toxicity of a contaminant refers to its ability to do systemic damage as a result of a one-time exposure to relatively large amounts of the contaminant. Quantitative acute toxicity information was only available for a limited number of contaminants. The acute oral toxicity values utilized to generate the generic acute SRVs are presented in Table A2.3.

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Table A2.3 Acute Toxicity Values (1999 Version)

Chemical	CAS No.	Acute Toxicity Value - - Oral Only	
		(mg/kg)	Source/Basis
Inorganics			
Antimony	7440360	0.528	Nonlethal toxic dose. Resulted in nausea and vomiting No uncertainty factor applied. (Calabrese et al. 1997. Environ Health Perspec.
Arsenic	7440382	0.10	ATSDR Toxicological Profile for Arsenic (1993). Minimum lethal dose reported to be approximately 1-3 mg/kg. Uncertainty safety factor - 10.
Barium	7440393	1	Lethal dose 43 - 57 mg/kg. Acute threshold for toxicity in adults 2.86-7.14 mg/kg. Uncertainty factor applied 3 - 10. (Calabrese et al. 1997. Environ Health Perspec.
Cadmium	7440439	0.05	Resulted in gatrointestinal irritation and vomiting No uncertainty factor applied. (Calabrese et al. 1997. Environ Health Perspec.
Copper	7440508	0.09	Resulted in gatrointestinal irritation and vomiting No uncertainty factor applied. (Calabrese et al. 1997. Environ Health Perspec.
Cyanide	57125	0.056	ATSDR Toxicological Profile for Cyanide (1993). Lowest fatal dose reported in humans approximately 0.56 mg/kg. Uncertainty safety factor - 10.
Fluorine (soluble fluoride)	7782414	0.5	Estimated lethal dose of 5 mg/kg based on child poisoning cases. Uncertainty safety factor - 10. GI effects have been reported at 0.04 - 3 mg/kg. (ATSDR Profile, 1993)
Non/Semi Volatile Organics			
Pentachlorophenol	87865	1.7	ATSDR Toxicological Profile for Pentachlorophenol (1994). Lethal dose reported to be approx. 17 mg/kg (cardiovascular effects at 0.2 - 0.5 mg/kg). Uncertainty Safety Factor - 10.
Phenol	108952	1	Lethal dose 10 - 50 mg/kg. (Calabrese et al, 1997 Environ Health Perspec. Uncertainty factor of 10.

3.1.2 Subchronic Noncancer Toxicity Values

Multiple exposures occurring over a small fraction of an individual's lifetime (e.g., ranging from several months to several years) are considered to be subchronic. The subchronic noncancer toxicity values are presented in Table A2. 4.

3.1.3 Chronic Noncancer Toxicity Values

The toxic effect of a contaminant depends in part on the dose and the rate at which the dose is administered. Multiple exposures occurring over an extended period of time or a significant fraction of an individual's lifetime are considered to be chronic. The chronic noncancer toxicity values are presented in Table A2. 5.

3.2 Cancer Toxicity Values

Unlike noncarcinogenic health effects the toxicity assessment for carcinogens assumes that there is no toxicity threshold dose for carcinogenicity; i.e., that there is no dose of a carcinogenic substance that is not associated with increased risk. The ability of a contaminant to increase the incidence of cancer in a target population is described by one of two measures: the cancer slope factor or the unit risk. The cancer slope factor is expressed as a plausible upper-bound estimate of probability of the risk per unit dose (mg/kg per day). The unit risk values are used in lieu of cancer slope factors when an estimate of a lifetime average media concentration of the contaminant is available. The unit risk is the upper 95% confidence limit of the mean incremental lifetime cancer risk estimated to result from lifetime exposure to a contaminant if it is in the air at a concentration of 1 ug/m^3 or in drinking water at a concentration of ug/L. The cancer slope factors and unit risk values are presented in Table A2.6.

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Inorganics						
Antimony		7440360	4.00E-04	Lifetime drinking water study of metallic antimony in rats. Target organ - blood system and whole body. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	2.00E-04	1 year intermittent antimony trioxide inhalation study in rats. Benchmark dose approach was used rather than a NOAEL/LOAEL approach. Target organ - respiratory system. Uncertainty factor - 30. Confidence in RfC - NA (HEAST 1997)
Arsenic		7440382	3.00E-04	Chronic drinking water study in humans. Chroic RfD was adopted as the subchronic RfD. Target organ - skin. Uncertainty factor applied - 3. Confidence in RfD - NA (HEAST 1997)	NA	NA
Barium		7440393	7.00E-02	10 week drinking water study in humans. Target organ - cardiovascular system. Uncertainty factor - 3. Confidence in RfD - NA (HEAST 1997)	5.00E-03	4 month inhalation study in rats. Target organ - fetus. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1997)
Beryllium		7440417	2.00E-03	Chronic RfD was adopted as the subchronic RfD as in the past. Target organ - intestinal lesions. Uncertainty factor - 300. Confidence in RfD - low to medium	NA	NA
Boron		7440428	9.00E-02	2 year dietary study in dogs. Chronic RfD was adopted as the subchronic RfD. Target organ - testis. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1995)	2.00E-02	Anhydrous borax occupational (intermittent inhalation) study in humans. Target organ - lung. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1995).
Chromium III		16065831	1.00E-00	840 day dietary study in rats. Chronic RfD was adopted as the subchronic RfD. Target organ - none observed at dose evaluated. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
Chromium VI		18540299	2.00E-02	1 year drinking water study in rats. Target organ - none observed at dose evaluated. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	1.00E-03	Chronic RfC with UF of 10 for short-term exposure removed. Target organ - respiratory system.
Copper		7440508	3.70E-02	Single oral dose in humans. Target organ - gastrointestinal. Uncertainty factor - NA. Confidence in RfD - NA (HEAST 1995).	NA	NA
Copper cyanide		544923	5.00E-02	Oral study in rats. Target organs - liver, kidney and whole body. Uncertainty factors applied - 100. Confidence in RfD - NA (HEAST 1995)	NA	NA
Cyanide		57125	2.00E-02	104 week dietary study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - nervous system, thyroid, and whole body. Uncertainty factors applied - 500. Confidence in RfD - NA (HEAST 1995)	NA	NA
Fluorine (soluble fluoride)		7782414	6.00E-02	Drinking water study in humans. Target organ - teeth and skeleton. Uncertainty factor applied - 1. Confidence in RfD - high (HEAST 1997)	NA	NA

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Manganese		7439965	1.40E-01	Chronic dietary study in humans. Target organ - nervous sytem. Uncertainty factor - 1. Confidence in RfD - NA (HEAST 1997)		
Methy mercury	v	22967926	1.00E-04	Methyl mercury exposure to humans. Target organ - developing nervous system. Uncertainty factor - 10. Confidence in RfD - NA (HEAST 1997)	NA	NA
Mercury (inorganic)		7439976	3.00E-03	Mercuric chloride feeding and subcutaneous studies in rats. Target organ - immune sytem. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	3.00E-04	Occupational exposure to elemental mercury in humans. Target organ - nervous system. Uncertainty factor - 30. Confidence in RfC - NA (HEAST 1997)
Nickel		various	2.00E-02	2 year dietary study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - whole body. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	NA	NA
Selenium		7782492	5.00E-03	Dietary study in humans. Chronic RfD was adopted as subchronic RfD. Target organ - whole body. Uncertainty factors - 3. Confidence i n RfD - NA (HEAST 1997)	NA	NA
Silver		7440224	5.00E-03	2-9 year study in humans. Chronic RfD was adopted as subchronic RfD. Target organ - skin. Uncertainty factor - 3. Confidence in RfD - NA (HEAST 1997)	NA	NA
Thallium		various	8.00E-04	90 day oral study in rats. Target organ - liver, hair and blood system. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	NA	NA
Tin		various	6.00E-01	2 year dietary study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Vanadium		7440622 1314621	7.00E-03	Lifetime drinking water study in rats. Target organ - NA. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Zinc		7440666	3.00E-01	10 week oral study in humans. Target organ - blood system. Uncertainty factor - 3. Confidence in RfD - NA (HEAST 1997)	NA	NA
Volatile Organics						
Acetone	v	67641	1.00E-00	90 day oral gavage study in rats. Target organ - kidney and liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	3.50E-00	Based on Chronic RfC and ratio of subchronic RfD/chronic RfD.
Benzene	v	71432	3.00E-03	Provisional value. Target organ - blood and immune system. Uncertainty factor - 3000. Confidence - medium. (STSC memo 1996)	6.00E-02	Provisonal value. Inhalation study in mice. Target organ - blood system. Uncertainty factor - 100. Confidence in RfC - low. (STSC memo 1996)

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Bromodichloromethane	v	75274	2.00E-02	102 week oral gavage study in mice. Chronic RfD was adopted as the subchronic RfD. Target organ - kidney. Uncertainty factor 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
Bromomethane *(methyl bromide)*	v	74839	5.00E-03	Provisional value. Oral study in rats. Target organ - intestinal system. Uncertainty factor - 300. Confidence in RfD - medium (STSC memo 1998)	2.00E-01	Provisional value. 13 week inhalation study in rats. Target organ - respiratory tract. Uncertainty factors - 30. Confidence in RfD - high (memo from NCEA, 1/96)
Carbon Disulfide	v	75150	1.00E-01	Intermittent Inhalation study in rabbits. Chronic RfD was adopted as subchronic RfD. Target organ - fetus. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	7.00E-01	Intermittent occupational study in humans. Duration 12.1 +/- 6.9 years. Benchmark dose approach used. Target organ - nervous system. Uncertainty factor - 30. Confidence in RfC - NA (HEAST 1997)
Chlorobenzene	v	108907	NA	NA	2.00E-01	Provisional value. Inhalation study in rats. Target organ - liver and kidney. Uncertainty factor - 300. Confidence in RfD - NA (NCEA memo, 1/96)
Chloroform (trichloromethane)	v	67663	1.00E-02	7.5 year oral study in dogs. Chronic RfD was adopted as the subchronic RfD. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
Chloromethane *(methyl chloride)*	v	74873	NA	NA	3.00E-01	Provisonal value. Inhalation study in mice and occupational study in humans. Target organ - nervous system Uncertainty & modifying factors - 300. Confidence in RfC - medium (NCEA memo, 8/98)
2-Chlorotoluene	v	95498	2.00E-01	103 day oral study in rats. Target organ - whole body. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Cumene (isopropylbenzene)	v	98828	4.00E-01	194 day oral study in rats. Target organ - kidney. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	4.00E-00	Minnesota Department of Health draft subchronic Health Risk Value for ambient air. (4/98). Target organ - kidney and endocrine sytems. Based on modified IRIS value.
1,2 - Dibromoethane *(ethylene dibromide)*	v	106934	NA	NA	2.00E-03	Occupational exposure in humans. Chronic RfC was modified to estimate subchronic RfC. Target organ - male reproductive system. Uncertainty factors applied - 100. Confidence in RfC - NA. (HEAST 1995)
Dibromomethane *(methylene bromide)*	v	74953	1.00E-01	90 day intermittent inhalation study in rats. Target organ - blood system. Uncertainty factor 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Dichlorodifluoromethane *(Freon 12)*	v	75718	9.00E-01	90 day dietary study in dogs. Target organ - none observed at dose evaluated. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997).	2.00E-00	6 week intermittent inhalation study in guinea pigs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1997).
1,1 - Dichloroethane	v	75343	1.00E-00	13 week inhalation study in rats. Target organ - none observed at dose evaluated. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	5.00E-00	13 week inhalation study in cats. Target organ - kidney. Uncertainty factor applied - 100. Confidence in RfC - NA (HEAST 1997).

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
1,1 - Dichloroethylene	v	75354	9.00E-03	2 year drinking water study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
cis - 1,2 - Dichloroethylene	v	154592	1.00E-01	90 day oral study in rats. Target organ - blood system. Uncertainty factor 300. Confidence in RfD - NA (HEAST 1997)	3.50E-01	Based on modified chronic value.
trans - 1,2 - Dichloroethylene	v	156605	2.00E-01	90 day drinking water study in mice. Target organ - blood system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	7.00E-01	Based on modified chronic value.
1,2 - Dichloroethylene (mixed isomers)	v	540590	9.00E-03	2 year 1,1-dichloroethylene drinking water study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	3.50E-01	Based on RfC for cis-1,2-Dichloroethlene
Dichloromethane *(methylene chloride)*	v	75092	6.00E-02	24 month drinking water study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
1,2 - Dichloropropane	v	78875	7.00E-02	ATSDR Minimal Risk Levels for hazardous substances, March 1996. Target organ - blood system. Uncertainty Factor - 1000. (Federal Register 61(101) May 23, 1996)	1.00E-02	Minnesota Department of Health draft subchronic inhalation health risk value. Target organ - respiratory system. Uncertainty factor - 100. (4/98) Based on modified IRIS value.
n-Hexane	v	110543	6.00E-01	Oral study in rats. Target organ - reproductive system and nervous system. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	2.00E-01	Occupational exposure in humans. Chronic RfC was adopted as subchronic RfC. Target organ - nervous system and respiratory system. Uncertainty factor - 300. Confidence in RfC - NA (HEAST 1997)
Methyl ethyl ketone *(2-butanone)*	v	78933	2.00E-00	Multigenerational drinking water study in rats. Chronic RfD was modified to estimate subchronic RfD. Target organ - fetus. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	1.00E-00	Inhalation study in mice. Target organ - fetus. Uncertainty factor - 3000. Confidence in RfC - NA (HEAST 1997)
Methyl isobutyl ketone *(MIBK)*	v	108101	8.00E-01	13 week oral study in rats. Target organ - liver, kidney, and whole body. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997).	8.00E-01	90 day intermittent inhalation study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1997).
Naphthalene	v	91203	2.00E-01	Based on chronic RfD with one UF of 10 removed.	3.00E-02	Based on chronic RfC with one factor of 10 removed.
Styrene	v	100425	NA	NA	3.00E-00	Occupational study in humans. Target organ - nervous system. Uncertainty factor - 10. Confidence in RfD - NA (HEAST 1997)
1,1,1,2 - Tetrachloroethane	v	630206	3.00E-02	103 week oral study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - liver and kidney. Uncertainty factor - 3000. Confidence in RfD - NA (HEAST 1997)	NA	NA

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
1,1,2,2 - Tetrachloroethane	v	79345	NA	NA	NA	NA
Tetrachloroethylene (PCE)	v	127184	1.00E-01	6 week oral study in mice. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Toluene	v	108883	2.00E-00	13 week oral study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	1.00E-00	Provisional value. Inhalation study in rats. Target organ - nervous system. Uncertainty factor - 300. Confidence in RfC - medium. (NCEA memo, 1/96) Currently under review.
1,2,4 - Trichlorobenzene	v	120821	1.00E-02	Multigenerational drinking water study in rats. Target organ - adrenal gland. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
1,1,2 - Trichloroethane	v	79005	4.00E-02	90 day drinking water study in mice. Target organ - blood system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Trichlorofluoromethane	v	75694	7.00E-01	6 week oral study in rats. Target organ - whole body. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	7.00E-00	90 day inhalation study in dogs. Target organ - kidney and lung. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1997)
Non/Semi Volatile Organics						
Benzoic acid		65850	4.00E-00	Dietary study in humans. Chronic RfD was adopted as the subchronic RfD. Target organ - none observed at doses evaluated. Uncertainty factor - 1. Confidence in RfD - NA (HEAST 1997)	NA	NA
Bromoform *(tribromomethane)*		75252	2.00E-01	13 week oral study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Butyl benzylphthalate		85687	2.00E-00	26 week dietary study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
1,4 - Dibromobenzene		106376	1.00E-01	45 or 90 day oral study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Dibromochloromethane		124481	2.00E-01	13 week oral study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Dibutyl phthalate		84742	1.00E-00	52 week dietaryl study in rats. Target organ - whole body. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
1,2 - Dichlorobenzene	v	95501	NA	NA	2.00E-00	Up to 7 month intermittent inhalation study in rats. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
1,4 - Dichlorobenzene	v	106467	NA	NA	8.00E-01	Minnesota Department of Health draft subchronic inhalation health risk value. Target organ - liver. Uncertainty factor - 100. (4/98) Based on modified IRIS value.
2,4-Dichlorophenol		120832	3.00E-03	2 generation drinking water study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - immune system. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1997)	3.00E-00	2 year intermittent inhalation study in dogs. Target organ - liver and bladder. Uncertainty factor - 10000. Confidence in RfC - NA (HEAST 1997)
2,4-Dimethylphenol		105679	2.00E-01	90 day oral study in mice. Target organ - nervous system and blood system. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	7.00E-01	Based on modified chronic RfC.
Di - n - octyl phthalate		117840	2.00E-02	7 - 12 month dietary study in rats. Target organ - liver and kidney. Uncertainty factors - 1000. Confidence in RfD - NA (HEAST 1995)	NA	NA
Ethylene glycol		107211	2.00E-00	Dietary study in rats. Target organ - fetus. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Hexachlorocyclopentadiene		77474	7.00E-02	Oral study in rats. Target organ - forestomach. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	7.00E-04	Inhalation study in rats. Target organ - respiratory system. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1997)
Methanol		67561	5.00E-00	Oral study in rats. Target organ - nrevous system and blood system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
2 - Methylphenol *(o-cresol)*		95487	5.00E-01	90 day oral study in rats. Target organ - nervous system and whole body. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
3 - Methylphenol *(m-cresol)*		108394	5.00E-01	90 day oral study in rats. Target organ - nervous system and whole body. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
4 - Methylphenol *(p-cresol)*		106445	5.00E-03	12 day oral study during gestation in rabbits. Target organ - nervous system, respiratory system, and whole body. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
Pentachlorophenol		87865	3.00E-02	62 day oral study in rats. Target organ - fetotoxicity. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Phenol		108952	6.00E-01	Oral study during gestation in rats. Target organ - fetus. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
2,3,4,6-Tetrachlorophenol		58902	3.00E-01	90 day oral study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
2,4,5-Trichlorophenol		95954	1.00E-00	98 day dietary study. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
PAHs (Polynuclear Aromatic Hydrocarbons)						
Acenaphthene	v	83329	6.00E-01	90 day oral gavage study in mice. Target organ - liver. Uncertainty factor - 300. Confidence in RfD - NA. (HEAST 1997)	2.10E-00	Modified chronic RfC based on subchronic RfD/chronic RfD ratio.
Anthracene	v	120127	3.00E-00	90 day oral gavage study in mice. Target organ - None observed at dose tested. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	1.10E+01	Modified chronic RfC based on subchronic RfD/chronic RfD ratio.
Fluoranthene		206440	4.00E-01	90 day oral study in mice. Target organ - kidney, blood, and liver. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	1.40E-00	Modified chronic RfC based on subchronic RfD/chronic RfD ratio.
Fluorene	v	86737	4.00E-01	13 week oral study in mice. Target organ - blood system. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	1.40E-00	Modified chronic RfC based on subchronic RfD/chronic RfD ratio.
Pyrene	v	129000	3.00E-01	13 week oral study in mice. Target organ - kidney. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	1.10E-00	Modified chronic RfC based on subchronic RfD/chronic RfD ratio.
Polychlorinated Biphenyls						
PCBs (Polychlorinated Biphenyls)		1336363	5.00E-05	5 year Aroclor 1254 ingestion study in non-human primates. Chronic RfD was modified to estimate the subchronic RfD. Target organ - immune system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Pesticides and Herbicides						
Aldrin		309002	3.00E-05	2 year dietary study in rats. Chronic value was adopted as subchronic value. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
Chlordane		57749	5.00E-04	Chronic RfD was adopted as subchronic RfD as in the past. Target organ - liver. Uncertainty factor - 300. Confidence in RfD - medium	7.00E-03	Minnesota Department of Health, Draft Health Risk Value for subchronic exposure (4/98). Target organ - liver. Based on modified IRIS value.
4, 4' - DDT		50293	5.00E-04	27 week dietary study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Diazinon		333415	9.00E-04	Dietary study in rats. Target endpoint - cholinesterase levels in blood. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1995)	NA	NA

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
2,4-Dichlorophenoxyacetic acid (2,4-D)		94757	1.00E-02	91 day oral study in rats. Chronic RfD was adopted as the subchronic RfD. Target organ - blood system, liver and kidney. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)		94826	8.00E-02	90 day dietary study in dogs. Target organ - blood system and whole body. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Dieldrin		60571	5.00E-05	2 year dietary study in rats. Chronic RfD was adopted as subchronic. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997).	NA	NA
Endosulfan		115297	6.00E-03	2 year dietary study in rats and 1 year dietary study in dogs. Target organ - kidney, nervous system, and cardiovascular system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Endrin		72208	3.00E-04	2 year dietary study in dogs. Chronic RfD was adopted as subchronic RfD. Target organ - nervous and liver/gastrointestinal system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Heptachlor		76448	5.00E-04	2 year dietary study in rats. Chronic RfD was adpoted as subchronic RfD. Target organ - liver. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	NA	NA
Heptachlor epoxide		1024573	1.30E-05	60 week dietary study in dogs. Chronic RfD was adopted as subchronic RfD. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)		58899	3.00E-03	12 week dietary study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Methoxychlor		72435	5.00E-04	13 day teratology study in rabbits. Target organ - reproductive/developmental effects. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997). Additional UF of 10 added. See chronic RfD.	1.80E-04	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996). Additional UF of 1 0 added. See chronic RfD.
2-Methyl-4-chlorophenoxyacetic acid (MCPA)		94746	5.00E-04	52 week dietary study in dogs. Chronic RfD was adopted as subchronic RfD. Target organ - kidney and liver. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	NA	NA
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)		93652	1.00E-02	90 day dietary study in rats. Target organ - kidney. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997)	NA	NA

