GUIDANCE FOR SCHOOL SITE RISK ASSESSMENT PURSUANT TO HEALTH AND SAFETY CODE SECTION 901(f):

GUIDANCE FOR ASSESSING EXPOSURES AND HEALTH RISKS AT EXISTING AND PROPOSED SCHOOL SITES

FINAL DRAFT REPORT

October 2003

Integrated Risk Assessment Section

Office of Environmental Health Hazard Assessment

California Environmental Protection Agency

Guidance for Assessing Exposures and Health Risks at Existing and Proposed School Sites Pursuant to Health and Safety Code §901(f):

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Executive Summary

This guidance document was prepared to comply with California Health and Safety Code Section 901(f), which requires the Office of Environmental Health Hazard Assessment (OEHHA) to develop and publish a guidance document for use by the Department of Toxic Substances Control and other state and local environmental and public health agencies to assess exposures and health risks at existing and proposed school sites. It presents methodology for estimating exposure of school users to toxic chemicals found as contaminants at existing and proposed school sites, and the health risks from those exposures. It incorporates exposure factors unique to the school environment, and considers the activity patterns of children from birth through age 18, and of adult school employees. It discusses uncertainties and steps that can be taken to address these uncertainties.

Table Of Contents

Introduction and Purpose

Section 901(f) of the California Health and Safety Code states that: "On or before December 31, 2002, the Office (of Environmental Health Hazard Assessment, OEHHA) shall publish a guidance document, for use by the California Department of Toxic Substances Control (DTSC) and other state and local environmental and public health agencies to assess exposures and health risks at existing and proposed school sites. The guidance document shall include, but not be limited to, all of the following:

(A) Appropriate child-specific routes of exposure unique to the school environment, in addition to those in existing exposure assessment models.

(B) Appropriate available child-specific numerical health effects guidance values and plans for the development of additional child-specific numerical health effects guidance values.

(C) The identification of uncertainties in the risk assessment guidance and those actions that should be taken to address those uncertainties."

Pursuant to HSC§901(f)(A) and (C), OEHHA is proposing these guidelines for multimedia, multipathway, risk assessment at existing and proposed school sites. HSC§901(f)(B) is addressed in a separate document (OEHHA, 2002a).

Need for Guidance

Children differ from adults anatomically, physiologically, and behaviorally in ways that may affect their exposure or their response to exposure to environmental contaminants. For example, on a body weight basis, children require more oxygen, food, and water, and have a higher skin surface area than adults. Children's activity patterns are different. Children are in a period of continuous change as they move from infancy through puberty and into adulthood. Most previous guidance has focused on residential or occupational scenarios, and has treated childhood as a homogeneous life stage. Recognizing that children are undergoing rapid development, this guidance addresses the differences between children and adults, and between the school setting and other settings.

Scope of Guidance

As required by HSC§901(f), this guidance is intended to support assessment of chemical exposures and health risks at existing and proposed school sites, to characterize uncertainty in assessing exposure and risk in the school setting, and to suggest which areas are most in need of further research. It is intended to be sufficiently flexible to accommodate a variety of situations: It may be used to support the evaluation of the suitability of a site for future school construction or to support the assessment of toxicological risk at an existing school site. These contrasting situations present different opportunities to measure contaminant concentrations in environmental media. In the first scenario, soil, soil gas, air, and ground water may be available for sampling, but concentrations in indoor media will have to be estimated. In the second scenario, indoor media such as surface dust and air may be available for sampling. By sampling these media, additional sources of contaminants, such as chemicals in building materials and furnishings and chemicals used in school operations, can be included in the assessment.

This guidance specifies toxicity criteria that should be used in assessing risk and hazard. It only addresses risk assessment for schools; it does not address chemical exposures that students and staff may receive outside the school setting. It does not include project-specific guidance such as selection of chemicals of potential concern, site characterization, sampling and analyses strategies, and determination of appropriate exposure point concentrations. This guidance does not provide risk management application or decision-making criteria. For information regarding the application of this document to regulatory programs, contact DTSC or other agencies that may utilize this guidance as a part of their regulatory program. This guidance assumes that the user is familiar with the principles of chemical risk assessment; it is not intended to provide basic instruction in risk assessment.

Tiered Approach

The model is designed to support a tiered approach to assessment of risk. It can be used in screening (Tier 1) mode, with conservative default input values and all pathways included (except pathways 9, 10, and 12 when these are not appropriate). It also accommodates a Tier 2 analysis using user-supplied site-specific input parameters and/or elimination of pathways that are not appropriate for a given site. Use of this guidance in Tier 1 or Tier 2 mode should be discussed with and approved by DTSC or other regulatory programs for which the risk assessment is being conducted. In some cases, it may be appropriate to add in additional sources of chemicals in the environment. For example there may be off-site emissions that may impact on-site concentrations. Case-specific approaches may be appropriate for these situations in lieu of, or in addition to default methods. Users should document and justify all departures from default conditions so that reviewers can duplicate the modeling conditions and verify the result.