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Table A2.4 Subchronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Non-Cancer Subchronic Toxicity Information			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Metolachlor		51218452	1.50E-01	2 year dietary study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - whole body. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997).	NA	NA
Terbufos		13071799	2.50E-05	6 month dietary study in dogs. Target organ - nervous system. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Toxaphene		8001352	1.00E-03	ATSDR Minimal Risk Levels for hazardous substances, March 1996. Target organ - liver. Uncertainty Factor - 100. (Federal Register 61(101) May 23, 1996)	NA	NA
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)		93765	1.00E-01	90 day dietary study in rats. Target organ - kidney and liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
Explosives						
1,3 - DNB		99650	1.00E-03	Drinking water study in rats. Target organ - spleen. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
2,4 - DNT		121142	2.00E-03	Oral study in dogs. Target organ - nervous system, cardiovascular/blood system, and liver. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
2,6 - DNT		606202	1.00E-02	13 week oral study in dogs. Target organ - nervous system, cardiovascular/blood system, liver and kidney. Uncertainty factor - 300. Confidence in RfD - NA (HEAST 1997).	NA	NA
RDX		121824	3.00E-03	105 week oral study in rats. Chronic RfD was adopted as subchronic RfD. Target organ - prostate. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1997)	NA	NA
2,4,6 - TNT		118967	5.00E-04	Oral study in dogs. Chronic RfD adopted as subchronic RfD. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997)	NA	NA

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Inorganics						
Aluminum		7429905	1.00E-00	Provisional value. Target organ - developmental and nervous system. Uncertainty factor - 100 Confidence in RfD - medium (NCEA memo, 1/96)	5.00E-03	Provisional value. Occupational data in humans. Target organ - nervous system. Uncertainty factor - 300. Confidence - medium. (STSC memo 1998)
Antimony		7440360	4.00E-04	Lifetime drinking water study of metallic antimony in rats. Target organ - blood system and whole body. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997) Also MDH chronic OHRV (4/98)	2.00E-04	Antimony trioxide inhalation study in rats. Target organ - lung. Uncertainty factor - 300. Confidence in RfC - medium (IRIS 12/95). Also MDH chronic HRV (4/98)
Arsenic		7440382	3.00E-04	Drinking water study in humans. Target organ - skin, cardiovascular and nervous systems. Uncertainty factor applied - 3. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Barium		7440393	7.00E-02	Experimental studies in humans and rats as well as epidemiological study in humans. Target organ - kidney. Uncertainty factor - 3. Confidence in RfD - medium. (IRIS 3/98)	5.00E-04	Inhalation study in rats. Target organ - fetus. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1997). Also MDH chronic HRV (4/98)
Beryllium		7440417	2.00E-03	Dietary study in dogs. Target organ - intestinal lesions. Uncertainty factor - 300. Confidence in RfD - low to medium (IRIS 4/98).	2.00E-05	Based on occupational and community study in humans. Target organ - respiratory system. Uncertainty factor - 10. Confidence in RfC - medium (IRIS 4/98)
Boron		7440428	9.00E-02	Dietary study in dogs. Target organ - male reproductive system. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95)	2.00E-02	Anhydrous borax occupational study in humans. Target organ - lung. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1995).
Cadmium		7440439	1.00E-03	Toxicokinetic modeling of critical target organ concentrations in humans. Target organ - kidney. Uncertainty factor - 10. Confidence in RfD - high (IRIS 12/95).	2.00E-04	NCEA provisional toxicity value. Study conducted in occupational workers. Target organ - kidneys. Uncertainty factors applied - NA. Confidence in RfC - NA. (Memorandum from NCEA, formerly ECAO, to EPA Region III, 3/96).
Chromium III		16065831	1.50E-00	Dietary study in rats. Target organ - none observed at the doses evaluated. UF - 100. MF - 10. Confidence in RfD - low (IRIS 9/98).	NA	NA
Chromium VI		18540299	3.00E-03	Drinking water study in rats. Target organ - none observed at the doses evaluated. UF - 300. MF - 3. Confidence in RfD - low (IRIS 9/98).	1.00E-04	Subchronic inhalation study of CrVI particulate in rats. Target organ - respiratory system. UF - 300. Confidence in RfC - low (IRIS 9/98)
Cobalt		7440484	6.00E-02	Value selected from provisional range of values. Target organ - blood system. Uncertainty factor - NA. Confidence in RfD - NA (EPA Region IX PRG table based on ECAO memo, 3/92).	1.02E-03	Provisional toxicity value. Target organ - respiratory and immune. Uncertainty factor - NA. Confidence in RfD - NA (ECAO memo, 3/92).
Copper		7440508	3.70E-02	Single oral dose in humans. Target organ - gastrointestinal. Uncertainty factor - NA. Confidence in RfD - NA (HEAST 1995).	NA	NA

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Copper cyanide		544923	5.00E-03	Oral study in rats. Target organs - liver, kidney and whole body. Uncertainty factors applied - 1000. Confidence in RfD - medium (IRIS 12/97)	NA	NA
Cyanide		57125	2.00E-02	Dietary study in rats. Target organ - nervous system, thyroid, and whole body. Uncertainty factors applied - 100. Confidence in RfD - medium (IRIS 12/95)	NA	NA
Fluorine (soluble fluoride)		7782414	6.00E-02	Drinking water study in humans. Target organ - teeth and skeleton. Uncertainty factor applied - 1. Confidence in RfD - high (IRIS 2/98)	NA	NA
Iron		7439896	3.00E-01	Provisional value. Based on NOAEL. Uncertainty factor - 1. Confidence in RfD - medium. (NCEA memo, 7/96)	NA	NA
Manganese		7439965	4.70E-02	Chronic exposure via diet and drinking water to humans. Target organ - nervous system. Uncertainty factor - 1. Modifying factor - 3. Confidence in RfD - medium (IRIS 12/95). Also MDH chronic OHRV (4/98)	2.00E-04	Minnesota Department of Health draft Chronic Health Risk Value (4/98). Target organ - nervous system. Based on modified IRIS value.
Methy mercury	v	22967926	1.00E-04	Methyl mercury exposure to humans. Target organ - developing nervous system. Uncertainty factor - 10. Confidence in RfD - medium (IRIS 12/95). Also MDH chronic OHRV (4/98)	NA	NA
Mercury (inorganic)		7439976	3.00E-04	Mercuric chloride feeding and subcutaneous studies in rats. Target organ - immune sytem. Uncertainty factor - 1000. Confidence in RfD - high. (IRIS 12/95)	3.00E-04	Occupational exposure to elemental mercury in humans. Target organ - nervous system. Uncertainty factor - 30. Confidence in RfC - medium (IRIS 12/95).
Nickel		various	2.00E-02	Dietary study in rats. Target organ - suppression of body and organ weights. Uncertainty factor - 300. Confidence in RfD - medium (IRIS 12/95). Also MDH chronic OHRV (4/98)	NA	NA
Selenium		7782492	5.00E-03	Epidemiological study in humans. Target organ - skin, liver, blood system, nervous system. Uncertainty factor - 3. Confidence in RfD - high (IRIS 12/95).	NA	NA
Silver		7440224	5.00E-03	Epidemiological study in humans. Target organ - skin. Uncertainty factor - 3. Confidence in RfD - low (IRIS 12/95).	NA	NA
Thallium		various	8.00E-05	Chronic oral thallium sulfate study in rats. Target organ - hair, male reproductive system, blood chemistry. Uncertainty factor 3000. Confidence in RfD - low. (IRIS 12/95)	NA	NA
Tin		various	6.00E-01	Dietary study in rats. Target organ - liver and kidney. Uncertainty factor 100. Confidence in RfD - NA (HEAST 1995).	NA	NA

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Titanium		7440326	4.00E-00	Provisional value. Dietary study in rats. Target organ - histopathological lesions in several organs. Uncertainty factor - 300. Confidence - medium. May not be protective for titanium soluble salts. (STSC 1998)	3.00E-02	Provisional value. Inhalation study in rats. Target organ - respiratory system. Uncertainty factor - 30. Confidence - medium to low. (STSC memo 1998)
Vanadium		7440622 1314621	7.00E-03	Drinking water study in rats. Target organ - NA. Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1995).	NA	NA
Zinc		7440666	3.00E-01	Dietary supplement study in humans. Target organ - blood system. Uncertainty factor - 3. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Volatile Organics						
Acetone	v	67641	1.00E-01	Oral study in rats. Target organ - liver and kidney. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	3.50E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Benzene	v	71432	3.00E-03	Provisional value. Target organ - blood and immune system. Uncertainty factor - 3000. Confidence - medium. (STSC memo 1996)	6.00E-03	Provisional toxicity value. Target organ - blood system. Uncertainty factor - 1000. Confidence in RfC - medium (STSC memo, 1996)
Bromodichloromethane	v	75274	2.00E-02	Oral study in mice. Target organ - kidney. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Bromomethane *(methyl bromide)*	v	74839	1.40E-03	Oral study in rats. Target organ - forestomach. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	5.00E-03	Inhalation study in rats. Target organ - respiratory system. Uncertainty factor - 100. Confidence in RfC - high (IRIS 12/95).
n-Butylbenzene	v	104518	1.00E-02	Provisional value. Based on toxicity studies in other chained butylbenzenes. Target organ - nervous system. Uncertainty factor - 10000. Confidence in RfD - low (ECAO memo, 1995).	4.00E-02	Based on oral provisional toxicity value provided to Region IX. (EPA Region XI PRG Table 1998)
sec-Butylbenzene	v	135988	1.00E-02	Provisional value. Based on toxicity studies in other chained butylbenzenes. Target organ - nervous system. Uncertainty factor - 10000. Confidence in RfD - low (ECAO memo, 1995).	4.00E-02	Based on oral provisional toxicity value provided to Region IX. (EPA Region XI PRG Table 1998)
tert-Butylbenzene	v	98066	1.00E-02	Provisional value. Based on toxicity studies in other chained butylbenzenes. Target organ - nervous system. Uncertainty factor - 10000. Confidence in RfD - low (ECAO memo, 1995).	4.00E-02	Based on oral provisional toxicity value provided to Region IX. (EPA Region XI PRG Table 1998)
Carbon Disulfide	v	75150	1.00E-01	Inhalation study in rabbits. Target organ - fetus. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	7.00E-01	Occupational studies in humans. Target organ - nervous system. Uncertainty factor - 30. Confidence in RfC - medium (IRIS 12/95). Also MDH chronic HRV (4/98)
Carbon Tetrachloride	v	56235	7.00E-04	Oral study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	2.00E-03	Study in guinea pigs. Target organ - liver. Uncertainty factor applied - 3000. Confidence in RfC - low. (NCEA, formerly ECAO, memorandum to EPA Region III, 6/96).

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Chlorobenzene	v	108907	2.00E-02	Oral study in dogs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	2.00E-02	Inhalation study in rats. Target organ - liver and kidney. Uncertainty factor - 10000. Confidence in RfC - NA (HEAST 1995).
Chloroethane *(ethyl chloride)*	v	75003	4.00E-01	Provisional value provided to EPA Region IX by NCEA (EPA Region IX PRG Table (1998). Target organ - developmental effects.	1.00E+01	Inhalation studies in mice. Target organ - developmental. Uncertainty factor - 300. Confidence in RfC - medium (IRIS 12/95).
Chloroform (trichloromethane)	v	67663	1.00E-02	Oral study in dogs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	3.00E-01	Chronic Inhalation Value. Target organs: GI/LIV; KIDN; Teratology. UF - 300. Confidence - NA (CalEPA 1997)
Chloromethane *(methyl chloride)*	v	74873	1.60E-02	Chronic oral toxicity values used by Cal/EPA (1996). Target organ - NA.	3.00E-01	Provisonal value. Inhalation study in mice and occupational study in humans. Target organ - nervous system Uncertainty & modifying factors - 300. Confidence in RfC - medium (NCEA memo, 8/98)
2-Chlorotoluene	v	95498	2.00E-02	Oral study in rats. Target organ - whole body. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	NA	NA
Cumene (isopropylbenzene)	v	98828	1.00E-01	Oral study in rats. Target organ - kidney. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 8/97).	4.00E-01	Subchronic inhalation study in rats. Target organ - kidney and adrenal. Uncertainty factor - 1000. Confidence in RfC - medium (IRIS 10/97).
1,2 - Dibromoethane *(ethylene dibromide)*	v	106934	NA	NA	2.00E-04	Occupational exposure in humans. Target organ - male reproductive system. Uncertainty factors applied - 1000. Confidence in RfC - NA. (HEAST 1995)
Dibromomethane *(methylene bromide)*	v	74953	1.00E-02	Inhalation study in rats. Target organ - blood system. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1995).	NA	NA
Dichlorodifluoromethane *(Freon 12)*	v	75718	2.00E-01	Dietary study in rats. Target organ - whole body. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	2.00E-01	Intermittent inhalation study in guinea pigs. Target organ - liver. Uncertainty factor - 10000. Confidence in RfC - NA (HEAST 1995).
1,1 - Dichloroethane	v	75343	1.00E-01	Inhalation study in rats. Target organ - no adverse effect observed at doses tested. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1995).	5.00E-01	Inhalation study in cats. Target organ - kidney. Uncertainty factor applied - 1000. Confidence in RfC - NA (HEAST 1995).
1,2 - Dichloroethane	v	107062	NA	NA	1.00E-02	Provisional RfC provided by EPA NCEA to Region IX (Region IX PRG tables 8/96).
1,1 - Dichloroethylene	v	75354	9.00E-03	Oral study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
cis - 1,2 - Dichloroethylene	v	154592	1.00E-02	Oral study in rats. Target organ - blood system. Uncertainty factor - 3000. Confidence in RfD - NA (HEAST 1995).	3.50E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
trans - 1,2 - Dichloroethylene	v	156605	2.00E-02	Drinking water study in rats. Target organ - liver. Uncertainty factor applied - 1000. Confidence in RfD - low (IRIS 12/95).	7.00E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
1,2 - Dichloroethylene (mixed isomers)	v	540590	9.00E-03	Drinking water study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1995).	3.50E-02	Based on extrapolated RfC for cis-1,2-dicholoroethylene.
Dichloromethane *(methylene chloride)*	v	75092	6.00E-02	Drinking water study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	3.00E-00	Inhalation study in rats. Target organ - liver. Uncertainty factor applied - 100. Confidence in RfC - NA (HEAST 1995).
1,2 - Dichloropropane	v	78875	NA	NA	2.00E-02	Inhalation study in rats. Target organ - respiratory system. Uncertainty factors - 300. Confidence in RfC - medium (IRIS 12/95).
Ethyl benzene	v	100414	1.00E-01	Oral study in rats. Target organ - liver and kidney. Uncertainty factor applied - 1000. Confidence in RfD - low (IRIS 12/95).	1.00E-00	Inhalation studies in rats and rabbits. Target organ - developmental. Uncertainty factor - 300. Confidence in RfC - low (IRIS 12/95).
n-Hexane	v	110543	6.00E-02	Oral study in rats. Target organ - reproductive system and nervous system. Uncertainty factor - 10000. Confidence in RfD - NA (HEAST 1995).	2.00E-01	Occupational exposure in humans. Target organ - nervous system and respiratory system. Uncertainty factor - 300. Confidence in RfC - medium (IRIS 12/96). Also MDH chronic HRV (4/98)
Methyl ethyl ketone *(2-butanone)*	v	78933	6.00E-01	Multigenerational dietary study in rats. Target organ - fetus. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	1.00E-00	Inhalation study in mice. Target organ - fetus. Uncertainty factor - 3000. Confidence in RfC - low (IRIS 12/95).
Methyl isobutyl ketone *(MIBK)*	v	108101	8.00E-02	Oral study in rats. Target organ - liver, kidney, and whole body. Uncertainty factor - 3000. Confidence in RfD - NA (HEAST 1995).	8.00E-02	Intermittent inhalation study in rats. Target organ - liver and kidney. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1995).
Naphthalene	v	91203	2.00E-02	Oral study in rats. Target organ - blood system and the eye. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 9/1998)	3.00E-03	Inhalation study in mice. Target organ - respiratory system. Uncertainty factors - 3000. Confidence - medium. (IRIS 9/98) Also Minnesota Department of Health draft Chronic Health Risk Value (12/98).
n-Propylbenzene		104518	1.00E-02	Provisional value. Based on toxicity studies in other chained butylbenzenes. Target organ - nervous system. Uncertainty factor - 10000. Confidence in RfD - low (ECAO memo, 1995).	4.00E-02	Based on oral provisional toxicity value provided to Region IX. (EPA Region XI PRG Table 1998)
Styrene	v	100425	2.00E-01	Oral study in dogs. Target organ - liver and blood systems. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95)	2.00E-01	Occupational inhalation exposure in humans. Target organ - nervous system. Uncertainty factor - 100. MDH chronic HRV (4/98) Based on modified IRIS value.
1,1,1,2 - Tetrachloroethane	v	630206	3.00E-02	Oral study in rats. Target organ - liver and kidney. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	NA	NA
1,1,2,2 - Tetrachloroethane	v	79345	1.40E-04	Chronic oral toxicity value used by Cal/EPA (1996). Target organ - liver and whole body.	NA	NA

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Tetrachloroethylene (PCE)	v	127184	1.00E-02	Oral study in mice. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95)	4.00E-01	Provisional value. Inhalation study in mice. Target organ - liver, kidney, nervous system. Uncertainty factor - 300. Confidence in RfC - medium/high (ECAO memo, 1995).
Toluene	v	108883	2.00E-01	Oral study in rats. Target organ - liver and kidney. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	4.00E-01	Inhalation exposure in humans. Target organ - respiratory and nervous systems. Uncertainty factor - 300. Confidence in RfC - medium (IRIS 12/95). Also MDH chronic HRV (4/98)
1,2,4 - Trichlorobenzene	v	120821	1.00E-02	Oral study in rats. Target organ - adrenal. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	2.00E-01	Inhalation studies in rats, rabbits, dogs and monkeys. Target organ - liver. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1995).
1,1,1 - Trichloroethane	v	71556	2.00E-02	Provisional value based on Office of Water RfD. Target organ - nervous system. Uncertainty factor - NA. Confidence in RfD - NA (NCEA memo, 8/96)	1.00E-00	Provisional value. Inhalation study in guinea pigs. Target organs - liver and nervous system. Uncertainty factors - 1000. Confidence in RfC - NA (ECAO memo, 1995).
1,1,2 - Trichloroethane	v	79005	4.00E-03	Drinking water study in mice. Target organ - blood chemistry indicating liver, immune and blood system effects. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Trichlorofluoromethane	v	75694	3.00E-01	Oral cancer bioassay in rats and mice. Target organ - survival and general histopathology. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 4/97).	7.00E-01	90 day inhalation study in dogs. Target organ - lung and kidney. Uncertainty factor - 10000. Confidence in RfC - NA (HEAST 1995)
1,1,2-Trichloro-1,2,2-trifluoroethane *(Freon 113)*	v	76131	3.00E+01	Occupational study in humans. Target organ - nervous system. Uncertainty factor - 10. Confidence in RfD - low (IRIS 7/96)	3.00E+01	Inhalation study in rats. Target organ - whole body. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1995).
1,2,4-Trimethylbenzene	v	95636	5.00E-02	Based on 1,3,5-trimethylbenzene	6.00E-03	Provisional value for trimethylbenzene isomers. Based on occupational study. Target organ - nervous, blood, and respiratory systems. Uncertainty factor - NA. Confidence in RfC - NA (NCEA memo, 3/96)
1,3,5-Trimethylbenzene	v	108678	5.00E-02	Provisional toxicity value based on oral study in rats. Target organ - kidney, liver, whole body. Uncertainty factor - 3000. Confidence in RfD - low (NCEA memo, 3/96).	6.00E-03	Provisional value for trimethylbenzene isomers. Based on occupational study. Target organ - nervous, blood, and respiratory systems. Uncertainty factor - NA. Confidence in RfC - NA (NCEA memo, 3/96)
Xylenes (mixed)	v	1330207	2.00E-00	Oral study in rats. Target organ - nervous system and whole body. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	3.00E-01	Human occupational studies. Target organ - nervous system and respiratory system. Uncertainty factor - 100. Confidence in RfC - NA (HEAST 1991).
Non/Semi Volatile Organics						
Benzoic acid		65850	4.00E-00	Dietary study in humans. Target organ - no adverse effects observed at levels evaluated. Uncertainty factor - none. Confidence in RfD - medium (IRIS 4/97)	1.40E+01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Benzyl alcohol		100518	3.00E-01	Oral study in rats. Target organ - forestomach. Uncertainty factor - 1000. Confidence in RfD - not available (HEAST 1995).	NA	NA
Bromoform *(tribromomethane)*		75252	2.00E-02	Oral gavage study in rats. Target organs - liver. Uncertainty factors applied 1000. Confidence in RfD - medium. (IRIS 12/95)	NA	NA
Butyl benzylphthalate		85687	2.00E-01	Dietary study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 4/97).	7.00E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Dibenzofuran (unsubstituted)		132649	4.00E-03	Provisional toxicity value. Target organ - kidney. Uncertainty factor - 3000. Confidence in RfD - low. (ECAO memo, 8/94).	NA	NA
1,4 - Dibromobenzene		106376	1.00E-02	Oral study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	NA	NA
Dibromochloromethane		124481	2.00E-02	Oral gavage study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Dibutyl phthalate		84742	1.00E-01	Oral study in rats. Target organ - whole body. Uncertainty factors - 1000. Confidence in RfD - low. (IRIS 12/95).	3.50E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
1,2 - Dichlorobenzene	v	95501	9.00E-02	Oral study in rats. Target organ - no adverse effect observed at the doses evaluated. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	3.00E-02	Provisional value provided to EPA Regions by NCEA (Region III RBC Table (10/97)
1,3 - Dichlorobenzene	v	541731	9.00E-04	Provisional value. Subchronic oral study in rats. Target organ - thyroid and liver. Uncertainty factor - 10000. Confidence - low. (STSC memo, 1998)	NA	NA
1,4 - Dichlorobenzene	v	106467	NA	NA	8.00E-01	Inhalation study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfC - medium (IRIS 12/95).
2,4-Dichlorophenol		120832	3.00E-03	Drinking water study in rats. Target organ - immune system. Uncertainty factors - 100. Confidence in RfD - low. (IRIS 4/96)	1.10E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*		117817	2.00E-02	Oral study in guinea pigs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
2,4-Dimethylphenol		105679	2.00E-02	Oral study in mice. Target organ - nervous system and cardiovascular/blood system. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	7.00E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Di - n - octyl phthalate		117840	2.00E-02	Dietary study in rats. Target organ - liver and kidney. Uncertainty factors - 1000. Confidence in RfD - NA (HEAST 1995)	7.00E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Ethylene glycol		107211	2.00E-00	Dietary study in rats. Target organ - liver and developmental. Uncertainty factor - 100. Confidence in RfD - high (IRIS 3/97)	NA	NA
Hexachlorobenzene		118741	8.00E-04	Chronic feeding study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - medium. (IRIS 12/96)	NA	NA
Hexachloro-1,3-butadiene		87683	2.00E-04	Dietary study in mice. Target organ - kidney. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1997). Note: currently under review.	NA	NA
Hexachlorocyclopentadiene		77474	7.00E-03	Subchronic oral study in rats. Target organ - stomach. Uncertainty factor - 1000. Confidence in RfD - low. (IRIS 12/95)	7.00E-05	Subchronic inhalation study in rats. Target organ - respiratory system. Uncertainty factor - 1000. Confidence in RfC - NA (HEAST 1997)
Methanol		67561	5.00E-01	Oral subchronic study in rats. Target organ - liver and brain. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 3/1998).	1.00E+01	Inhalation study in mice. Target organ - developmental. UF - 30. Confidence - NA (Cal EPA 1997)
2 - Methylphenol *(o-cresol)*		95487	5.00E-02	Oral study in rats. Target organ - nervous system and whole body. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	1.80E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996) Value also used by Cal-EPA (1996)
3 - Methylphenol *(m-cresol)*		108394	5.00E-02	Oral study in rats. Target organ - nervous system and whole body. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	1.80E-01	Based on 2-methylphenol
4 - Methylphenol *(p-cresol)*		106445	5.00E-03	Oral study in rabbits. Target organ - nervous system and respiratory system. Uncertainty factor - 1000. Confidence in RfD - NA (HEAST 1995).	1.80E-01	Based on 2-methylphenol
Pentachlorophenol		87865	3.00E-02	Oral study in rats. Target organ - liver and kidney. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	1.00E-01	Based on oral studies. Target organ - kidney and liver. UF - 100. Cal/EPA (1997)
Phenol		108952	6.00E-01	Oral study in rats. Target organ - reduced fetal weights. Uncertainty factor - 100. Confidence in RfD - low (IRIS 4/97)	2.10E-00	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
2,3,4,6-Tetrachlorophenol		58902	3.00E-02	Oral gavage study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
2,4,5-Trichlorophenol		95954	1.00E-01	Dietary study in rats. Target organ - liver and kidney. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	3.50E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
PAHs (Polynuclear Aromatic Hydrocarbons)						
Acenaphthene	v	83329	6.00E-02	Oral study in mice. Target organ - liver. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	2.10E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values: RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Anthracene	v	120127	3.00E-01	Oral study in mice. Target organ - none observed at the doses evaluated. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	1.10E-00	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Fluoranthene		206440	4.00E-02	Oral study in mice. Target organ - kidney, blood, and liver. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	1.40E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Fluorene	v	86737	4.00E-02	Oral study in mice. Target organ - blood system. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	1.40E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Pyrene	v	129000	3.00E-02	Oral study in mice. Target organ - kidney. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	1.10E-01	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Polychlorinated Biphenyls						
PCBs (Polychlorinated Biphenyls)		1336363	5.00E-05	Minnesota Department of Health draft Chronic Oral Health Risk Value (4/98). Target organ - developmental.	NA	NA
Pesticides and Herbicides						
Aldrin		309002	3.00E-05	Dietary study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95)	NA	NA
Chloramben		133904	1.50E-02	Dietary study in mice. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 4/97).	NA	NA
Chlordane		57749	5.00E-04	Chronic oral study in mice. Target organ - liver. Uncertainty factor - 300. Confidence in RfD - medium. (IRIS 2/98)	7.00E-04	Subchronic inhalation study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfC - low. (IRIS 2/98)
4, 4' - DDT		50293	5.00E-04	Dietary study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Diazinon		333415	9.00E-04	Dietary study in rats. Target endpoint - cholinesterase levels in blood. Uncertainty factors - 100. Confidence in RfD - NA (HEAST 1995)	NA	NA
2,4-Dichlorophenoxyacetic acid (2,4-D)		94757	1.00E-02	Oral study in rats. Target organ - blood system, liver and kidney. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	NA	NA
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)		94826	8.00E-03	Dietary study in dogs. Target organ - blood system, liver, whole body. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 4/97)	NA	NA
Dieldrin		60571	5.00E-05	Dietary study in rats. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Endosulfan		115297	6.00E-03	Dietary study in rats. Target organ - kidney, nervous system, and cardiovascular system. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	2.10E-02	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
Endrin		72208	3.00E-04	Oral study in dogs. Target organ - nervous system and liver/gastrointestinal system. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 12/95).	1.10E-03	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Heptachlor		76448	5.00E-04	Dietary study in rats. Target organ - liver. Uncertainty factor - 300. Confidence in RfD - low (IRIS 12/95).	NA	NA
Heptachlor epoxide		1024573	1.30E-05	Dietary study in dogs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	NA	NA
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)		58899	3.00E-04	Dietary study in rats. Target organ - liver and kidney. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Methoxychlor		72435	5.00E-04	Rabbit NOAEL level (basis of IRIS RfD) found to be an effect level (Chapin et al., FAT 1997). Additional uncertainty factor added since NOAEL is an effect level. Target organ - reproductive/developmental effects.	1.80E-04	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996). Additional UF of 1 0 added. See chronic RfD.
2-Methyl-4-chlorophenoxyacetic acid (MCPA)		94746	5.00E-04	Dietary study in dogs. Target organ - kidney and liver. Uncertainty factor - 300. Confidence in RfD - medium (IRIS 12/95).	NA	NA
2-(2-Methyl-4-chlorophenoxy)propionic acid (MCPP)		93652	1.00E-03	Dietary study in rats. Target organ - kidney. Uncertainty factor - 3000. Confidence in RfD - medium (IRIS 12/95).	NA	NA
Metolachlor		51218452	1.50E-01	Dietary study in rats. Target organ - whole body. Uncertainty factor - 100. Confidence in RfD - high (IRIS 12/95).	NA	NA
Picloram		1918021	7.00E-02	DIetary study in dogs. Target organ - liver. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 4/97).	NA	NA
Terbufos		13071799	2.50E-05	Dietary study in dogs. Target organ - nervous system (cholinesterase inhibition). Uncertainty factor - 100. Confidence in RfD - NA (HEAST 1995).	NA	NA
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)		93765	1.00E-02	Dietary study in rats. Target organ - kidney and neonatal survival. Uncertainty factor - 300. Confidence in RfD - medium (IRIS 4/97).	NA	NA
Explosives						
1,3 - DNB		99650	1.00E-04	Drinking water study in rats. Target organ - spleen. Uncertainty factor - 3000. Confidence in RfD - low (IRIS 12/95).	NA	NA
2,4 - DNT		121142	2.00E-03	Oral study in dogs. Target organ - nervous system, cardiovascular/blood system, and liver. Uncertainty factor - 100. Confidence in RfD - high (IRIS 12/95).	NA	NA

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Table A2.5 Chronic Noncancer Toxicity Values (1999 Version)

Chemical		CAS No.	Chronic Noncancer Toxicity Values			
			RfD (mg/kg per day)	Basis of RfD	RfC (mg/m3)	Basis of RfC
2,6 - DNT		606202	1.00E-03	Oral study in dogs. Target organ - nervous system, cardiovascular/blood system, liver and kidney. Uncertainty factor - 3000. Confidence in RfD - NA (HEAST 1997).	NA	NA
2,4- and 2,6 DNT Mixture			NA	see 2,4- or 2,6-DNT	NA	see 2,4- or 2,6-DNT
HMX		2691410	5.00E-02	Dietary study in rats. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - low (IRIS 12/95).	NA	NA
RDX		121824	3.00E-03	Oral study in rats. Target organ - prostate. Uncertainty factor - 100. Confidence in RfD - high (IRIS 12/95).	NA	NA
1,3,5 - TNB		99354	3.00E-02	Dietary study in rats. Target organ - blood system and spleen. Uncertainty factor - 100. Confidence in RfD - medium (IRIS 10/97).	NA	NA
2,4,6 - TNT		118967	5.00E-04	Dietary study in dogs. Target organ - liver. Uncertainty factor - 1000. Confidence in RfD - medium (IRIS 12/95).	NA	NA

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Table A2.6 Cancer Toxicity Values (1999 Version)

Chemical		CAS No.	Cancer Toxicity Information: Oral Slope Factor $(mg/kg/d)^{-1}$	Basis of Oral Cancer Slope Factor	Inhalation Unit Risk $(ug/m3)^{-1}$	Basis of Inhalation Unit Risk Factor
Inorganics						
Arsenic		7440382	1.50E-00	Epidemiological study of humans exposed via drinking water. Cancer target organs - skin, lung, liver, kidney and bladder. Note: CPF based on skin cancer incidence only. Class A (IRIS 12/95). Also MDH chronic OHRV (4/98)	4.00E-03	Human occupational studies. Cancer target organ - lung. Class A (IRIS 12/95). Also, MDH chronic HRV (4/98)
Beryllium		7440417	NA	NA	2.40E-03	Occupational study in humans. Cancer target organ - respiratory system. Class B2 (IRIS 12/95). Also MDH chronic HRV (4/98)
Cadmium		7440439	NA	NA	1.80E-03	Occupational studies in humans. Cancer target organ - lung. Class B1 (IRIS 12/95). Also MDH chronic HRV (4/98)
Chromium VI		18540299	NA	NA	1.20E-02	Occupational studies in humans. Cancer target organ - lung. Class A carcinogen (IRIS 9/98). Also MDH chronic HRV (4/98)
Nickel		various	NA	NA	4.80E-04	Occupational exposure of humans to nickel subsulfide. Cancer target organ - respiratory system. Class A. (IRIS 12/95). Also MDH chronic HRV (4/98)
Volatile Organics						
Benzene	v	71432	2.90E-02	Occupational studies in humans. Cancer target organ - blood system. Class A (IRIS 12/95).	7.80E-06	Occupational studies in humans. Cancer target organ - blood system. Class A (IRIS 10/98). Also MDH chronic HRV (12/98)
Bromodichloromethane	v	75274	6.20E-02	Oral study in mice. Cancer target organ - kidney. Class B2 (IRIS 12/95).	1.80E-05	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
1,3 - Butadiene	v	106990	NA	NA	2.80E-04	Inhalation study in rats. Cancer target organ - tumors at multiple sites. Class B2 (IRIS 12/95). Also MDH chronic HRV (4/98)
Carbon Tetrachloride	v	56235	1.30E-01	Geometric mean of unit risks calculated from dose-response data from multiple animal species. Cancer target organ - liver. Class B2 (IRIS 12/95).	1.50E-05	Based on oral studies (IRIS 12/95).
Chloroethane *(ethyl chloride)*	v	75003	2.90E-03	Provisional value. Inhalation study in mice. Cancer target organ - uterine carcinomas. Class B2 (STSC memo 1998)	NA	NA
Chloroform (trichloromethane)	v	67663	6.10E-03	Drinking water study in rats. Cancer target organ - kidney. Class B2 (IRIS 12/95).	2.30E-05	Based on oral study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95).
Chloromethane *(methyl chloride)*	v	74873	1.30E-02	Inhalation study in mice. Cancer target organ - kidney. Class C (HEAST 1995)	1.80E-06	Inhalation study in mice. Cancer target organ - kidney. Class C (HEAST 1995)
1,2 - Dibromoethane *(ethylene dibromide)*	v	106934	8.50E+01	Oral study in rats. Cancer target organ - forestomach tumors. Class B2. (IRIS 12/95).	2.20E-04	Inhalation study in rats. Cancer target organ - respiratory system. Class B2. (IRIS 12/95). Also MDH chronic HRV (4/98)

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Table A2.6 Cancer Toxicity Values (1999 Version)

Chemical		CAS No.	Cancer Toxicity Information: Oral Slope Factor $(mg/kg/d)^{-1}$	Basis of Oral Cancer Slope Factor	Inhalation Unit Risk $(ug/m3)^{-1}$	Basis of Inhalation Unit Risk Factor
1,1 - Dichloroethane	v	75343	5.70E-03	Cancer potency values used by Cal/EPA (1996)	1.60E-06	Cancer potency value used by Cal/EPA
1,2 - Dichloroethane	v	107062	9.10E-02	Oral study in rats. Cancer target organ - tumors at multiple sites. Class B2. (IRIS 12/95)	2.60E-05	Based on oral studies. (IRIS 12/95)
1,1 - Dichloroethylene	v	75354	6.00E-01	Drinking water study in rats. Cancer target organ - adrenal tumors. Class C. (IRIS 12/95).	5.00E-05	Inhalation study in mice. Cancer target organ - kidney tumors. Class C (IRIS 12/95).
Dichloromethane *(methylene chloride)*	v	75092	7.00E-03	Arithmetic mean of slope factors based on tumor incidence in mice. Cancer target organ - liver (other sites observed in rats). Class B2 (IRIS 12/95).	4.70E-07	Inhalation study in mice. Unit risk incorporates pharmacokinetic and metabolism information. Class B2 (IRIS 12/95). Also MDH chronic HRV (4/98)
1,2 - Dichloropropane	v	78875	6.80E-02	Oral gavage study in mice. Cancer target organ - liver. Class B2 (HEAST 1995).	1.80E-05	Cancer potency value used by Cal/EPA. (1996)
Styrene	v	100425	NA	Under review	NA	Under review
1,1,1,2 - Tetrachloroethane	v	630206	2.60E-02	Oral study in mice. Cancer target organ - liver. Class C (IRIS 12/95).	7.40E-06	Based on oral study. (IRIS 12/95)
1,1,2,2 - Tetrachloroethane	v	79345	2.00E-01	Oral study in mice. Cancer target organ - liver. Class C (IRIS 12/95)	5.80E-05	Based on oral study. (IRIS 12/95)
Tetrachloroethylene (PCE)	v	127184	5.20E-02	Provisional value. Oral study in mice. Cancer target organ - liver. Class B2/C (ECAO memo, 1995).	5.80E-07	Provisional value. Geometric mean of unit risks calculated from inhalation study data from rats and mice. Cancer target organ - liver and blood system. Class B2/C (ECAO memo, 1995).
1,1,2 - Trichloroethane	v	79005	5.70E-02	Oral study in mice. Cancer target organ - liver. Class C (IRIS 12/95).	1.60E-05	Based on oral study in mice (IRIS 12/95)
Trichloroethylene (TCE)	v	79016	1.10E-02	Provisional value. Oral study in mice. Cancer target organ - liver. Class B2/C (ECAO memo, 1995).	1.70E-06	Provisional value. Inhalation study in mice. Cancer target organ - lung. Class B2/C (ECAO memo, 1995).
Vinyl chloride	v	75014	1.90E-00	Dietary studies in rats. Cancer target organ - liver and lung. Class A (HEAST 1995). Under review - - possible increase in potency.	8.40E-05	Inhalation studies in rats. Cancer target organ - liver. Class A (HEAST 1995). Under review - - possible increase in potency.
Non/Semi Volatile Organics						
Bis (2 - chloroethyl)ether	v	111444	1.10E-00	Oral study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	3.30E-04	Based on oral study. Class B2 (IRIS 12/95).
Bis (chloromethyl) ether	v	542881	2.20E+02	Inhalation study in rats. Class A (IRIS 12/95).	6.20E-02	Inhalation study in rats. Cancer target organ - respiratory system. Class A (IRIS 12/95). Also MDH chronic HRV (4/98)
Bromoform *(tribromomethane)*		75252	7.90E-03	Oral gavage study in rats. Cancer target organ - large intestine. Class B2. (IRIS 12/95)	1.10E-06	Value estimated from oral study. (IRIS 12/95)
Butyl benzylphthalate		85687	NA	Class C. Increase in leukemia seen in rats but not mice.	NA	NA
Dibromochloromethane		124481	8.40E-02	Oral gavage study in mice. Cancer target organ - liver. Class C (IRIS 12/95).	2.40E-05	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)

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Table A2.6 Cancer Toxicity Values (1999 Version)

Chemical		CAS No.	Cancer Toxicity Information: Oral Slope Factor $(mg/kg/d)^{-1}$	Basis of Oral Cancer Slope Factor	Inhalation Unit Risk $(ug/m3)^{-1}$	Basis of Inhalation Unit Risk Factor
1,4 - Dichlorobenzene	v	106467	2.40E-02	Oral study in mice. Target organ - liver. Class C (HEAST 1995).	1.10E-05	Based on California EPA Cancer Potency Factors: Update (11/1/94).
3,3' - Dichlorobenzidine		91941	4.50E-01	Dietary study in rats. Cancer target organ - mammary glands. Class B2. (IRIS 12/95)	1.30E-04	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*		117817	1.40E-02	Dietary study in mice. Cancer target organ - liver tumors. Class B2 (IRIS 12/95).	4.00E-06	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Hexachlorobenzene		118741	1.60E-00	Dietary study in rats. Cancer target organ - liver. Class B2 (IRIS 12/96)	4.60E-04	Based on oral studies. Class B2 (IRIS 12/96)
Hexachloro-1,3-butadiene		87683	7.80E-02	Dietary study in rats. Cancer target organ - kidney. Class C. (IRIS 12/96)	2.20E-05	Based on oral studies. Class C (IRIS 12/96)
2 - Methylphenol *(o-cresol)*		95487	NA	NA (Class C)	NA	NA (Class C)
3 - Methylphenol *(m-cresol)*		108394	NA	NA (Class C)	NA	NA (Class C)
4 - Methylphenol *(p-cresol)*		106445	NA	NA (Class C)	NA	NA (Class C)
N-Nitrosodiphenylamine		86306	4.90E-03	Drinking water study in rats. Cancer target organ - bladder. Class B2 (IRIS 12/95).	1.40E-06	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
N-Nitroso-di-n-propylamine		621647	7.00E-00	Drinking water study in rats. Cancer target organ - liver and gastrointestinal tract. Class B2 (IRIS 4/97)	2.00E-03	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Pentachlorophenol		87865	1.20E-01	Dietary study in mice. Cancer target organ - multiple sites. Class B2 (IRIS 12/95)	3.40E-05	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
2,4,6-Trichlorophenol		88062	1.00E-02	Dietary study in rats. Cancer target organ - blood system. Class B2 (IRIS 4/96).	3.10E-06	Based on oral study in mice. (IRIS 4/96).
PAHs (Polynuclear Aromatic Hydrocarbons)						
Benzo(a)pyrene (BaP equiv)		50328	7.30E-00	Geometric mean of four slope factors obtained by different modeling methods using 2 different studies in more than 1 sex and species. Class B2 (IRIS 12/95). Also MDH chronic OHRV (4/98)	9.00E-04	Provisional value provided by NCEA to EPA Region Offices (EPA Region IX PRG Table, 1998)
Quinoline		91225	1.20E+01	Dietary study in rats. Cancer target organ - liver. Class C (HEAST 1995).	NA	NA
Polychlorinated Biphenyls						
PCBs (Polychlorinated Biphenyls)		1336363	2.00E-00	Dietary studies in rats. Cancer target organ - liver. Class B2. (IRIS 10/96)	5.70E-04	Based on oral studies. Cancer target organ - liver. (CalEPA 1997)
Pesticides and Herbicides						
Aldrin		309002	1.70E+01	Dietary study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	4.90E-03	Estimated from oral study (IRIS 12/95).

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Table A2.6 Cancer Toxicity Values (1999 Version)

Chemical		CAS No.	Cancer Toxicity Information: Oral Slope Factor $(mg/kg/d)^{-1}$	Basis of Oral Cancer Slope Factor	Inhalation Unit Risk $(ug/m3)^{-1}$	Basis of Inhalation Unit Risk Factor
Carbazole		86748	2.00E-02	Dietary study in mice. Cancer target organ - liver. Class B2 (HEAST 1997)	NA	NA
Chloramben		133904	NA	Classification under review (IRIS 4/97)	NA	Classification under review (IRIS 4/97)
Chlordane		57749	3.50E-01	Based on geometric mean of 5 data sets from studies in mice. Cancer target organ - liver. Class B2 (IRIS 2/98)	1.00E-04	Based on oral studies (IRIS 2/98).
4, 4' - DDD		72548	2.40E-01	Dietary study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	6.90E-05	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
4, 4' - DDE		72559	3.40E-01	Dietary study in mice and hamsters. Cancer target organ - liver. Class B2 (IRIS 12/95).	9.70E-05	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
4, 4' - DDT		50293	3.40E-01	Dietary study in mice and rats. Cancer target organ - liver. Class B2 (IRIS 12/95).	9.70E-05	Based on oral studies (IRIS 12/95).
Dieldrin		60571	1.60E+01	Geometric mean of 13 slope factors. Cancer target organ - liver. Class B2 (IRIS 12/95).	4.60E-03	Based on oral studies. (IRIS 12/95)
Heptachlor		76448	4.50E-00	Geometric mean of slope factors from four data sets from mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	1.30E-03	Oral data. Class B2 (IRIS 12/95).
Heptachlor epoxide		1024573	9.10E-00	Geometric mean of slope factors from four data sets from mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	2.60E-03	Oral data. Class B2 (IRIS 12/95).
alpha-Hexachlorocyclohexane (alpha-BHC or alpha-HCH)		319846	6.30E-00	Dietary study in mice. Cancer target organ - liver. Class B2. (IRIS 12/95)	1.80E-03	Based on oral studies. Class B2 (IRIS 12/95)
beta-Hexachlorocyclohexane) (beta-BHC or beta-HCH)		319857	1.80E-00	Dietary study in mice. Cancer target organ - liver. Class C. (IRIS 12/95)	5.30E-04	Based on oral studies. Class C (IRIS 12/95)
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)		58899	1.30E-00	Dietary study in mice. Cancer target organ - liver. Class B2/C (HEAST 1995).	3.70E-04	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
Hexachlorocyclohexane, technical grade		608731	1.80E-00	Dietary study in mice. Cancer target organ - liver. Class B2. (IRIS 12/95)	5.10E-04	Based on oral studies. Class B2 (IRIS 12/95)
Metolachlor		51218452	NA	NA (Class C)	NA	NA (Class C)
Toxaphene		8001352	1.10E-00	Dietary study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95).	3.20E-04	Oral studies (IRIS 12/95).
Dioxins/Furans						
Hexachlorodibenzo-p-dioxin, mixture		19408743	6.20E+03	Oral study in mice. Cancer target organ - liver. Class B2 (IRIS 12/95)	1.30E-00	Based on oral data (IRIS 12/95)
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)		1746016	1.50E+05	Dietary study in rats. Cancer target organ - liver. Class B2 (HEAST 1995).	3.30E+01	Oral study. HEAST 1995).
Explosives						

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Table A2.6 Cancer Toxicity Values (1999 Version)

Chemical		CAS No.	Cancer Toxicity Information			
			Oral Slope Factor $(mg/kg/d)^{-1}$	Basis of Oral Cancer Slope Factor	Inhalation Unit Risk $(ug/m3)^{-1}$	Basis of Inhalation Unit Risk Factor
2,4- and 2,6 DNT Mixture			6.80E-01	Dietary study in rats and mice. Cancer target organ - multiple sites. Class B2 (IRIS 12/95).	1.90E-04	Route-to-route extrapolated inhalation benchmark. (EPA Soil Screening Guidance: Technical Background Document, Appendix B. 1996)
RDX		121824	1.10E-01	Dietary study in mice. Cancer target organ - liver. Class C (IRIS 12/95).	NA	NA
2,4,6 - TNT		118967	3.00E-02	Dietary studies in rats and mice. Cancer target organ - multiple sites. Class C (IRIS 12/95).	NA	NA

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APPENDIX 3 GENERIC SOIL REFERENCE VALUES (SRVS)

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1.0 BACKGROUND

The soil reference values (SRVs) represent acceptable soil concentrations for specific exposure scenarios. Generic SRVs were developed for facilitate site investigations and remedy selection for sites in the Superfund and Voluntary Investigation and Cleanup programs. The generic SRVs are based on risk assessment methodology, modeling, and risk management policy. The generic SRVs address the three most common exposure pathways - incidental soil ingestion, dermal contact with soil, and inhalation of outdoor vapors and particulates from soil. Appendix 1 contains the exposure equations and input values for the exposure pathways.

In calculating SRVs, a set of acceptable risk levels has been established to ensure the same level of protection of human health regardless of the receptor or intended property use. The acceptable risk levels targeted by the risk-based evaluation process are as follows:

- Carcinogenic effects - a total or cumulative site excess lifetime cancer risk (ELCR) not to exceed 1 in 100,000 (i.e., 1E-5) for chronic exposure. In other words, the acceptable risk level is a maximum of one additional case of cancer per 100,00 chronically exposed individuals above background cancer rates in the general population. For subchronic exposures where higher exposures occur during a shorter exposure period (e.g., 1 year) the acceptable cumulative ELCR is limited to ten percent of the chronic ELCR (i.e., 1E-6); and

- Noncarcinogenic effects - a noncancer risk not to exceed a hazard quotient (HQ) of 0.2 per contaminant for chronic exposure or 1 for subchronic and acute exposure and a cumulative hazard index (HI) of 1 for multiple contaminants with similar target endpoints. The HQ is determined by dividing the site contaminant exposure by the contaminant reference dose, which is an estimate of the daily exposure that is not likely to result in an appreciable risk of deleterious effects. The HI is determined by adding the HQs for each contaminant with similar endpoints.

Note that when a cancer toxicity value was not available for a Class C carcinogen the generic SRV was based on the noncarcinogenic endpoints with an additional uncertainty factor of 10 applied. When a cancer toxicity value was available for a Class C carcinogen it was utilized in the same manner as cancer toxicity values for Class A, B1 and B2 carcinogens. This is consistent with methodology utilized by MDH in the development of Health Risk Limits (HRLs) for groundwater.

The acceptable risk levels remain the same regardless of the tier level of evaluation. The individual SRVs are calculated such that risk to human health will be at or below the acceptable risk levels established by the MPCA. Risk is evaluated separately for carcinogenic (cancer-causing) and noncarcinogenic effects. It assumes that the risk posed by individual contaminants with similar target endpoints (i.e., that affect the same parts of the body, such as liver or kidney, or cause the same effect, such as cancer) is additive. Therefore, when multiple contaminants having carcinogenic or noncarcinogenic effects are present at a site, the combined risk posed by the contaminants must be evaluated. The combined risks are referred to as the cumulative site risks. Evaluation of the cumulative site risks is facilitated by a set of Excel spreadsheets available on the MPCA web site.

The toxic effect of a contaminant depends in part on the dose and the rate at which the dose is administered. A specific dose given in a short period of time may not produce the same effect when given over a longer period of time. To adequately evaluate the potential risk acute , subchronic and chronic exposure scenarios were evaluated. Appendix 2 contains the chemical specific toxicity information utilized in the acute, subchronic and chronic exposure evaluations.

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In general, the chronic exposure scenario resulted in the lowest value and therefore was utilized as the generic SRV. There are several cases which are exceptions to this rule:

- Acutely toxic contaminants. A “one time” exposure (i.e., a toddler ingesting a bolus of soil) was utilized as the exposure scenario to evaluate acutely toxic contaminants. When the risk estimate for a “one time” exposure exceeded the risks from chronic exposure the SRV was set at the acute value.

- Subchronic SRVs. Two subchronic exposure scenarios were utilized: 1) a young child (< 6 years) was utilized as the receptor for the residential and recreational exposure setting; and 2) a short-term worker engaged in high exposure activities was utilized as the receptor for the industrial exposure setting. . The generic child-based subchronic SRVs were not more restrictive than the generic chronic residential SRVs. However, they were more restrictive than the generic chronic recreational SRVs for several contaminants. The generic short-term worker-based subchronic SRVs were also more restrictive than the generic chronic industrial SRVs for several contaminants.

- Soil saturation limits (Csast). Csat was utilized as the generic SRV if the inhalation pathway was the major pathway and if the estimated Csat value was lower than the calculated SRV. This is done for two reasons: 1) the soil-to-air volatilization model is only valid at soil concentrations at or below Csat; and 2) above Csat the contaminant may be present as free product.

- Maximum soil concentration. A concentration of 100,000 mg/kg (i.e., 10%) is utilized as a maximum soil concentration. If the calculated SRV is greater than the maximum soil concentration the generic tier SRV is set at 100,000 mg/kg.

The specific SRVs affected by these exceptions are briefly discussed in the appropriate section below and are highlighted in the SRV tables.

2.0 TIER 1 (SCREENING) SOIL REFERENCE VALUES

Table A3.1 presents the Tier 1 (Screening) Soil Reference Values (SRVs). In calculating the Tier 1 SRVs a residential exposure scenario was utilized. The specific exposure equations and input values are presented in Appendix 1. To facilitate the cumulative risk evaluation of site contamination utilization of the Tier1 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) is recommended.

As stated above the chronic exposure scenario typically resulted in the lowest value and therefore was utilized as the generic SRV. The Tier 1 exceptions to this rule are bolded in the SRV tables and are summarized below (see Section 1 for more discussion):

- Acutely toxic contaminants. The SRV was set at the acute value for barium, copper, cyanide, fluorine, and phenol.

- Soil saturation limits (Csast). The SRV was set at Csat for 2-chlorotoluene, ethylbenzene, and 1,2,4-trimethylbenzene.

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NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods

Source: M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other. If multiple sources utilized the source of the driving pathway is given.
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		26000	0.2	E		Or	CNS/PNS; REPROD	NA	NA			
Antimony	7440360		14	0.2	MI		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		10	0.2	I	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	1E-05	MI		Or
Barium	7440393		1200	*1*	O		Or	KIDN;REPROD (Based on Acute Intake)	NA	NA			
Beryllium	7440417		55	0.2	I		Or	LIV/GI; RESP; CANCER	B2	8E-08	I	Or De	In
Boron	7440428		3000	0.2	I		Or	REPRO	D	NA			
Cadmium	7440439		35	0.2	I		Or	KIDN; CANCER	B1	4E-08	MI	Or De	In
Chromium III	16065831		34300	0.2	I	In	Or	Not Available	NA	NA			
Chromium VI	18540299		71	0.2	I		Or	Not Available; CANCER	A	8E-07	MI	Or De	In
Cobalt	7440484		2000	0.2	E		Or	CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		100	*1*	O	In	Or	LIV/GI (Based on Acute Intake)	D	NA			
Copper Cyanide	544923		150	0.2	I	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		62	*1*	A	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: Based on Acute Intake)	NA	NA			
Fluorine (soluble fluoride)	7782414		550	*1*	I	In	Or	BONE; LIV/GI (Based on Acute Intake)	NA	NA			
Iron	7439896		7000	0.2	E	In	Or	No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		400	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			

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NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods

Source: M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other. If multiple sources utilized the source of the driving pathway is given.
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Manganese	7439965		1400	0.2	MI		Or	CNS/PNS	D	NA			
Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	0.7	0.2	I		In	CNS/PNS; IMMUNE	D	NA			
Methyl Mercury	22967926		3	0.2	MI	In	Or	CNS/PNS; REPROD	NA	NA			
Nickel	various		520	0.2	MI	In	Or	WHOLE BODY; CANCER	A	1E-07	MI	Or De	In
Selenium	7782492		170	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		170	0.2	I	In	Or	SKIN	D	NA			
Thallium	various		3	0.2	I	In	Or	CV/BLD; HAIR; REPROD	D	NA			
Tin	various		15000	0.2	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium			100000	0.2	E		Or	WHOLE BODY	NA	NA			
Vanadium	7440622 1314621		210	0.2	H	In	Or	Not Available	D	NA			
Zinc	7440666		8700	0.2	I	In	Or	CV/BLD	D	NA			
Volatile Organics													
Acetone	67641	y	320	0.2	E		In	KIDN; LIV/GI	D	NA			
Benzene	71432	y	1.5	0.2	E		In	CV/BLD; CANCER	A	2E-06	MI		In
Bromodichloromethane	75274	y	10	NA	I	In	?	KIDN; CANCER	B2	1E-05	E		In
Bromomethane *(methyl bromide)*	74839	y	0.7	0.2	I		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.07	NA	I			CANCER	B2	1E-05	MI	Or De	In
n-Butylbenzene	104518	y	30	0.2	E		In	CNS/PNS	NA	NA			

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NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods

Source: M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other. If multiple sources utilized the source of the driving pathway is given.
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
sec-Butylbenzene	135988	y	25	0.2	E		In	CNS/PNS	NA	NA			
tert-Butylbenzene (surrogate - n-butylbenzene)	98066	y	30	0.2	E		In	CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	65	0.2	I		In	CNS/PNS; REPROD	NA	NA			
Carbon Tetrachloride	56235	y	0.3	0.2	E		In	LIV/GI; CANCER	B2	1E-06	I		In
Chlorobenzene	108907	y	11	0.2	H		In	KIDN; LIV/GI	D	NA			
Chloroethane (*ethyl chloride*)	75003	y	1000	0.2	E		In	REPROD;CANCER	NA	2E-06	E	In	Or
Chloroform (trichloromethane)	67663	y	2.5	0.01	C		In	LIV/GI; CANCER	B2	1E-05	I		In
Chloromethane *(methyl chloride)*	74873	y	13	0.1	E		In	CNS/PNS;WHOLE BODY; CANCER (?)	C	1E-05	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	30	0.2	I		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane *(ethylene dibromide)*	106934	y	0.14	0.2	H	Or De	In	REPROD; CANCER	B2	1E-05	MI		Or
Dibromomethane *(methylene bromide)*	74953	y	260	0.2	H	In	?	CV/BLD	NA	NA			
Dichlorodifluoromethane *(Freon 12)*	75718	y	16	0.2	H		In	LIV/GI; WHOLE BODY	NA	NA			
1,1 - Dichloroethane	75343	y	34	0.06	H		In	KIDN; CANCER (?)	C	1E-05	C		In
1,2 - Dichloroethane	107062	y	4	0.2	E	Or De	In	NA; CANCER	B2	1E-05	I		In
1,1 - Dichloroethylene	75354	y	0.6	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	I		In
cis - 1,2 - Dichloroethylene	154592	y	8	0.2	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	11	0.2	E		In	LIV/GI	D	NA			

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Source: M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other. If multiple sources utilized the source of the driving pathway is given.
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TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,2 - Dichloroethylene (mixed isomers)	540590	y	8	0.2	E		In	LIV/GI	D	NA			
Dichloromethane *(methylene chloride)*	75092	y	97	0.04	H		In	LIV/GI; CANCER	B2	1E-05	MI		In
1,2 - Dichloropropane	78875	y	4	0.14	I	Or De	In	RESP; CANCER	B2	1E-05	C		In
Ethyl benzene	100414	y	200	0.14	I		In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			
Hexane	110543	y	100	*1*	M		In	CNS/PNS; REPRO; RESP (Note: Csat utilized)	NA	NA			
Methyl ethyl ketone *(2-butanone)*	78933	y	1400	0.2	I		In	REPROD	D	NA			
Methyl isobutyl ketone *(MIBK)*	108101	y	140	0.2	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	10	0.2	MI		In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	30	0.2	E		In	CNS/PNS	NA	NA			
Styrene	100425	y	210	0.2	M		In	CV/BLD; CNS/PNS; LIV/GI; CANCER (?)	?	Under Review			
1,1,1,2 - Tetrachloroethane	630206	y	31	NA	I	In	?	KIDN; LIV/GI; CANCER (?)	C	1E-05	I		In
1,1,2,2 - Tetrachloroethane	79345	y	3.5	0.2	C	In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	9E-06	I		In
Tetrachloroethylene (PCE)	127184	y	72	0.2	E		In	CNS/PNS; KIDN; LIV/GI; CANCER	B2/C	9E-06	E		In
Toluene	108883	y	107	0.2	MI		In	CNS/PNS; KIDN; LIV/GI; RESP	D	NA			
1,2,4 - Trichlorobenzene	120821	y	200	0.2	I		Or	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	140	0.2	E		In	CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	9	NA	I	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?)	C	1E-05	I		In
Trichloroethylene (TCE)	79016	y	29	NA				CANCER	B2/C	1E-05	E		In
Trichlorofluoromethane	75694	y	67	0.2	H		In	KIDN; RESP; WHOLE BODY	NA	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	3745	0.2	H		In	CNS/PNS; WHOLE BODY	NA	NA			
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			
1,3,5-Trimethylbenzene	108678	y	4	0.2	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.25	NA	H			CANCER	A	1E-05	H		In
Xylenes (mixed)	1330207	y	110	0.2	H		In	CNS/PNS; RESP; WHOLE BODY	D	NA			
Non/Semi Volatile Organics													
Benzoic acid	65850		50000	0.2	E I		In Or	No Adverse Effects Observed at Doses Tested.	D	NA			
Benzyl alcohol	100516		8700	0.2	H	In	Or	LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		2.5	NA				CANCER	B2	1E-05	I		In
Bis (chloromethyl) ether	542881		0.002	NA				CANCER	A	1E-05	MI		In
Bromoform (tribromomethane)	75252		370	0.1	I	In	?	LIV/GI; CANCER	B2	1E-05	I		In
Butyl benzylphthalate	85687		580	0.2	I		Or	LIV/GI; CANCER (? Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		104	0.2	E	In	Or	KIDN	NA	NA			
1,4 - Dibromobenzene	106376		260	0.2	I	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		12	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	E		In
Dibutyl phthalate	84742		2440	0.2	I		Or	WHOLE BODY	D	NA			
1,2 - Dichlorobenzene	95501		26	0.2	E		In	WHOLE BODY	D	NA			
1,3 - Dichlorobenzene	541731		26	0.2	E	In	?	LIV/GI; THYROID	D	NA			

WORKING DRAFT

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Source: M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other. If multiple sources utilized the source of the driving pathway is given.
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TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,4 - Dichlorobenzene	106467		30	0.01	I	Or De	In	KIDN; LIV/GI; CANCER (?)	C	1E-05	C		In
3,3' - Dichlorobenzidine	91941		25	NA				CANCER	B2	1E-05	I		Or
2,4-Dichlorophenol	120832		48	0.2	I		Or	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*	117817		570	0.2	I	In	Or	LIV/GI; CANCER	B2	6E-06	I		Or
2,4-Dimethylphenol	105679		390	0.2	I		Or	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		520	0.2	H		Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		50000	0.2	I	In	Or	LIV/GI; REPROD	NA	NA			
Hexachlorobenzene	118741		5	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		Or In
Hexachlorobutadiene	87683		6	0.2	H	In	?	KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		0.8	0.2	H		In	LIV/GI	D	NA			
Methanol	67561		9100	0.2	C		In	CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		75	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
3 - Methylphenol (m-cresol)	108394		75	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
4 - Methylphenol *(p-cresol)*	106445		10	0.2	H		Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		1950	NA				CANCER	B2	1E-05	I		Or
N-Nitrosodi-N-propylamine	621647		0.7	NA				CANCER	B2	1E-05	E		In
Pentachlorophenol	87865		71	0.02	I		Or	KIDN; LIV/GI; CANCER	B2	1E-05	I		Or

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Phenol	108952		1100	*1*	O	In De	Or	DEATH (Note: SRV based on Acute Intake)	D	NA			
2,3,4,6-Tetrachlorophenol	58902		636	0.2	I	In	Or	LIV/GI	NA	NA			
2,4,5-Trichlorophenol	95954		1920	0.2	I		Or	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		595	NA				CANCER	B2	1E-05	I		Or In
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	1200	0.2	I E		Or	LIV/GI	NA	NA			
Anthracene	120127		7880	0.2	I		Or	None Observed at Doses Evaluated.	D	NA			
Benzo[a]pyrene Equivalents)	50328		2	NA				CANCER	B2	1E-05	MI		Or
Fluoranthene	206440		1080	0.2	I		Or	CV/BLD; KIDN; LIV/GI	D	NA			
Fluorene	86737		1140	0.2	E			CV/BLD	D	NA			
Naphthalene - see Volatile Organics													
Pyrene	129000		890	0.2	I		Or	KIDN	D	NA			
Quinoline	91225		1.2	NA				CANCER (?)	C	1E-05	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		1.2	0.2	M	In	Or	IMMUNE; REPROD; CANCER	B2	3E-06	I		Or In
Pesticides and Herbicides													
Aldrin	309002		1	0.2	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Carbazole	86748		700					CANCER	B2	1E-05	H	In	Or
Chloramben	133904		430	0.2	I	In	Or	LIV/GI	under review				

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Chlordane	57749		13	0.2	I		Or	LIV/GI; CANCER	B2	4E-06	I		Or
4, 4' - DDD	72548		56	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDE	72559		40	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDT	50293		15	0.2	I	In	Or	LIV/GI; CANCER	B2	4E-06	I		Or
Diazinon	333415		26	0.2	H	In	Or	CNS/PNS	NA	NA			
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		285	0.2	I	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		226	0.2	I	In	Or	CV/BLD; LIV/GI; WHOLE BODY	NA	NA			
Dieldrin	60571		0.8	0.1	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Endosulfan	115297		120	0.2	I		Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		8	0.2	I		Or	CNS/PNS; LIV/GI	D	NA			
Heptachlor	76448		2	0.03	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or In
Heptachlor epoxide	1024573		0.4	0.2	I	In	Or	LIV/GI; CANCER	B2	3E-06	I		Or
alpha-Hexachlorocyclohexane	319846		2	NA				CANCER	B2	1E-05	I		Or
beta-Hexachlorocyclohexane	319857		7	NA				CANCER (?)	C	1E-05	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		9	0.2	I	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-05	H		Or
Hexachlorocyclohexane, technical grade	608731		6	NA				CANCER	B2	1E-05	I		Or
Methoxychlor	72435		11	0.2	O		Or	REPROD	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		16	0.2	I	In	Or	KIDN; LIV/GI	NA	NA			

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		29	0.2	I	In	Or	KIDN	NA	NA			
Metolachlor	51218452		435	0.2	I	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		2000	0.2	I	In	Or	LIV/GI	NA	NA			
Terbufos	13071799		0.6	0.2	H	In	Or	CNS/PNS	NA	NA			
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		290	0.2	I	In	Or	KIDN; REPRO	NA	NA			
Toxaphene	8001352		13	NA				CANCER	B2	1E-05	I		Or
Dioxins and Furans													
Hexachlorodibenzodioxin mixture	19408743		0.002	NA				CANCER	B2	1E-05	I		Or
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.0002	NA				IMMUNE; REPROD; CANCER	B2	1E-05	H		Or
Explosives													
1,3 - DNB	99650		2	0.2	I	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		50	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	see mixture below				
2,6 - DNT	606202		25	0.2	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	see mixture below				
2,4- AND 2,6 DNT MIXTURE			12	NA				CANCER	B2	1E-05	I		Or
HMX	2691410		1360	0.2	I	In	Or	LIV/GI	D	NA			
RDX	121824		35	0.2	I	In	De	PROST CANCER (?)	C	8E-06	I	In	De
1,3,5 - TNB	99354		610	0.2	I	In	Or	CV/BLD; SPLEEN	NA	NA			
2,4,6 – TNT	118967		10	0.2	I	In	Or	LIVER; CANCER (?)	C	3E-07	I	In	Or

VOC? - - y indicates that contaminant is considered volative.

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Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.1 SUMMARY OF TIER 1 SOIL REFERENCE VALUE (SRV) INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Tier 1 SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**

(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY - increased mortality, decreased growth rate, etc.
(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.

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3.0 TIER 2 (SIMPLE SITE-SPECIFIC) SOIL REFERENCE VALUES

Recommended default exposure parameters have been developed for residential (applicable to unrestricted commercial use), industrial (applicable to restricted commercial use) and recreational property use settings. Please see the Working Draft Guidance on Incorporation of Planned Property Use into Site Decisions for complete descriptions of these property use categories. Note that these property categories were developed to aid in determining exposure potential, not to correspond to zoning categories. The exposure scenarios utilized represent reasonable maximum exposure (RME) activities for the planned use of the site. These activities represent full use of the site and may not be presently occurring but are consistent with the planned use of the property.

In calculating SRVs for the residential and recreational property use categories a child exposure scenario was utilized for evaluating noncarcinogenic risk whereas an exposure scenario encompassing childhood and adult years was utilized for evaluating carcinogenic risk. In calculating SRVs for the industrial property use category an adult site worker exposure scenario was utilized for evaluating both carcinogenic and noncarcinogenic effects. The exposure equations and default values are presented in Appendix 1 "Exposure Equations and Default Values". The chemical-specific information utilized in the development of the SRVs is presented in Appendix 2 "Chemical-Specific Information".

3.1 Tier 2 Residential Soil Reference Values

3.1.1 Tier 2 Residential Chronic-based Soil Reference Values

Since the Tier 1 SRVs are based on a residential exposure scenario the generic Tier 2 residential SRVs are the same as the Tier 1 SRVs. The chronic exposure scenario typically resulted in the lowest value and therefore was utilized as the generic SRV. There are several exceptions to this rule. See Section 2.0 for further discussion. A summary of the Tier 2 Residential SRVs are presented in Table A3.2.

To facilitate the cumulative risk evaluation of site contamination utilization of the Residential Chronic Risk worksheet in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) is recommended.

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.2 SUMMARY OF TIER 2 CHRONIC RESIDENTIAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Residential SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		26000	0.2	E		Or	CNS/PNS; REPROD	NA	NA			
Antimony	7440360		14	0.2	MI		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		10	0.2	I	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	1E-05	MI		Or
Barium	7440393		1200	*1*	O		Or	KIDN;REPROD (Based on Acute Intake)	NA	NA			
Beryllium	7440417		55	0.2	I		Or	LIV/GI; RESP; CANCER	B2	8E-08	I	Or De	In
Boron	7440428		3000	0.2	I		Or	REPRO	D	NA			
Cadmium	7440439		35	0.2	I		Or	KIDN; CANCER	B1	4E-08	MI	Or De	In
Chromium III	16065831		34300	0.2	I	In	Or	Not Available	NA	NA			
Chromium VI	18540299		71	0.2	I		Or	Not Available; CANCER	A	8E-07	MI	Or De	In
Cobalt	7440484		2000	0.2	E		Or	CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		100	*1*	O	In	Or	LIV/GI (Based on Acute Intake)	D	NA			
Copper Cyanide	544923		150	0.2	I	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		62	*1*	A	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: Based on Acute Intake)	NA	NA			
Fluorine (soluble fluoride)	7782414		550	*1*	I	In	Or	BONE; LIV/GI (Based on Acute Intake)	NA	NA			
Iron	7439896		7000	0.2	E	In	Or	No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		400	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			

WORKING DRAFT

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Manganese	7439965		1400	0.2	MI		Or	CNS/PNS	D	NA			
Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	0.7	0.2	I		In	CNS/PNS; IMMUNE	D	NA			
Methyl Mercury	22967926		3	0.2	MI	In	Or	CNS/PNS; REPROD	NA	NA			
Nickel	various		520	0.2	MI	In	Or	WHOLE BODY; CANCER	A	1E-07	MI	Or De	In
Selenium	7782492		170	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		170	0.2	I	In	Or	SKIN	D	NA			
Thallium	various		3	0.2	I	In	Or	CV/BLD; HAIR; REPROD	D	NA			
Tin	various		15000	0.2	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium	7440326		100000	0.2	E		Or	WHOLE BODY	NA	NA			
Vanadium	7440622 1314621		210	0.2	H	In	Or	Not Available	D	NA			
Zinc	7440666		8700	0.2	I	In	Or	CV/BLD	D	NA			
Volatile Organics													
Acetone	67641	y	320	0.2	E		In	KIDN; LIV/GI	D	NA			
Benzene	71432	y	1.5	0.2	E		In	CV/BLD; CANCER	A	2E-06	MI		In
Bromodichloromethane	75274	y	10	NA	I	In	?	KIDN; CANCER	B2	1E-05	E		In
Bromomethane *(methyl bromide)*	74839	y	0.7	0.2	I		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.07	NA	I			CANCER	B2	1E-05	MI	Or De	In
n-Butylbenzene	104518	y	30	0.2	E		In	CNS/PNS	NA	NA			

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sec-Butylbenzene	135988	y	25	0.2	E		In	CNS/PNS	NA	NA			
tert-Butylbenzene	98066	y	30	0.2	E		In	CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	65	0.2	I		In	CNS/PNS; REPROD	NA	NA			
Carbon Tetrachloride	56235	y	0.3	0.2	E		In	LIV/GI; CANCER	B2	1E-06	I		In
Chlorobenzene	108907	y	11	0.2	H		In	KIDN; LIV/GI	D	NA			
Chloroethane (*ethyl chloride*)	75003	y	1000	0.2	E		In	REPROD;CANCER	NA	2E-06	E	In	Or
Chloroform (trichloromethane)	67663	y	2.5	0.01	C		In	LIV/GI; CANCER	B2	1E-05	I		In
Chloromethane *(methyl chloride)*	74873	y	13	0.1	E		In	CNS/PNS;WHOLE BODY; CANCER (?)	C	1E-05	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	30	0.2	I		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane *(ethylene dibromide)*	106934	y	0.14	0.2	H	Or De	In	REPROD; CANCER	B2	1E-05	MI		Or
Dibromomethane *(methylene bromide)*	74953	y	260	0.2	H	In	?	CV/BLD	NA	NA			
Dichlorodifluoromethane *(Freon 12)*	75718	y	16	0.2	H		In	LIV/GI; WHOLE BODY	NA	NA			
1,1 - Dichloroethane	75343	y	34	0.06	H		In	KIDN; CANCER (?)	C	1E-05	C		In
1,2 - Dichloroethane	107062	y	4	0.2	E	Or De	In	NA; CANCER	B2	1E-05	I		In
1,1 - Dichloroethylene	75354	y	0.6	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	I		In
cis - 1,2 - Dichloroethylene	154592	y	8	0.2	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	11	0.2	E		In	LIV/GI	D	NA			

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1,2 - Dichloroethylene (mixed isomers)	540590	y	8	0.2	E		In	LIV/GI	D	NA			
Dichloromethane *(methylene chloride)*	75092	y	97	0.04	H		In	LIV/GI; CANCER	B2	1E-05	MI		In
1,2 - Dichloropropane	78875	y	4	0.14	I	Or De	In	RESP; CANCER	B2	1E-05	C		In
Ethyl benzene	100414	y	200	0.14	I		In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			
Hexane	110543	y	100	*1*	M		In	CNS/PNS; REPRO; RESP (Note: Csat utilized)	NA	NA			
Methyl ethyl ketone *(2-butanone)*	78933	y	1400	0.2	I		In	REPROD	D	NA			
Methyl isobutyl ketone *(MIBK)*	108101	y	140	0.2	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	10	0.2	MI		In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	30	0.2	E		In	CNS/PNS	NA	NA			
Styrene	100425	y	210	0.2	M		In	CV/BLD; CNS/PNS; LIV/GI; CANCER (?)	?	Under Review			
1,1,1,2 - Tetrachloroethane	630206	y	31	NA	I	In	?	KIDN; LIV/GI; CANCER (?)	C	1E-05	I		In
1,1,2,2 - Tetrachloroethane	79345	y	3.5	0.2	C	In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	9E-06	I		In
Tetrachloroethylene (PCE)	127184	y	72	0.2	E		In	CNS/PNS; KIDN; LIV/GI; CANCER	B2/C	9E-06	E		In
Toluene	108883	y	107	0.2	MI		In	CNS/PNS; KIDN; LIV/GI; RESP	D	NA			
1,2,4 - Trichlorobenzene	120821	y	200	0.2	I		Or	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	140	0.2	E		In	CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	9	NA	I	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?)	C	1E-05	I		In
Trichloroethylene (TCE)	79016	y	29	NA				CANCER	B2/C	1E-05	E		In
Trichlorofluoromethane	75694	y	67	0.2	H		In	KIDN; RESP; WHOLE BODY	NA	NA			

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1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	3745	0.2	H		In	CNS/PNS; WHOLE BODY	NA	NA			
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			
1,3,5-Trimethylbenzene	108678	y	4	0.2	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.25	NA	H			CANCER	A	1E-05	H		In
Xylenes (mixed)	1330207	y	110	0.2	H		In	CNS/PNS; RESP; WHOLE BODY	D	NA			
Non/Semi Volatile Organics													
Benzoic acid	65850		50000	0.2	E I		In Or	No Adverse Effects Observed at Doses Tested.	D	NA			
Benzyl alcohol	100516		8700	0.2	H	In	Or	LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		2.5	NA				CANCER	B2	1E-05	I		In
Bis (chloromethyl) ether	542881		0.002	NA				CANCER	A	1E-05	MI		In
Bromoform (tribromomethane)	75252		370	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		In
Butyl benzylphthalate	85687		580	0.2	I		Or	LIV/GI; CANCER (? Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		104	0.2	E	In	Or	KIDN	NA	NA			
1,4 - Dibromobenzene	106376		260	0.2	I	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		12	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	E		In
Dibutyl phthalate	84742		2440	0.2	I		Or	WHOLE BODY	D	NA			
1,2 - Dichlorobenzene	95501		26	0.2	E		In	WHOLE BODY	D	NA			
1,3 - Dichlorobenzene	541731		26	0.2	E	In	?	LIV/GI; THYROID	D	NA			

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1,4 - Dichlorobenzene	106467		30	0.01	I	Or De	In	KIDN; LIV/GI; CANCER (?)	C	1E-05	C		In
3,3' - Dichlorobenzidine	91941		25	NA				CANCER	B2	1E-05	I		Or
2,4-Dichlorophenol	120832		48	0.2	I		Or	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate *(bis-ethylhexyl phthalate)*	117817		570	0.2	I	In	Or	LIV/GI; CANCER	B2	6E-06	I		Or
2,4-Dimethylphenol	105679		390	0.2	I		Or	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		520	0.2	H		Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		50000	0.2	I	In	Or	LIV/GI; REPROD	NA	NA			
Hexachlorobenzene	118741		5	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		Or In
Hexachlorobutadiene	87683		6	0.2	H	In	?	KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		0.8	0.2	H		In	LIV/GI	D	NA			
Methanol	67561		9100	0.2	C		In	CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		75	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
3 - Methylphenol (m-cresol)	108394		75	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
4 - Methylphenol *(p-cresol)*	106445		10	0.2	H		Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		1950	NA				CANCER	B2	1E-05	I		Or
N-Nitrosodi-N-propylamine	621647		0.7	NA				CANCER	B2	1E-05	E		In

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Pentachlorophenol	87865		71	0.02	I		Or	KIDN; LIV/GI; CANCER	B2	1-05	I		Or
Phenol	108952		1100	*1*	O	In De	Or	DEATH (Note: SRV based on Acute Intake)	D	NA			
2,3,4,6-Tetrachlorophenol	58902		636	0.2	I	In	Or	LIV/GI	NA	NA			
2,4,5-Trichlorophenol	95954		1920	0.2	I		Or	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		595	NA				CANCER	B2	1E-05	I		Or In
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	1200	0.2	I		Or	LIV/GI	NA	NA			
Anthracene	120127		7880	0.2	I		Or	None Observed at Doses Evaluated.	D	NA			
Benzo[a]pyrene (or BaP equivalents)	50328		2	NA				CANCER	B2	1E-05	MI		Or
Fluoranthene	206440		1080	0.2	I		Or	CV/BLD; KIDN; LIV/GI	D	NA			
Fluorene	86737		850	0.2	E			CV/BLD	D	NA			
Naphthalene - see Volatile Organics													
Pyrene	129000		890	0.2	I		Or	KIDN	D	NA			
Quinoline	91225		1.2	NA				CANCER (?)	C	1E-05	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		1.2	0.2	M	In	Or	IMMUNE; REPROD; CANCER	B2	3E-06	I		Or In
Pesticides and Herbicides													
Aldrin	309002		1	0.2	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or

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Carbazole	86748		700					CANCER	B2	1E-05	H	In	Or
Chloramben	133904		430	0.2	I	In	Or	LIV/GI	under review				
Chlordane	57749		13	0.2	I		Or	LIV/GI; CANCER	B2	4E-06	I		Or
4, 4' - DDD	72548		56	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDE	72559		40	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDT	50293		15	0.2	I	In	Or	LIV/GI; CANCER	B2	4E-06	I		Or
Diazinon	333415		26	0.2	H	In	Or	CNS/PNS	NA	NA			
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		285	0.2	I	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		226	0.2	I	In	Or	CV/BLD; LIV/GI; WHOLE BODY	NA	NA			
Dieldrin	60571		0.8	0.1	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Endosulfan	115297		120	0.2	I		Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		8	0.2	I		Or	CNS/PNS; LIV/GI	D	NA			
Heptachlor	76448		2	0.03	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or In
Heptachlor epoxide	1024573		0.4	0.2	I	In	Or	LIV/GI; CANCER	B2	3E-06	I		Or
alpha-Hexachlorocyclohexane	319846		2	NA				CANCER	B2	1E-05	I		Or
beta-Hexachlorocyclohexane	319857		7	NA				CANCER (?)	C	1E-05	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		9	0.2	I	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-05	H		Or
Hexachlorocyclohexane, technical grade	608731		6	NA				CANCER	B2	1E-05	I		Or

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TABLE A3.2 SUMMARY OF TIER 2 CHRONIC RESIDENTIAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Residential SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Methoxychlor	72435		11	0.2	O		Or	REPROD	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		16	0.2	I	In	Or	KIDN; LIV/GI	NA	NA			
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		29	0.2	I	In	Or	KIDN	NA	NA			
Metolachlor	51218452		435	0.2	I	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		2000	0.2	I	In	Or	LIV/GI	NA	NA			
Terbufos	13071799		0.6	0.2	H	In	Or	CNS/PNS	NA	NA			
Toxaphene	8001352		13	NA				CANCER	B2	1E-05	I		Or
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		290	0.2	I	In	Or	KIDN; REPRO	NA	NA			
Dioxins and Furans													
Hexachlorodibenzodioxin mixture	19408743		0.002	NA				CANCER	B2	1E-05	I		Or
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.0002	NA				IMMUNE; REPROD; CANCER	B2	1E-05	H		Or
Explosives													
1,3 - DNB	99650		2	0.2	I	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		50	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	see mixture below				
2,6 - DNT	606202		25	0.2	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	see mixture below				
2,4- AND 2,6 DNT MIXTURE			12	NA				CANCER	B2	1E-05	I		Or
HMX	2691410		1360	0.2	I	In	Or	LIV/GI	D	NA			
RDX	121824		35	0.2	I	In	De	PROSTATE; CANCER (?)	C	8E-06	I	In	De

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
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TABLE A3.2 SUMMARY OF TIER 2 CHRONIC RESIDENTIAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Residential SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,3,5 - TNB	99354		610	0.2	I	In	Or	CV/BLD; SPLEEN	NA	NA			
2,4,6 - TNT	118967		10	0.2	I	In	Or	LIVER; CANCER (?)	C	3E-07	I	In	Or

VOC? - - y indicates that contaminant is considered volative.

(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY - increased mortality, decreased growth rate, etc.
(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.

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3.1.2 Tier 2 Child Subchronic Soil Reference Values

Since the toxic effect of a contaminant depends in part on the dose and the rate at which the dose is administered a subchronic exposure scenario was evaluated for the residential exposure setting. The generic subchronic SRVs were *not* more restrictive than the generic chronic residential SRVs. Note, that this was not the case for the recreational setting. Subchronic SRVs may be useful for evaluating short-term hazards and as guidelines for not to exceed residual contaminant levels.

The acute child-based SRVs were lower than the subchronic-based SRVs for several contaminants. In these cases the acute SRV is utilized. A summary of the Tier 2 Child Subchronic SRVs are presented in Table A3.3.

The cumulative risk posed by multiple contaminants must also be evaluated for subchronic exposure. To evaluate the cumulative subchronic risk posed by site contamination it is recommended that the Child Subchronic Risk worksheet in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) be utilized.

The subchronic exposure scenario utilized as the basis of the subchronic SRV. The exceptions to this rule are bolded in the SRV table and are summarized below (see Section 1 for more discussion):

- Acutely toxic contaminants. The SRV was set at the acute value for barium, copper, cyanide, fluorine, and phenol.

- Soil saturation limits (Csast). The SRV was set at Csat for 2-chlorotoluene, ethylbenzene, n-propylbenzene, styrene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,4-trimethylbenzene, and xylenes.

- Maximum soil concentration. The SRV was set at of 100,000 mg/kg (i.e., 10%) for benzoic acid and anthracene.

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TABLE A.3.3 SUMMARY OF TIER 2 CHILD SUBCHRONIC SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		NA	NA					NA	NA			
Antimony	7440360		27	1	H		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		13	1	H	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	1E-06	MI		Or
Barium	7440393		1200	*1*	H		Or	CV/BLD;REPROD (Based on Acute Intake)	NA	NA			
Beryllium	7440417		112	1	H O	In	Or	LIV/GI; CANCER	B2	2E-09	I	Or De	In
Boron	7440428		6000	1	H		Or	REPRO	D	NA			
Cadmium	7440439		NA					KIDN; CANCER	B1	NA	MI		
Chromium III	16065831		47000	1	H	In	Or	Not Available	NA	NA			
Chromium VI	18540299		950	1	H		Or	Not Available; CANCER	A	7E-08	MI	Or De	In
Cobalt	7440484		NA					CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		100	*1*	O	In	Or	LIV/GI (Based on Acute Intake)	D	NA			
Copper Cyanide	544923		3000	1	H	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		62	*1*	A	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: Based on Acute Intake)	NA	NA			
Fluorine (soluble fluoride)	7782414		550	*1*	A	In	Or	BONE; LIV/GI (Based on Acute Intake)	NA	NA			
Iron	7439896		NA	NA				No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		400	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			
Manganese	7439965		NA					CNS/PNS	D	NA			

WORKING DRAFT

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Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	0.8	1	H		In	CNS/PNS; IMMUNE	D	NA			
Methyl Mercury	22967926		6	1	H	In	Or	CNS/PNS; REPROD	NA	NA			
Nickel	various		950	1	H	In	Or	WHOLE BODY; CANCER	A	3E-09	MI	Or De	In
Selenium	7782492		340	1	H	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		340	1	H	In	Or	SKIN	D	NA			
Thallium	various		54	1	H	In	Or	CV/BLD; LIV/GI;HAIR	D	NA			
Tin	various		28000	1	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium	7440326		NA					WHOLE BODY	NA	NA			
Vanadium	7440622 1314621		400	1	H	In	Or	Not Available	D	NA			
Zinc	7440666		19000	1	H	In	Or	CV/BLD	D	NA			
Volatile Organics									0				
Acetone	67641	y	3600	1	HE		In	KIDN; LIV/GI	D	NA			
Benzene	71432	y	8	1	E		In	CV/BLD; IMMUN;CANCER	A	1E-06	MI		In
Bromodichloromethane	75274	y	13	NA	H	In	?	KIDN; CANCER	B2	1E-06	E		In
Bromomethane (methyl bromide)	74839	y	26	1	E		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.08	NA	I			CANCER	B2	1E-06	MI	Or De	In
n-Butylbenzene	104518	y	NA	NA				CNS/PNS	NA	NA			
sec-Butylbenzene	135988	y	NA	NA				CNS/PNS	NA	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
tert-Butylbenzene	98066	y	NA	NA				CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	70	1	H		In	CNS/PNS; REPROD	NA	NA			
Carbon Tetrachloride	56235	y	3	NA				LIV/GI; CANCER	B2	1E-06	I		In
Chlorobenzene	108907	y	100	1	E	Or De	In	KIDN; LIV/GI	D	NA			
Chloroethane (ethyl chloride)	75003	y	NA	NA			In	REPROD;CANCER	NA	NA	E	In	Or
Chloroform (trichloromethane)	67663	y	3	NA	H	In	?	LIV/GI; CANCER	B2	1E-06	I		In
Chloromethane (methyl chloride)	74873	y	15	0.5	E	Or De	In	CNS/PNS; CANCER (?)	C	1E-06	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	300	1	MI		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane (ethylene dibromide)	106934	y	0.16	0.1	H	Or De	In	REPROD; CANCER	B2	1E-06	MI		Or
Dibromomethane (methylene bromide)	74953	y	5200	1	H	In	?	CV/BLD (NOTE: No inhalation toxicity value.)	NA	NA			
Dichlorodifluoromethane (Freon 12)	75718	y	180	1	H		In	LIV/GI	NA	NA			
1,1 - Dichloroethane	75343	y	39	0.04	H		In	KIDN; CANCER (?)	C	1E-06	C		In
1,2 - Dichloroethane	107062	y	4.5	NA				NA; CANCER	B2	1E-06	I		In
1,1 - Dichloroethylene	75354	y	0.7	NA	H	In	?	LIV/GI; CANCER (?)	C	1E-06	I		In
cis - 1,2 - Dichloroethylene	154592	y	80	1	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	116	1	E		In	CV/BLD;LIV/GI	D	NA			
1,2 - Dichloroethylene (mixed isomers)	540590	y	68	1	E		In	CV/BLD;LIV/GI	D	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Dichloromethane (methylene chloride)	75092	y	115	NA	H	In	?	LIV/GI; CANCER	B2	1E-06	MI		In
1,2 - Dichloropropane	78875	y	3	1	MI		In	RESP; CANCER	B2	7E-07	C		In
Ethyl benzene	100414	y	200	*1*			In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			
Hexane	110543	y	100	*1*	M		In	CNS/PNS; RESP (Note: Csat utilized)	NA	NA			
Methyl ethyl ketone (2-butanone)	78933	y	1580	1	H		In	REPROD	D	NA			
Methyl isobutyl ketone (MIBK)	108101	y	1560	1	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	99	1	I		In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	200	*1*			In	CNS/PNS (NOTE: Csat utilized)	NA	NA			
Styrene	100425	y	1450	*1*			In	CNS/PNS; CANCER (?) (NOTE: Csat utilized)	Under review				
1,1,1,2 - Tetrachloroethane	630206	y	37	NA	H	In	?	KIDN; LIV/GI; CANCER (?)	C	1E-06	I		In
1,1,2,2 - Tetrachloroethane	79345	y	5	NA		In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	1E-06	I		In
Tetrachloroethylene (PCE)	127184	y	90	NA	H	In		CNS/PNS; KIDN; LIV/GI; CANCER	B2/C	1E-06	E		In
Toluene	108883	y	274	1	E		In	CNS/PNS; KIDN; LIV/GI	D	NA			
1,2,4 - Trichlorobenzene	120821	y	NA	NA	H	In	?	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	NA	NA				CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	11	NA	H	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?)	C	1E-06	I		In
Trichloroethylene (TCE)	79016	y	34	NA				CANCER	B2/C	1E-06	E		In
Trichlorofluoromethane	75694	y	690	1	H		In	KIDN; RESP; WHOLE BODY	NA	NA			
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	5430	*1*	H		In	CNS/PNS; WHOLE BODY (NOTE: Csat utilitized)	NA	NA			

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			
1,3,5-Trimethylbenzene	108678	y	NA	NA				CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.3	NA				CANCER	A	1E-06	H		In
Xylenes (mixed)	1330207	y	248	*1*				CNS/PNS; RESP; WHOLE BODY (NOTE: Csat utilized)	D	NA			
Non/Semi Volatile Organics									0				
Benzoic acid	65850		100000	*1*				NA (NOTE: Soil Maximum Utilized)	D	NA			
Benzyl alcohol	100516		NA	NA				LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		3	NA				CANCER	B2	1E-06	I		In
Bis (chloromethyl) ether	542881		0.0025	NA				CANCER	A	1E-06	I		In
Bromoform (tribromomethane)	75252		435	NA	I	In	?	LIV/GI; CANCER	B2	1E-06	I		In
Butyl benzylphthalate	85687		11000	1	H	In	Or	LIV/GI; CANCER (? Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		NA	NA				KIDN	NA	NA			
1,4 - Dibromobenzene	106376		5200	1	H	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		13	NA	H	In	?	LIV/GI; CANCER (?)	C	1E-06	E		In
Dibutyl phthalate	84742		57700	1	H	In	Or	WHOLE BODY	D	NA			
1,2 - Dichlorobenzene	95501		1730	1	H	Or De	In	NA	D	NA			
1,3 - Dichlorobenzene	541731		NA	NA				LIV/GI; THYROID	D	NA			
1,4 - Dichlorobenzene	106467		30	0.03	M	Or De	In	LIV/GI; CANCER (?)	C	1E-06	C		In

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
3,3' - Dichlorobenzidine	91941		30	NA				CANCER	B2	1E-06	I		Or
2,4-Dichlorophenol	120832		130	1	H		Or	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate (bis-ethylhexyl phthalate)	117817		1200	NA				LIV/GI; CANCER	B2	1E-06	I		Or
2,4-Dimethylphenol	105679		6500	1	H		Or In	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		1110	1	H	In	Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		100000	1	H	In	Or	LIV/GI; REPROD	NA	NA			
Hexachlorobenzene	118741		6	NA				LIV/GI; CANCER	B2	1E-06	I		Or In
Hexachlorobutadiene	87683		51	NA				KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		8	1	H		In	LIV/GI	D	NA			
Methanol	67561		NA	NA			In	CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		NA	NA				CNS/PNS; WHOLE BODY; CANCER (?)	C	NA			
3 - Methylphenol (m-cresol)	108394		NA	NA				CNS/PNS; WHOLE BODY; CANCER (?)	C	NA			
4 - Methylphenol (p-cresol)	106445		20	1	H	In	Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		2350	NA				CANCER	B2	1E-06	I		Or
N-Nitrosodi-N-propylamine	621647		0.8	NA				CANCER	B2	1E-06	E		In
Pentachlorophenol	87865		88	0.07	H	In	Or	REPRO; CANCER	B2	1E-06	I		Or
Phenol	108952		1100	*1*	O	In De	Or	DEATH (Note: SRV based on Acute Intake)	D	NA			
2,3,4,6-Tetrachlorophenol	58902		12720	1	H	In	Or	LIV/GI	NA	NA			

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
2,4,5-Trichlorophenol	95954		40000	1	H	In	Or	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		720	NA				CANCER	B2	1E-06	I		Or In
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	17400	1	E		Or	LIV/GI	NA	NA			
Anthracene	120127		100000	*1*				NA (Note: Soil Maximum Utilized)	D	NA			
Benzo[a]pyrene (or BaP equivalents)	50328		2.3	NA				CANCER	B2	1E-06	MI		Or
Fluoranthene	206440		21200	1	H		Or	CV/BLD; KIDN; LIV/GI	D	NA			
Fluorene	86737		13500	1	E		In	CV/BLD	D	NA			
Naphthalene - see Volatile Organics									0				
Pyrene	129000		17800	1	H		Or	KIDN	D	NA			
Quinoline	91225		1.4	NA				CANCER (?)	C	1E-06	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		2.5	1	H	In	Or	IMMUNE; REPROD; CANCER	B2	4E-07	I		Or In
Pesticides and Herbicides													
Aldrin	309002		0.9	0.5	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or
Carbazole	86748		780					CANCER	B2	1E-06	H	In	Or
Chloramben	133904		NA	NA				LIV/GI	under review				
Chlordane	57749		30	1	E		Or	LIV/GI; CANCER	B2	7E-07	I		Or
4, 4' - DDD	72548		72	NA				CANCER	B2	1E-06	I		Or
4, 4' - DDE	72559		50	NA				CANCER	B2	1E-06	I		Or
4, 4' - DDT	50293		30	1	H	In	Or	LIV/GI; CANCER	B2	6E-07	I		Or
Diazinon	333415		55	1	H	In	Or	CNS/PNS	NA	NA			

WORKING DRAFT

NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A.3.3 SUMMARY OF TIER 2 CHILD SUBCHRONIC SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		600	1	H	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		4500	1	H	In	Or	CV/BLD; WHOLE BODY	NA	NA			
Dieldrin	60571		1	0.3	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or
Endosulfan	115297		260	1	H	In	Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		19	1	H	In	Or	CNS/PNS; LIV/GI	D	NA			
Heptachlor	76448		2	0.1	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or In
Heptachlor epoxide	1024573		0.8	1	H	In	Or	LIV/GI; CANCER	B2	4E-07	I		Or
alpha-Hexachlorocyclohexane	319846		2	NA				CANCER	B2	1E-06	I		Or
beta-Hexachlorocyclohexane	319857		9	NA				CANCER (?)	C	1E-06	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		10	0.05	H	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-06	H		Or
Hexachlorocyclohexane, technical grade	608731		7	NA				CANCER	B2	1E-06	I		Or
Methoxychlor	72435		16	1	O		Or	REPROD	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		31	1	H	In	Or	KIDN; LIV/GI	NA	NA			
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		610	1	I	In	Or	KIDN	NA	NA			
Metolachlor	51218452		925	1	H	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		NA	NA				LIV/GI	NA	NA			

WORKING DRAFT

NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A.3.3 SUMMARY OF TIER 2 CHILD SUBCHRONIC SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Terbufos	13071799		1	1	H	In	Or	CNS/PNS	NA	NA			
Toxaphene	8001352		16	0.3	A	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		5800	1	H	In	Or	KIDN; LIV/GI	NA	NA			
Dioxins and Furans													
Hexachlorodibenzodioxin mixture	19408743		0.003	NA				CANCER	B2	1E-06	I		Or
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.0002	NA				IMMUNE; REPROD; CANCER	B2	1E-06	H		Or
Explosives									0				
1,3 - DNB	99650		40	1	H	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		106	1	H	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	see mixture below				
2,6 - DNT	606202		500	1	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	see mixture below				
2,4- AND 2,6 DNT MIXTURE			14	NA				CANCER	B2	1E-06	I		Or
HMX	2691410		NA	NA				LIV/GI	D	NA			
RDX	121824		54	1	H	In	De	PROSTATE; CANCER (?)	C	1E-06	I	In	De
1,3,5 - TNB	99354		NA	NA				CV/BLD; SPLEEN	NA	NA			
2,4,6 - TNT	118967		20	1	H	In	Or	LIVER; CANCER (?)	C	5E-08	I	In	Or

VOC? - - y indicates that contaminant is considered volative.

(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY – increased mortality, decreased growth rate, etc.

WORKING DRAFT

NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A.3.3 SUMMARY OF TIER 2 CHILD SUBCHRONIC SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Child Subchronic SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**

(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.

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3.1.3 Tier 2 Child Acute Soil Reference Values

With acutely toxic contaminants, the risk estimate for a "one time" exposure may exceed the risks from long term exposures when the magnitude of exposure during the acute episode is very high. Acute (i.e., "one time") risk estimates are based on the highest concentration detected. Acute child-based SRVs are only available for a small number of contaminants. This is due in large part to a lack of quantitative toxicity information. A summary of the acute child-based SRVs are presented in Table A.3.4. The acute SRVs are also contained in the Child Acute Risk worksheet in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html).

TABLE A3.4 TIER 2 CHILD ACUTE INGESTION SOIL REFERENCE VALUES (1999 Version)

Chemical	CAS No.	Source	Acute Exposure Concentration (mg/kg)	Acute Effect(s)
Inorganics:				
Antimony	7440360	C	600	Nausea and vomiting.
Arsenic	7440382	A	110	Death. UF of 10 applied.
Barium	7440393	C	1200	Reported to be acute threshold for toxicity in adults. UF of 3-10 applied.
Cadmium	7440439	C	55	GI irritation and vomiting.
Copper	7440508	C	100	GI irritation and vomiting.
Cyanide, free	57125	A	62	Death. UF of 10 applied.
Fluorine (soluble fluoride)	7782414	A	550	Death. UF of 10 applied.
Lead	7439921		2000	Acute lead poisoning at blood lead levels of $\geq$ 60 ug/dL.
Non/Semi Volatile Organics				
Pentachlorophenol	87865	A	220	Cardiovascular effects.
Phenol	108952	C	1100	Death. UF of 10 applied.

NOTE: Based on incidental ingestion of a bolus of soil. Other exposure pathways are NOT addressed. If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source: A = ATSDR; C = Calabrese, et al., 1997; O = Other

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3.2 Tier 2 Recreational Soil Reference Values

3.2.1 Tier 2 Recreational Chronic-Based Soil Reference Values

A summary of the Tier 2 Chronic Recreational SRVs are presented in Table A3.5. The child subchronic and acute exposure scenarios are applicable to the recreational setting as well as the residential setting. As with the residential exposure scenario the chronic recreational exposure scenario typically resulted in the lowest value and was therefore utilized as the generic SRV. Exceptions to this rule are bolded in the SRV table and are summarized below (see Section 1 for more discussion):

- Acutely toxic contaminants. The SRV was set at the acute value for barium, copper, cyanide, fluorine, and phenol.

- Tier 2 Child Subchronic Exposure Scenario. The subchronic exposure scenario resulted in a lower SRV for the following contaminants: inorganic mercury, bis(2-chloroethyl)ether, bis(chloromethyl)ether, bromodichloromethane, bromoform, 1,3-butadiene, carbon disulfide, chloroform, chloromethane, dibromochloromethane, 1,4-dichlorobenzene, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethylene, dichloromethane (i.e., methylene chloride), 1,2-dichloropropane, hexane, methyl ethyl ketone (i.e., 2-butanone), 1,1,1,2-tetrachloroethane, tetrachloroethylene (i.e., PCE), 1,1,2-trichloroethane, trichloroethylene (i.e., TCE), and vinyl chloride. **NOTE: Chronic and subchronic cumulative risk must be evaluated separately. When the subchronic SRV is lower than the chronic SRV a notation " NOTE: Not Protective of Subchronic Exposure" is included in the generic Recreational Chronic SRV table. The SRV listed is based on chronic not subchronic exposure. To adequately assess subchronic risk a separate additional evaluation utilizing the Tier 2 Child Subchronic SRVs must be conducted. See Section 3.1.2 for discussion of the Tier 2 Child Subchronic SRVs.**

- Soil saturation limits (Csast). The SRV was set at Csat for 2-chlorotoluene, ethylbenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,4-trimethylbenzene, .

- Maximum soil concentration. The SRV was set at of 100,000 mg/kg (i.e., 10%) for benzoic acid and anthracene.

To evaluate the cumulative risk posed by site contamination it is recommended that the Recreational Chronic Risk worksheet in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) be utilized.

3.2.2 Tier 2 Recreational Child Subchronic Soil Reference Values

See Section 3.1.2 for discussion of the Child Subchronic Soil Reference Values. **NOTE: Subchronic risk must be evaluated, particularly when the subchronic SRV is lower than the chronic SRV (See Section 3.2.1).**

3.2.3 Tier 2 Child Acute Soil Reference Values

See Section 3.1.3 for discussion of the Child Acute SRVs.

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NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		31000	0.2	E		Or	CNS/PNS; REPROD	NA	NA			
Antimony	7440360		16	0.2	MI		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		12	0.2	I	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	8E-06	MI		Or
Barium	7440393		1200	*1*	O		Or	KIDN;REPROD (Based on Acute Intake)	NA	NA			
Beryllium	7440417		64	0.2	I		Or	LIV/GI; RESP; CANCER	B2	5E-08	I	Or De	In
Boron	7440428		3600	0.2	I		Or	REPRO	D	NA			
Cadmium	7440439		40	0.2	I		Or	KIDN; CANCER	B1	2E-08	MI	Or De	In
Chromium III	16065831		40000	0.2	I	In	Or	Not Available	NA	NA			
Chromium VI	18540299		80	0.2	I		Or	Not Available; CANCER	A	3E-07	MI	Or De	In
Cobalt	7440484		2300	0.2	E		Or	CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		100	*1*	O	In	Or	LIV/GI (Based on Acute Intake)	D	NA			
Copper Cyanide	544923		200	0.2	I	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		62	*1*	A	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: Based on Acute Intake)	NA	NA			
Fluorine (soluble fluoride)	7782414		550	*1*	I	In	Or	BONE; LIV/GI (Based on Acute Intake)	NA	NA			
Iron	7439896		8000	0.2	E	In	Or	No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		400	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			
Manganese	7439965		1800	0.2	MI		Or	CNS/PNS	D	NA			
Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	1.5	0.2	I		In	CNS/PNS; IMMUNE **(NOTE: Not Protective of Subchronic Exposure)**	D	NA			
Methyl Mercury	22967926		4	0.2	MI	In	Or	CNS/PNS; REPROD	NA	NA			

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Nickel	various		550	0.2	MI	In	Or	WHOLE BODY; CANCER	A	8E-08	MI	Or De	In
Selenium	7782492		200	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		200	0.2	I	In	Or	SKIN	D	NA			
Thallium	various		3	0.2	I	In	Or	CV/BLD; HAIR; REPROD	D	NA			
Tin	various		16000	0.2	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium	7440326		100000	0.2	E		Or	WHOLE BODY	NA	NA			
Vanadium	7440622 1314621		230	0.2	H	In	Or	Not Available	D	NA			
Zinc	7440666		11300	0.2	I	In	Or	CV/BLD	D	NA			
Volatile Organics									*0*				
Acetone	67641	y	700	0.2	E		In	KIDN; LIV/GI	D	NA			
Benzene	71432	y	3	0.2	E		In	CV/BLD; CANCER	A	2E-06	MI		In
Bromodichloromethane	75274	y	28	NA	E	In	?	KIDN; CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	E		In
Bromomethane (methyl bromide)	74839	y	2	0.2	I		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.2	NA	I			CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	MI	Or De	In
n-Butylbenzene	104518	y	70	0.2	E		In	CNS/PNS	NA	NA			
sec-Butylbenzene	135988	y	55	0.2	E		In	CNS/PNS	NA	NA			
tert-Butylbenzene	98066	y	55	0.2	E		In	CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	160	0.2	I		In	CNS/PNS; REPROD **(NOTE: Not Protective of Subchronic Exposure)**	NA	NA			
Carbon Tetrachloride	56235	y	0.7	0.2	E		In	LIV/GI; CANCER	B2	1E-06	I		In
Chlorobenzene	108907	y	23	0.2	H		In	KIDN; LIV/GI	D	NA			
Chloroethane (ethyl chloride)	75003	y	2250	0.2	E		In	REPROD;CANCER	NA	4E-06	E	In	Or

WORKING DRAFT

NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Chloroform (trichloromethane)	67663	y	7	0.01	C		In	LIV/GI; CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	I		In
Chloromethane (methyl chloride)	74873	y	36	0.1	E		In	CNS/PNS;WHOLE BODY; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (NOTE: Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	74	0.2	I		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane (ethylene dibromide)	106934	y	0.16	0.1	H	Or De	In	REPROD; CANCER	B2	1E-05	MI		Or
Dibromomethane (methylene bromide)	74953	y	316	0.2	H	In	?	CV/BLD	NA	NA			
Dichlorodifluoromethane (Freon 12)	75718	y	42	0.2	H		In	LIV/GI; WHOLE BODY	NA	NA			
1,1 - Dichloroethane	75343	y	97	0.08	H		In	KIDN; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	C		In
1,2 - Dichloroethane	107062	y	10	0.2	E	Or De	In	NA; CANCER (NOTE: Not Protective of Subchronic Exposure)	B2	1E-05	I		In
1,1 - Dichloroethylene	75354	y	1.6	NA	I	In	?	LIV/GI; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	I		In
cis - 1,2 - Dichloroethylene	154592	y	19	0.2	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	28	0.2	E		In	LIV/GI	D	NA			
1,2 - Dichloroethylene (mixed isomers)	540590	y	19	0.2	E		In	LIV/GI	D	NA			
Dichloromethane (methylene chloride)	75092	y	270	0.04	H		In	LIV/GI; CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	MI		In
1,2 - Dichloropropane	78875	y	11	0.14	I	Or De	In	RESP; CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	C		In

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Ethyl benzene	100414	y	200	0.14	I		In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			
Hexane	110543	y	100	*1*	M		In	CNS/PNS; REPRO; RESP (Note: Csat utilized)	NA	NA			
Methyl ethyl ketone (2-butanone)	78933	y	3200	0.2	I		In	REPROD **(NOTE: Not Protective of Subchronic Exposure)**	D	NA			
Methyl isobutyl ketone (MIBK)	108101	y	330	0.2	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	24	0.2	MI		In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	70	0.2	E		In	CNS/PNS	NA	NA			
Styrene	100425	y	500	0.2	M		In	CV/BLD; CNS/PNS; LIV/GI; CANCER (?)	Under review				
1,1,1,2 - Tetrachloroethane	630206	y	83	NA	I	In	?	KIDN; LIV/GI; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	I		In
1,1,2,2 - Tetrachloroethane	79345	y	4	0.2	C	In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	4E-06	I		In
Tetrachloroethylene (PCE)	127184	y	145	0.2	E		In	CNS/PNS; KIDN; LIV/GI; CANCER **(NOTE: Not be Protective of Subchronic Exposure)**	B2/C	9E-06	E		In
Toluene	108883	y	260	0.2	MI		In	CNS/PNS; KIDN; LIV/GI; RESP	D	NA			
1,2,4 - Trichlorobenzene	120821	y	290	0.2	I		Or	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	280	0.2	E		In	CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	24	NA	I	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	I		In
Trichloroethylene (TCE)	79016	y	82	NA				CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2/C	1E-05	E		In
Trichlorofluoromethane	75694	y	168	0.2	H		In	KIDN; RESP; WHOLE BODY	NA	NA			
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	5430	*1*	H		In	CNS/PNS; WHOLE BODY (NOTE: Csat utilitized)	NA	NA			
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			

WORKING DRAFT

NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,3,5-Trimethylbenzene	108678	y	9	0.2	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.7	NA	H			CANCER **(NOTE: Not Protective of Subchronic Exposure)**	A	1E-05	H		In
Xylenes (mixed)	1330207	y	248	0.2	H		In	CNS/PNS; RESP; WHOLE BODY	D	NA			
Non/Semi Volatile Organics									*0*				
Benzoic acid	65850		83000	0.2	E I		In Or	No Adverse Effects Observed at Doses Tested.	D	NA			
Benzyl alcohol	100516		9500	0.2	H	In	Or	LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		6	NA				CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	1E-05	I		In
Bis (chloromethyl) ether	542881		0.006	NA				CANCER **(NOTE: Not Protective of Subchronic Exposure)**	A	1E-05	MI		In
Bromoform (tribromomethane)	75252		630	0.2	I	In	?	LIV/GI; CANCER **(NOTE: Not Protective of Subchronic Exposure)**	B2	8E-06	I		In
Butyl benzylphthalate	85687		623	0.2	I		Or	LIV/GI; CANCER (? Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		130	0.2	E	In	Or	KIDN	NA	NA			
1,4 - Dibromobenzene	106376		306	0.2	I	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		30	NA	I	In	?	LIV/GI; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	E		In
Dibutyl phthalate	84742		3070	0.2	I		Or	WHOLE BODY	D	NA			
1,2 - Dichlorobenzene	95501		63	0.2	E		In	WHOLE BODY	D	NA			
1,3 - Dichlorobenzene	541731		32	0.2	E	In	?	LIV/GI; THYROID	D	NA			
1,4 - Dichlorobenzene	106467		72	0.01	I	Or De	In	KIDN; LIV/GI; CANCER (?) **(NOTE: Not Protective of Subchronic Exposure)**	C	1E-05	C		In
3,3' - Dichlorobenzidine	91941		30	NA				CANCER	B2	1E-05	I		Or

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
2,4-Dichlorophenol	120832		61	0.2	I		Or	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate (bis-ethylhexyl phthalate)	117817		690	0.2	I	In	Or	LIV/GI; CANCER	B2	6E-06	I		Or
2,4-Dimethylphenol	105679		530	0.2	I		Or	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		630	0.2	H		Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		63000	0.2	I	In	Or	LIV/GI; REPROD	NA	NA			
Hexachlorobenzene	118741		8	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		Or In
Hexachlorobutadiene	87683		6	0.2	H	In	?	KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		2	0.2	H		In	LIV/GI	D	NA			
Methanol	67561		12900	0.2	C		In	CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		95	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
3 - Methylphenol (m-cresol)	108394		95	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
4 - Methylphenol (p-cresol)	106445		11	0.2	H		Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		2585	NA				CANCER	B2	1E-05	I		Or
N-Nitrosodi-N-propylamine	621647		1.2	NA				CANCER	B2	1E-05	E		In
Pentachlorophenol	87865		67	0.02	I		Or	KIDN; LIV/GI; CANCER	B2	1E-05	I		Or
Phenol	108952		1100	*1*	O	In De	Or	DEATH (Note: SRV based on Acute Intake)	D	NA			
2,3,4,6-Tetrachlorophenol	58902		700	0.2	I	In	Or	LIV/GI	NA	NA			
2,4,5-Trichlorophenol	95954		2212	0.2	I		Or	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		705	NA				CANCER	B2	1E-05	I		Or In

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	1860	0.2	I		Or	LIV/GI	NA	NA			
Anthracene	120127		10000	0.2	I		Or	None Observed at Doses Evaluated.	D	NA			
Benzo[a]pyrene (or BaP equivalents)	50328		2	NA				CANCER	B2	1E-05	MI		Or
Fluoranthene	206440		1290	0.2	I		Or	CV/BLD; KIDN; LIV/GI	D	NA			
Fluorene	86737		1200	0.2	E		Or	CV/BLD	D	NA			
Naphthalene - see Volatile Organics									0				
Pyrene	129000		1060	0.2	I		Or	KIDN	D	NA			
Quinoline	91225		1.2	NA				CANCER (?)	C	1E-05	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		1.4	0.2	M	In	Or	IMMUNE; REPROD; CANCER	B2	3E-06	I		Or In
Pesticides and Herbicides													
Aldrin	309002		1	0.2	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Carbazole	86748		720					CANCER	B2	1E-05	H	In	Or
Chloramben	133904		540	0.2	I	In	Or	LIV/GI	under review				
Chlordane	57749		16	0.2	I		Or	LIV/GI; CANCER	B2	3E-06	I		Or
4, 4' - DDD	72548		74	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDE	72559		52	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDT	50293		18	0.2	I	In	Or	LIV/GI; CANCER	B2	3E-06	I		Or
Diazinon	333415		32	0.2	H	In	Or	CNS/PNS	NA	NA			
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		360	0.2	I	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		286	0.2	I	In	Or	CV/BLD; LIV/GI; WHOLE BODY	NA	NA			

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Dieldrin	60571		1.2	0.1	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Endosulfan	115297		140	0.2	I		Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		10	0.2	I		Or	CNS/PNS; LIV/GI	D	NA			
Heptachlor	76448		3	0.03	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or In
Heptachlor epoxide	1024573		0.5	0.2	I	In	Or	LIV/GI; CANCER	B2	2E-06	I		Or
alpha-Hexachlorocyclohexane	319846		3	NA				CANCER	B2	1E-05	I		Or
beta-Hexachlorocyclohexane	319857		11	NA				CANCER (?)	C	1E-05	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		12	0.2	I	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-05	H		Or
Hexachlorocyclohexane, technical grade	608731		9	NA				CANCER	B2	1E-05	I		Or
Methoxychlor	72435		13	0.2	O		Or	REPROD	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		18	0.2	I	In	Or	KIDN; LIV/GI	NA	NA			
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		36	0.2	I	In	Or	KIDN	NA	NA			
Metolachlor	51218452		536	0.2	I	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		2500	0.2	I	In	Or	LIV/GI	NA	NA			
Terbufos	13071799		0.6	0.2	H	In	Or	CNS/PNS	NA	NA			
Toxaphene	8001352		17	NA				CANCER	B2	1E-05	I		Or
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		360	0.2	I	In	Or	KIDN; REPRO	NA	NA			
Dioxins and Furans									*0*				
Hexachlorodibenzodioxin mixture	19408743		0.0025	NA				CANCER	B2	1E-05	I		Or

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.5 SUMMARY OF TIER 2 CHRONIC RECREATIONAL SOIL REFERENCE VALUE INFORMATION (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Recreational SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.0002	NA				IMMUNE; REPROD; CANCER	B2	1E-05	H		Or
Explosives									*0*				
1,3 - DNB	99650		2	0.2	I	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		60	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	see mixture below				
2,6 - DNT	606202		30	0.2	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	see mixture below				
2,4- AND 2,6 DNT MIXTURE			17	NA				CANCER	B2	1E-05	I		Or
HMX	2691410		1611	0.2	I	In	Or	LIV/GI	D	NA			
RDX	121824		27	0.2	I	In	De	PROSTATE; CANCER (?)	C	8E-06	I	In	De
1,3,5 – TNB	99354		660	0.2	I	In	Or	CV/BLD; SPLEEN	NA	NA			
2,4,6 - TNT	118967		11	0.2	I	In	Or	LIVER; CANCER (?)	C	3E-07	I	In	Or

VOC? - - y indicates that contaminant is considered volative.

(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY - increased mortality, decreased growth rate, etc.
(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.

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3.3 Tier 2 Industrial Soil Reference Values

3.3.1 Tier 2 Industrial Chronic-Based Soil Reference Values

A summary of the Tier 2 Industrial SRVs are presented in Table A3.6. As with the residential and recreational exposure scenario the chronic exposure scenario typically resulted in the lowest value and was therefore utilized as the generic SRV. Exceptions to this rule are bolded in the SRV table and are summarized below (see Section 1 for more discussion):

- Tier 2 Short-term Worker Exposure Scenario. The subchronic exposure scenario resulted in a lower SRV for the following contaminants: inorganic mercury, carbon disulfide, 1,2-dichloropropane, hexane, methoxychlor, methyl ethyl ketone (i.e., 2-butanone), and phenol. **NOTE: If high exposure activities potentially occur the risk from short-term exposure must be evaluated. When the short-term worker-based SRV is lower than the chronic industrial SRV a notation " NOTE: Not Protective of High Short-term Exposure" is included in the generic Industrial Chronic SRV table. The SRV listed is based on the lower level chronic exposure not the short-term high level exposure. To adequately assess short-term, high exposure risk a separate additional evaluation utilizing the Tier 2 Short-term Worker SRVs must be conducted. See Section 3.3.2 for discussion of the Tier 2 Short-term Worker SRVs.**

- Soil saturation limits (Csast). The SRV was set at Csat for 2-chlorotoluene, ethylbenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,4-trimethylbenzene, .

- Maximum soil concentration. The SRV was set at of 100,000 mg/kg (i.e., 10%) for benzoic acid, trivalent chromium, ethylene glycol, and titanium.

To evaluate the cumulative risk posed by site contamination it is recommended that the Industrial Chronic Risk worksheet in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) be utilized.

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.6 SUMMARY OF TIER 2 CHRONIC INDUSTRIAL SOIL REFERENCE VALUE INFORMATION. (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		100000	0.2	E		Or In	CNS/PNS; REPROD	NA	NA			
Antimony	7440360		100	0.2	MI		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		25	0.07	I	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	1E-05	MI		Or
Barium	7440393		12500	0.2	I		Or	KIDN;REPROD	NA	NA			
Beryllium	7440417		290	0.2	I		Or	LIV/GI; RESP; CANCER	B2	9E-07	I	Or De	In
Boron	7440428		23000	0.2	I		Or	REPRO	D	NA			
Cadmium	7440439		250	0.2	I		Or	KIDN; CANCER	B1	6E-07	MI	Or De	In
Chromium III	16065831		100000	*1*	I	In	Or	Not Available (Note: Soil Maximum Utilized)	NA	NA			
Chromium VI	18540299		425	0.2	I		Or	Not Available; CANCER	A	1E-05	MI	Or De	In
Cobalt	7440484		13000	0.2	E		Or	CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		9000	0.2	H	In	Or	LIV/GI	D	NA			
Copper Cyanide	544923		1200	0.2	I	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		5000	0.2	I	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: does not address HCN)	NA	NA			
Fluorine (soluble fluoride)	7782414		20000	0.2	I	In	Or	BONE	NA	NA			
Iron	7439896		46000	0.2	E	In	Or	No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		700	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			
Manganese	7439965		5600	0.2	MI		In Or	CNS/PNS	D	NA			

WORKING DRAFT

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Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	2	0.2	I		In	CNS/PNS; IMMUNE **(NOTE: Not Protective of High Short-term Exposure)**	D	NA			
Methyl Mercury	22967926		22	0.2	MI	In	Or	CNS/PNS; REPROD	NA	NA			
Nickel	various		3000	0.2	MI	In	Or	WHOLE BODY; CANCER	A	2E-06	MI	Or De	In
Selenium	7782492		1250	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		1250	0.2	I	In	Or	SKIN	D	NA			
Thallium	various		21	0.2	I	In	Or	CV/BLD; HAIR; REPROD	D	NA			
Tin	various		100000	0.2	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium	7440326		100000	*1*	E		Or	WHOLE BODY (Note: Soil Maximum Utilized)	NA	NA			
Vanadium	7440622 1314621		1340	0.2	H	In	Or	Not Available	D	NA			
Zinc	7440666		70000	0.2	I	In	Or	CV/BLD	D	NA			
Volatile Organics													
Acetone	67641	y	1000	0.2	E		In	KIDN; LIV/GI	D	NA			
Benzene	71432	y	4	0.2	E		In	CV/BLD; CANCER	A	4E-06	MI		In
Bromodichloromethane	75274	y	17	NA	I	In	?	KIDN; CANCER	B2	1E-05	E		In
Bromomethane (methyl bromide)	74839	y	2	0.2	I		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.1	NA	I			CANCER	B2	1E-05	MI	Or De	In
n-Butylbenzene	104518	y	92	0.2	E		In	CNS/PNS	NA	NA			
sec-Butylbenzene	135988	y	70	0.2	E		In	CNS/PNS	NA	NA			
tert-Butylbenzene	98066	y	90	0.2	E		In	CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	190	0.2	I		In	CNS/PNS; REPROD **(Note: Not Protective of High Short-term Exposure)**	NA	NA			

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Carbon Tetrachloride	56235	y	0.9	0.2	E		In	LIV/GI; CANCER	B2	2E-06	I		In
Chlorobenzene	108907	y	32	0.2	H		In	KIDN; LIV/GI	D	NA			
Chloroethane (ethyl chloride)	75003	y	3000	0.2	E		In	REPROD;CANCER	NA	3E-06	E	In	Or
Chloroform (trichloromethane)	67663	y	4	0.004	C		In	LIV/GI; CANCER	B2	1E-05	I		In
Chloromethane (methyl chloride)	74873	y	21	0.05	E		In	CNS/PNS;WHOLE BODY; CANCER (?)	C	1E-05	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	87	0.2	I		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane (ethylene dibromide)	106934	y	0.25	0.1	H	Or De	In	REPROD; CANCER	B2	1E-05	MI		Or
Dibromomethane (methylene bromide)	74953	y	1860	0.2	H	In	?	CV/BLD	NA	NA			
Dichlorodifluoromethane (Freon 12)	75718	y	50	0.2	H		In	LIV/GI; WHOLE BODY	NA	NA			
1,1 - Dichloroethane	75343	y	55	0.04	H		In	KIDN; CANCER (?)	C	1E-05	C		In
1,2 - Dichloroethane	107062	y	6	0.1	E	Or De	In	NA; CANCER	B2	1E-05	I		In
1,1 - Dichloroethylene	75354	y	1	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	I		In
cis - 1,2 - Dichloroethylene	154592	y	22	0.2	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	33	0.2	E		In	LIV/GI	D	NA			
1,2 - Dichloroethylene (mixed isomers)	540590	y	22	0.2	E		In	LIV/GI	D	NA			
Dichloromethane (methylene chloride)	75092	y	158	0.02	H		In	LIV/GI; CANCER	B2	1E-05	MI		In
1,2 - Dichloropropane	78875	y	6	0.07	I	Or De	In	RESP; CANCER **(NOTE: Not Protective of High Short-term Exposure)**	B2	1E-05	C		In
Ethyl benzene	100414	y	200	*1*	I		In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			
Hexane	110543	y	100	*1*	M		In	CNS/PNS; REPRO; RESP (Note: Csat utilized)	NA	NA			

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Methyl ethyl ketone (2-butanone)	78933	y	4300	0.2	I		In	REPROD **(NOTE: Not Protective of High Short-term Exposure)**	D	NA			
Methyl isobutyl ketone (MIBK)	108101	y	420	0.2	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	28	0.2	MI		In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	93	0.2	E		In	CNS/PNS	NA	NA			
Styrene	100425	y	600	0.2	M		In	CV/BLD; CNS/PNS; LIV/GI; CANCER (?)	?	Under Review			
1,1,1,2 - Tetrachloroethane	630206	y	51	NA	I	In	?	KIDN; LIV/GI; CANCER (?)	C	1E-05	I		In
1,1,2,2 - Tetrachloroethane	79345	y	6.5	NA	C	In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	1E-05	I		In
Tetrachloroethylene (PCE)	127184	y	131	0.1	E		In	CNS/PNS; KIDN; LIV/GI; CANCER	B2/C	1E-05	E		In
Toluene	108883	y	305	0.2	I		In	CNS/PNS; KIDN; LIV/GI; RESP	D	NA			
1,2,4 - Trichlorobenzene	120821	y	985	0.2	H		In	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	472	0.2	E		In	CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	14	NA	I	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?)	C	1E-05	I		In
Trichloroethylene (TCE)	79016	y	46	NA				CANCER	B2/C	1E-05	E		In
Trichlorofluoromethane	75694	y	195	0.2	H		In	KIDN; RESP; WHOLE BODY	NA	NA			
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	5430	*1*	H		In	CNS/PNS; WHOLE BODY (Note: Csat Utilized)	NA	NA			
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			
1,3,5-Trimethylbenzene	108678	y	10	0.2	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.4	NA	H			CANCER	A	1E-05	H		In
Xylenes (mixed)	1330207	y	248	0.2	H		In	CNS/PNS; RESP; WHOLE BODY	D	NA			
Non/Semi Volatile Organics													

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Benzoic acid	65850		100000	*1*	E I		In Or	No Adverse Effects Observed at Doses Tested. (Note: Soil Maximum Utilized)	D	NA			
Benzyl alcohol	100516		56000	0.2	H	In	Or	LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		5	NA				CANCER	B2	1E-05	I		In
Bis (chloromethyl) ether	542881		0.0035	NA				CANCER	A	1E-05	MI		In
Bromoform (tribromomethane)	75252		650	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		In
Butyl benzylphthalate	85687		3700	0.2	I		Or	LIV/GI; CANCER (? Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		810	0.2	E	In	?	KIDN	NA	NA			
1,4 - Dibromobenzene	106376		1760	0.2	I	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		20	NA	I	In	?	LIV/GI; CANCER (?)	C	1E-05	E		In
Dibutyl phthalate	84742		16300	0.2	I		Or	WHOLE BODY	D	NA			
1,2 - Dichlorobenzene	95501		75	0.2	E		In	WHOLE BODY	D	NA			
1,3 - Dichlorobenzene	541731		200	0.2	E	In	?	LIV/GI; THYROID	D	NA			
1,4 - Dichlorobenzene	106467		50	0.004	I	Or De	In	KIDN; LIV/GI; CANCER (?)	C	1E-05	C		In
3,3' - Dichlorobenzidine	91941		50	NA				CANCER	B2	1E-05	I		Or
2,4-Dichlorophenol	120832		230	0.2	I		Or In	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate (bis-ethylhexyl phthalate)	117817		2100	0.1	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
2,4-Dimethylphenol	105679		1925	0.2	I		Or In	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		3700	0.2	H		Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		100000	*1*	I	In	Or	LIV/GI; REPROD (Note: Soil Maximum Utilized)	NA	NA			
Hexachlorobenzene	118741		9	NA	I	In	?	LIV/GI; CANCER	B2	1E-05	I		Or In

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Hexachlorobutadiene	87683		37	0.2	H	In	?	KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		2	0.2	H		In	LIV/GI	D	NA			
Methanol	67561		43500	0.2	C		In	CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		352	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
3 - Methylphenol (m-cresol)	108394		352	0.2	I		Or	CNS/PNS; WHOLE BODY; CANCER (? Class C extra UF of 10)	C	NA			
4 - Methylphenol (p-cresol)	106445		59	0.2	H		Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		3720	NA				CANCER	B2	1E-05	I		Or
N-Nitrosodi-N-propylamine	621647		1.2	NA				CANCER	B2	1E-05	E		In
Pentachlorophenol	87865		135	0.01	I	In	Or	KIDN; LIV/GI; CANCER	B2	1E-05	I		Or
Phenol	108952		26800	0.2	O	In De	Or	REPRO **(Note: Not Protective of High Short-term Exposure)**	D	NA			
2,3,4,6-Tetrachlorophenol	58902		3700	0.2	I	In	Or De	LIV/GI	NA	NA			
2,4,5-Trichlorophenol	95954		10600	0.2	I		Or De	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		1060	NA				CANCER	B2	1E-05	I		Or In
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	5260	0.2	E		In	LIV/GI	NA	NA			
Anthracene	120127		45400	0.2	I		Or	None Observed at Doses Evaluated.	D	NA			
Benzo[a]pyrene (or BaP equivalents)	50328		4	NA				CANCER	B2	1E-05	MI		Or
Fluoranthene	206440		6800	0.2	I		Or	CV/BLD; KIDN; LIV/GI	D	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Fluorene	86737		4120	0.2	E		Or In	CV/BLD	D	NA			
Naphthalene - see Volatile Organics													
Pyrene	129000		5800	0.2	I		Or	KIDN	D	NA			
Quinoline	91225		2.5	NA				CANCER (?)	C	1E-05	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		8	0.2	M	In	Or	IMMUNE; REPROD; CANCER	B2	9E-06	I		Or In
Pesticides and Herbicides													
Aldrin	309002		2	0.06	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Carbazole	86748		1310					CANCER	B2	1E-05	H	In	Or
Chloramben	133904		3200	0.2	I	In	Or	LIV/GI	Under Review				
Chlordane	57749		74	0.2	I		Or	LIV/GI; CANCER	B2	1E-05	I		Or
4, 4' - DDD	72548		125	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDE	72559		80	NA				CANCER	B2	1E-05	I		Or
4, 4' - DDT	50293		88	0.2	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Diazinon	333415		200	0.2	H	In	Or	CNS/PNS	NA	NA			
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		2200	0.2	I	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		1750	0.2	I	In	Or	CV/BLD; LIV/GI; WHOLE BODY	NA	NA			
Dieldrin	60571		2	0.04	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
Endosulfan	115297		700	0.2	I		Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		56	0.2	I		Or	CNS/PNS; LIV/GI	D	NA			

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Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Heptachlor	76448		3.5	0.01	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or In
Heptachlor epoxide	1024573		3	0.2	I	In	Or	LIV/GI; CANCER	B2	1E-05	I		Or
alpha-Hexachlorocyclohexane	319846		3.5	NA				CANCER	B2	1E-05	I		Or
beta-Hexachlorocyclohexane	319857		15	NA				CANCER (?)	C	1E-05	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		15	0.05	I	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-05	H		Or
Hexachlorocyclohexane, technical grade	608731		11	NA				CANCER	B2	1E-05	I		Or
Methoxychlor	72435		50	0.2	O		Or In	REPROD **(Note: Not Protective of High Short-term Exposure)**	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		110	0.2	I	In	Or	KIDN; LIV/GI	NA	NA			
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		220	0.2	I	In	Or	KIDN	NA	NA			
Metolachlor	51218452		3300	0.2	I	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		15000	0.2	I	In	Or	LIV/GI	NA	NA			
Terbufos	13071799		3.5	0.2	H	In	Or	CNS/PNS	NA	NA			
Toxaphene	8001352		28	NA				CANCER	B2	1E-05	I		Or
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		2150	0.2	I	In	Or	KIDN; REPRO	NA	NA			
Dioxins and Furans													
Hexachlorodibenzodioxin mixture	19408743		0.005	NA				CANCER	B2	1E-05	I		Or
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.00035	NA				IMMUNE; REPROD; CANCER	B2	1E-05	H		Or

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Chronic Industrial SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Explosives													
1,3 - DNB	99650		13	0.2	I	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		355	0.2	I	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	See mixture below				
2,6 - DNT	606202		175	0.2	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	See mixture below				
2,4- AND 2,6 DNT MIXTURE	0		23	NA				CANCER	B2	1E-05	I		Or
HMX	2691410		9560	0.2	I	In	Or	LIV/GI	D	NA			
RDX	121824		75	0.08	I	In	De	PROSTATE; CANCER (?)	C	1E-05	I	In	De
1,3,5 - TNB	99354		3760	0.2	I	In	Or De	CV/BLD; SPLEEN	NA	NA			
2,4,6 - TNT	118967		63	0.2	I	In	Or De	LIVER; CANCER (?)	C	3E-07	I	In	Or De

VOC? - - y indicates that contaminant is considered volative.

(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY - increased mortality, decreased growth rate, etc.
(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.
NOTE: Not Protective of High Short-term Exposure - SRV based on short-term worker scenario (e.g., construction worker, utility worker, landscaper, etc.) is significantly lower than the industrial worker SRV presented here.

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3.3.2 Tier 2 Short-Term Worker Soil Reference Values

Since the toxic effect of a contaminant depends in part on the dose and the rate at which the dose is administered a short-term, high exposure scenario was evaluated for the industrial setting. The generic short-term, high exposure SRVs were more restrictive than the generic chronic industrial SRVs for several contaminants. A summary of the Tier 2 Short-term Worker SRVs are presented in Table A3.7.

The cumulative risk posed by multiple contaminants must also be evaluated for short-term exposure. To evaluate the cumulative short-term risk posed by site contamination it is recommended that the Short-Term Worker_Risk worksheet contained in the Tier 2 Excel spreadsheet available on the MPCA website (http://www.pca.state.mn.us/cleanup/riskbasedoc.html) be utilized.

The short-term worker exposure scenario was utilized as the basis of the short-term worker SRVs with the following exceptions (Note these exceptions are bolded in the SRV table):

- Soil saturation limits (Csast). The SRV was set at Csat for 2-chlorotoluene, dibromomethane (i.e., methylene bromide), ethylbenzene, naphthalene, n-propylbenzene, styrene, 1,1,2-trichloro-1,2,2-trifluoroethane, 1,2,4-trimethylbenzene, and xylenes.

- Maximum soil concentration. The SRV was set at of 100,000 mg/kg (i.e., 10%) for acetone, anthracene, benzoic acid, trivalent chromium, dibutyl phthalate, ethylene glycol, and titanium

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.7 SUMMARY OF TIER 2 SHORT-TERM WORKER SOIL REFERENCE VALUE INFORMATION. (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Inorganics:													
Aluminum	7429905		NA	NA				CNS/PNS; REPROD	NA	NA			
Antimony	7440360		100	1	H		Or	CV/BLD; WHOLE BODY	NA	NA			
Arsenic	7440382		55	1	H	In	Or	CV/BLD; CNS/PNS; SKIN; CANCER	A	1E-06	MI		Or
Barium	7440393		12500	1	H		Or	CV/BLD;REPROD	NA	NA			
Beryllium	7440417		800	1	H	In	Or	NA; CANCER	B2	5E-07	I	Or De	In
Boron	7440428		16000	1	H		Or	REPRO	D	NA			
Cadmium	7440439		NA	NA				KIDN; CANCER	B1	6E-07	MI	Or De	In
Chromium III	16065831		100000	*1*	H	In	Or	Not Available (NOTE: Soil Maximum Utilized)	NA	NA			
Chromium VI	18540299		340	1	H		Or	Not Available; CANCER	A	1E-06	MI	Or De	In
Cobalt	7440484		NA	NA				CV/BLD; IMMUN; RESP	D	NA			
Copper	7440508		9000	1	H	In	Or	LIV/GI	D	NA			
Copper Cyanide	544923		9200	1	H	In	Or	KIDN;LIV/GI;WHOLE BODY	NA	NA			
Cyanide, free	57125		3700	1	H	In	Or	CNS/PNS;THYROID; WHOLE BODY (Note: does not address HCN)	NA	NA			
Fluorine (soluble fluoride)	7782414		16200	1	H	In	Or	BONE	NA	NA			
Iron	7439896		NA	NA				No Adverse Effects Observed at Dose Levels Evaluated.	NA	NA			
Lead	7439921		700	*1*	E		Or	CV/BLD; CNS/PNS; REPRO; CANCER	B2	NA			
Manganese	7439965		NA		H			CNS/PNS	D	NA			

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Mercury (inorganic: elemental and mercuric chloride)	7439976 7487947	y	0.7	1	H		In	CNS/PNS; IMMUNE	D	NA			
Methyl Mercury	22967926		22	1	H	In	Or	CNS/PNS; REPROD	NA	NA			
Nickel	various		3000	1	H	In	Or	WHOLE BODY; CANCER	A	4E-07	MI	Or De	In
Selenium	7782492		950	1	H	In	Or	CV/BLD; CNS/PNS; LIV/GI; SKIN	D	NA			
Silver	7440224		950	1	H	In	Or	SKIN	D	NA			
Thallium	various		152	1	H	In	Or	CV/BLD; LIV/GI;HAIR	D	NA			
Tin	various		82000	1	H	In	Or	KIDN; LIV/GI	D	NA			
Titanium	7440326		100000	*1*				WHOLE BODY (NOTE: Soil Maximum Utilized)	NA	NA			
Vanadium	7440622 1314621		1340	1	H	In	Or	Not Available	D	NA			
Zinc	7440666		54000	1	H	In	Or	CV/BLD	D	NA			
Volatile Organics													
Acetone	67641	y	100000	1				KIDN; LIV/GI (NOTE: Soil Maximum Utilized)	D	NA			
Benzene	71432	y	10	1	E		In	CV/BLD; IMMUN;CANCER	A	1E-06	MI		In
Bromodichloromethane	75274	y	17	NA	H	In	?	KIDN; CANCER	B2	1E-06	E		In
Bromomethane (methyl bromide)	74839	y	22	1	E		In	LIV/GI; RESP	D	NA			
1,3 - Butadiene	106990	y	0.1	NA	I			CANCER	B2	1E-06	MI	Or De	In
n-Butylbenzene	104518	y	NA	NA				CNS/PNS	NA	NA			
sec-Butylbenzene	135988	y	NA	NA				CNS/PNS	NA	NA			
tert-Butylbenzene	98066	y	NA	NA				CNS/PNS	NA	NA			
Carbon Disulfide	75150	y	55	1	H		In	CNS/PNS; REPROD	NA	NA			

WORKING DRAFT

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Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
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TABLE A3.7 SUMMARY OF TIER 2 SHORT-TERM WORKER SOIL REFERENCE VALUE INFORMATION. (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Carbon Tetrachloride	56235	y	3.5	NA				CANCER	B2	1E-06	I		In
Chlorobenzene	108907	y	76	1	E	Or De	In	KIDN; LIV/GI	D	NA			
Chloroethane (ethyl chloride)	75003	y	NA					REPROD;CANCER	NA	NA	I	In	Or
Chloroform (trichloromethane)	67663	y	4	NA	H	In		LIV/GI; CANCER	B2	1E-06	I		In
Chloromethane (methyl chloride)	74873	y	21	1	E	Or De	In	CNS/PNS;CANCER (?)	C	1E-06	H		In
2-Chlorotoluene	95498	y	436	1	I	In	?	WHOLE BODY (Csat Utilized)	NA	NA			
Cumene (isopropylbenzene)	98828	y	240	1	MI		In	ADRENAL; KIDN	NA	NA			
1,2 - Dibromoethane (ethylene dibromide)	106934	y	0.5	0.4	H	Or De	In	REPROD; CANCER	B2	1E-06	MI		Or
Dibromomethane (methylene bromide)	74953	y	11182	*1*	H	In	?	CV/BLD (NOTE: No inhalation toxicity value. Csat utilized)	NA	NA			
Dichlorodifluoromethane (Freon 12)	75718	y	135	1	H		In	LIV/GI	NA	NA			
1,1 - Dichloroethane	75343	y	55	0.06	H		In	KIDN; CANCER (?)	C	1E-06	C		In
1,2 - Dichloroethane	107062	y	6	NA				NA; CANCER	B2	1E-06	I		In
1,1 - Dichloroethylene	75354	y	1	NA	H	In	?	LIV/GI; CANCER (?)	C	1E-06	I		In
cis - 1,2 - Dichloroethylene	154592	y	62	1	E		In	CV/BLD	D	NA			
trans - 1,2 - Dichloroethylene	156605	y	91	1	E		In	CV/BLD; LIV/GI	D	NA			
1,2 - Dichloroethylene (mixed isomers)	540590	y	62	1	E		In	CV/BLD; LIV/GI	D	NA			
Dichloromethane (methylene chloride)	75092	y	158	NA	H	In		LIV/GI; CANCER	B2	1E-06	MI		In
1,2 - Dichloropropane	78875	y	3	1	H		In	RESP; CANCER	B2	6E-07	C		In
Ethyl benzene	100414	y	200	*1*			In	KIDN; LIV/GI; REPRO (Note: Csat utilized)	D	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Hexane	110543	y	100	*1*	M		In	CNS/PNS; RESP (Note: Csat utilized)	NA	NA			
Methyl ethyl ketone (2-butanone)	78933	y	1240	1	H		In	REPROD	D	NA			
Methyl isobutyl ketone (MIBK)	108101	y	1180	1	H		In	KID; LIV/GI; WHOLE BODY	NA	NA			
Naphthalene	91203	y	78	*1*			In	CV/BLD; RESP; WHOLE BODY	D	NA			
n-Propylbenzene	103651	y	200	*1*			In	CNS/PNS (NOTE: Csat utilized)	NA	NA			
Styrene	100425	y	1450	*1*			In	CNS/PNS; CANCER (?) (NOTE: Csat utilized)	Under Review				
1,1,1,2 - Tetrachloroethane	630206	y	45	NA	H	In	?	KIDN; LIV/GI; CANCER (?)	C	1E-06	I		In
1,1,2,2 - Tetrachloroethane	79345	y	6.5	NA		In	?	LIV/GI; WHOLE BODY; CANCER (?)	C	1E-06	I		In
Tetrachloroethylene (PCE)	127184	y	131	NA	H	In		CNS/PNS; KIDN; LIV/GI; CANCER	B2/C	1E-06	E		In
Toluene	108883	y	215	1	E		In	CNS/PNS; KIDN; LIV/GI	D	NA			
1,2,4 - Trichlorobenzene	120821	y	NA	NA	H	In	?	ADREN; LIV/GI	D	NA			
1,1,1 - Trichloroethane	71556	y	NA	NA				CNS/PNS; LIV/GI	D	NA			
1,1,2 - Trichloroethane	79005	y	14	NA	H	In	?	CV/BLD; IMMUNE; LIV/GI; CANCER (?)	C	1E-06	I		In
Trichloroethylene (TCE)	79016	y	46	NA				CANCER	B2/C	1E-06	E		In
Trichlorofluoromethane	75694	y	545	1	H		In	KIDN; RESP; WHOLE BODY	NA	NA			
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113)	76131	y	5430	*1*	H		In	CNS/PNS; WHOLE BODY (Note: Csat Utilized)	NA	NA			
1,2,4-Trimethylbenzene	95636	y	5	*1*	E		In	CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY (Note: Csat utilized)	NA	NA			
1,3,5-Trimethylbenzene	108678	y	NA	NA				CV/BLD; CNS/PNS; KIDN; LIV/GI; RESP; WHOLE BODY	NA	NA			
Vinyl chloride	75014	y	0.33	NA				CANCER	A	1E-06	H		In
Xylenes (mixed)	1330207	y	248	1	H			CNS/PNS; RESP; WHOLE BODY (NOTE: Csat utilized)	D	NA			

WORKING DRAFT

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Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Non/Semi Volatile Organics													
Benzoic acid	65850		100000	*1*				NA (Note: Soil Maximum Utilized)	D	NA			
Benzyl alcohol	100516		NA	NA				LIV/GI	NA	NA			
Bis (2 - chloroethyl)ether	111444		4	NA				CANCER	B2	1E-06	I		In
Bis (chloromethyl) ether	542881		0.0035	NA				CANCER	A	1E-06	I		In
Bromoform (tribromomethane)	75252		650	NA	H	In	?	LIV/GI; CANCER	B2	1E-06	I		In
Butyl benzylphthalate	85687		31450	1	H	In	Or	LIV/GI; CANCER (?) (Class C - extra UF of 10)	C	NA			
Dibenzofuran	132649		NA	NA				KIDN	NA	NA			
1,4 - Dibromobenzene	106376		15000	1	H	In	?	LIV/GI	NA	NA			
Dibromochloromethane	124481		20	NA	H	In	?	LIV/GI; CANCER (?)	C	1E-06	E		In
Dibutyl phthalate	84742		100000	*1*	H	In	Or	WHOLE BODY (Note: Soil Maximum Utilized)	D	NA			
1,2 - Dichlorobenzene	95501		1390	1	H	Or De	In	NA	D	NA			
1,3 - Dichlorobenzene	541731		NA	NA				LIV/GI; THYROID	D	NA			
1,4 - Dichlorobenzene	106467		38	0.050	M	Or De	In	LIV/GI; CANCER (?)	C	1E-06	C		In
3,3' - Dichlorobenzidine	91941		93	NA				CANCER	B2	1E-06	I		Or
2,4-Dichlorophenol	120832		365	1	H		Or	IMMUNE	NA	NA			
Di(2 - ethylhexyl)phthalate (bis-ethylhexyl phthalate)	117817		5000	NA				LIV/GI; CANCER	B2	1E-06	I		Or
2,4-Dimethylphenol	105679		8200	1	H		In	CV/BLD; CNS/PNS	NA	NA			
Di - n - octyl phthalate	117840		3700	1	H	In	Or	KIDN; LIV/GI	NA	NA			
Ethylene glycol	107211		100000	*1*	H	In	Or	LIV/GI; REPROD (Note: Soil Maximum Utilized)	NA	NA			

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Hexachlorobenzene	118741		10	NA				LIV/GI; CANCER	B2	1E-06	I		Or In
Hexachlorobutadiene	87683		73	NA				KIDN; CANCER (?)	C	1E-06	I		In
Hexachlorocyclopentadiene	77474		6	1	H		In	LIV/GI	D	NA			
Methanol	67561		NA	NA				CNS/PNS; LIV/GI; REPRO	NA	NA			
2 - Methylphenol (o-cresol)	95487		NA	NA				CNS/PNS; WHOLE BODY; CANCER (?)	C	NA			
3 - Methylphenol (m-cresol)	108394		NA	NA				CNS/PNS; WHOLE BODY; CANCER (?)	C	NA			
4 - Methylphenol (p-cresol)	106445		59	1	H	In	Or	CNS/PNS; RESP; CANCER (? Class C extra UF of 10)	C	NA			
N-Nitrosodiphenylamine	86306		5900	NA				CANCER	B2	1E-06	I		Or
N-Nitrosodi-N-propylamine	621647		1.3	NA				CANCER	B2	1E-06	E		In
Pentachlorophenol	87865		290	0.08	H	In	Or	REPRO; CANCER	B2	1E-06	I		Or
Phenol	108952		15070	1	E		In	REPRO	D	NA			
2,3,4,6-Tetrachlorophenol	58902		36600	1	H	In	Or	LIV/GI	NA	NA			
2,4,5-Trichlorophenol	95954		100000	1	H	In	Or	KIDN; LI/GI	NA	NA			
2,4,6-Trichlorophenol	88062		1495	NA				CANCER	B2	1E-06	I		Or In
Polyaromatic Hydrocarbons													
Acenaphthene	83329	y	19000	1	E		In	LIV/GI	NA	NA			
Anthracene	120127		100000	*1*				NA (Note: Soil Maximum Utilized)	D	NA			
Benzo[a]pyrene (or BaP equivalents)	50328		10	NA				CANCER	B2	1E-06	MI		Or
Fluoranthene	206440		48600	1	H		Or	CV/BLD; KIDN; LIV/GI	D	NA			
Fluorene	86737		17240	1	E		In	CV/BLD	D	NA			
Naphthalene - see Volatile Organics													

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Pyrene	129000		43000	1	H		Or	KIDN	D	NA			
Quinoline	91225		6	NA				CANCER (?)	C	1E-06	H	In	Or
Polychlorinated Biphenyls													
PCBs (Polychlorinated Biphenyls)	1336363		8	1	H	In	Or	IMMUNE; REPROD; CANCER	B2	5E-07	I		Or In
Pesticides and Herbicides													
Aldrin	309002		2.5	0.5	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or In
Carbazole	86748		3300					CANCER	B2	1E-06	H	In	Or
Chloramben	133904		NA	NA				LIV/GI	Under Review				
Chlordane	57749		78	1	E		Or	LIV/GI; CANCER	B2	5E-07	I		Or
4, 4' - DDD	72548		260	NA				CANCER	B2	1E-06	I		Or
4, 4' - DDE	72559		175	NA				CANCER	B2	1E-06	I		Or
4, 4' - DDT	50293		88	1	H	In	Or	LIV/GI; CANCER	B2	4E-07	I		Or
Diazinon	333415		160	1	H	In	Or	CNS/PNS	NA	NA			
2,4-Dichlorophenoxyacetic acid (2,4-D)	94757		1740	1	H	In	Or	CV/BLD; KIDN; LIV/GI	NA	NA			
4-(2,4-Dichlorophenoxy) butyric acid (2,4-DB)	94826		14000	1	H	In	Or	CV/BLD; WHOLE BODY	NA	NA			
Dieldrin	60571		3.5	0.4	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or
Endosulfan	115297		765	1	H	In	Or	CV/BLD; CNS/PNS; KIDN	NA	NA			
Endrin	72208		56	1	H	In	Or	CNS/PNS; LIV/GI	D	NA			
Heptachlor	76448		4	0.05	H	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or In

WORKING DRAFT

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					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
Heptachlor epoxide	1024573		2.3	1	H	In	Or	LIV/GI; CANCER	B2	3E-07	I		Or
alpha-Hexachlorocyclohexane	319846		5	NA				CANCER	B2	1E-06	I		Or
beta-Hexachlorocyclohexane	319857		27	NA				CANCER (?)	C	1E-06	I		Or
gamma-Hexachlorocyclohexane (gamma-BHC, Lindane)	58899		22	NA	H	In	Or	KIDN; LIV/GI; CANCER	B2/C	1E-06	H		Or
Hexachlorocyclohexane, technical grade	608731		16	NA				CANCER	B2	1E-06	I		Or
Methoxychlor	72435		25	1	O		In	REPROD	D	NA			
2-Methyl-4-chloropphenoxyacetic acid (MCPA)	94746		87	1	H	In	Or	KIDN; LIV/GI	NA	NA			
2-(2-Methyl-4-chlorophenoxy) propionic acid (MCPP)	93652		1730	1	H	In	Or	KIDN	NA	NA			
Metolachlor	51218452		2610	1	H	In	Or	WHOLE BODY; CANCER (?) (Class C - extra UF of 10 used)	C	NA			
Picloram	1918021		NA	NA				LIV/GI	NA	NA			
Terbufos	13071799		3.5	1	H	In	Or	CNS/PNS	NA	NA			
Toxaphene	8001352		60	0.3	A	In	Or	LIV/GI; CANCER	B2	1E-06	I		Or
2,4,5-Trichlorophenoxyacetic acid (2,4,5-T)	93765		17300	1	H	In	Or	KIDN; LIV/GI	NA	NA			
Dioxins and Furans													
Hexachlorodibenzodioxin mixture	19408743		0.01	NA				CANCER	B2	1E-06	I		Or
2,3,7,8-TCDD (or 2,3,7,8-TCDD equivalents)	1746016		0.0008	NA				IMMUNE; REPROD; CANCER	B2	1E-06	H		Or
Explosives													

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NOTE: Based on LIMITED multiple pathway exposure scenario (i.e., incidental soil/dust ingestion, dermal contact and inhalation). If multiple contaminants are present cumulative risk MUST be evaluated. Impacts to ecological receptors or to ground water must be evaluated utilizing other methods.

Source (if multiple sources the source of the driving pathway is given): M = MDH; MI = IRIS adopted by MDH; I = IRIS; H = HEAST; E = EPA NCEA/STSC or SSL; C = California EPA; A = ATSDR; O = Other
Pathways: Or = oral; De= Dermal; In = Inhalation; ? = not known.

TABLE A3.7 SUMMARY OF TIER 2 SHORT-TERM WORKER SOIL REFERENCE VALUE INFORMATION. (1999 Version)

					Pathways						Pathways		
Chemical	**CAS No.**	**VOC?**	**Short-term Worker SRV (mg/kg)**	**HQ (1)**	**Source**	**Missing**	**Driving**	**Target Organ(s) (2)**	**Cancer Class (3)**	**ELCR**	**Source**	**Missing**	**Driving**
1,3 - DNB	99650		117	1	H	In	Or	SPLEEN	D	NA			
2,4 - DNT	121142		303	1	H	In	Or	CV/BLD; CNS/PNS; LIV/GI; CANCER	See mixture below				
2,6 - DNT	606202		1508	1	H	In	Or	CV/BLD; CNS/PNS; KID; LIV/GI; CANCER	See mixture below				
2,4- AND 2,6 DNT MIXTURE	0		32	NA				CANCER	B2	1E-06	I		Or
HMX	2691410		NA	NA				LIV/GI	D	NA			
RDX	121824		187	1	H	In	De	PROSTATE; CANCER (?)	C	1E-06	I	In	De
1,3,5 - TNB	99354		NA	NA		In	Or De	CV/BLD; SPLEEN	NA	NA			
2,4,6 - TNT	118967		63	1	H	In	Or	LIVER; CANCER (?)	C	4E-08	I	In	Or

VOC? - - y indicates that contaminant is considered volative.
(1) Italics indicates unity with Csat, maximum soil concentration or acute target concentration not unity with chronic RfD/RfC.
(2) ADREN – adrenal; BONE; CV/BLD - cardiovascular/blood system; CNS/PNS - central/peripheral nervous system; EYE; IMMUN – immune system; KIDN - kidney; LIV/GI - liver/gastrointestinal system; PROST – prostate; REPRO - reproductive system (incl. teratogenic/developmental effects); RESP – respiratory system; SKIN - skin irritation or other effects; SPLEEN; THYROID; WHOLE BODY - increased mortality, decreased growth rate, etc.
(3) Cancer Classification: Class A – known human carcinogen; Class B – probable human carcinogen (B1 – limited evidence in humans; B2 – inadequate evidence in humans); Class C – possible human carcinogen; Class D – not classified; NA – not available.

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