Mathematical models

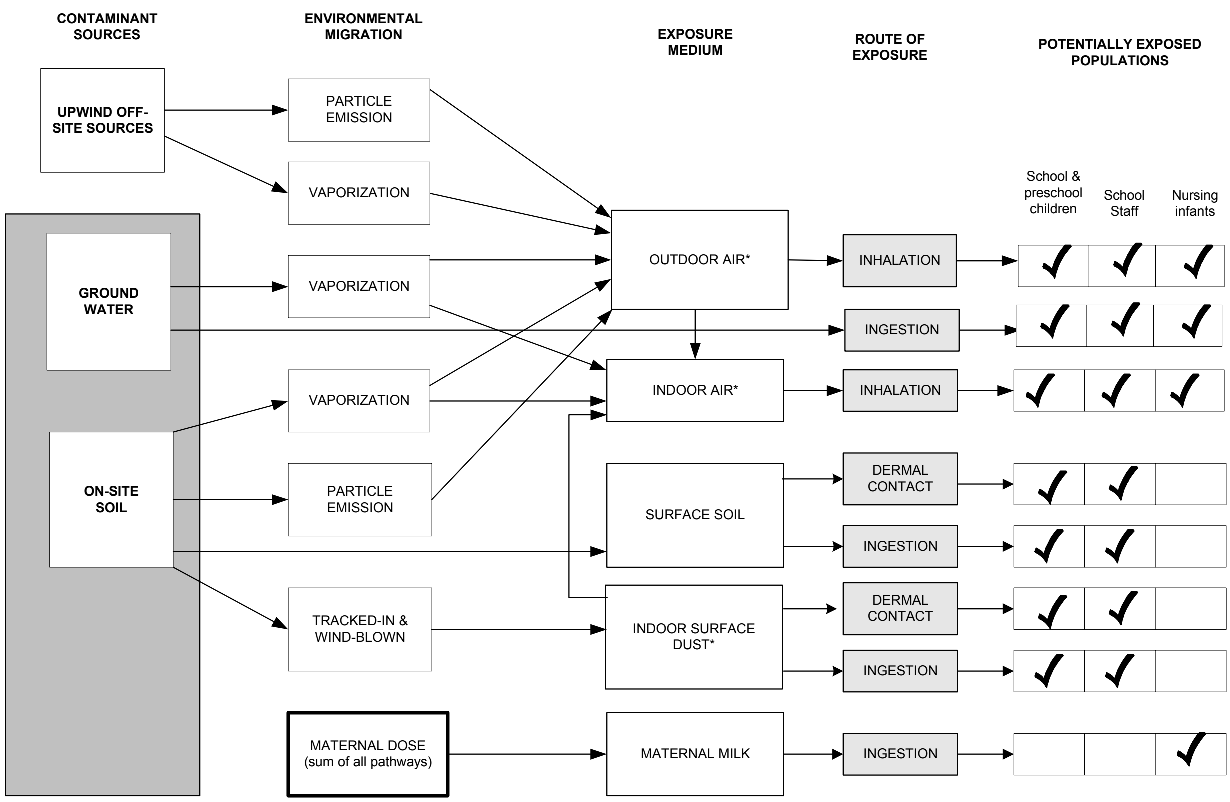
Mathematical models can be used to predict exposures and risks to specified groups of people from chemicals in specified environmental media under defined conditions. This guidance lays out a modeling approach to predicting exposures and risks to preschoolers, students, teachers and other school personnel, and their offspring, from chemicals in the soil, shallow ground water, and air at the school site. A separate document, (OEHHA, 2003) presents a spreadsheet adaptation of this model. The use of this spreadsheet (SchoolScreen.xls) is optional, and the user retains the responsibility to ensure that the model parameters including toxicity parameters are current and correct. The model is applicable to most chemicals, the notable exception being lead. OEHHA recommends the use of the DTSC Lead Risk Assessment Spreadsheet for assessment of exposure to lead at school sites.

Schools Conceptual Site Model

A conceptual site model includes the contaminated environmental media, the movement of the chemicals within and between environmental compartments (intermedia transfers), the concentration of the chemical(s) in various personal exposure media, exposure pathways and routes, exposed populations, and the amount of the chemical(s) taken into the body. These movements and concentrations may be described by a series of mathematical relationships. This guidance proposes a series of such mathematical relationships, which are described below.

As depicted in Figure 1, this model considers contaminated soil, ground water, and unspecified off-site sources as primary source media. Contaminated soil can be an exposure medium (by ingestion or dermal contact) and can be a source for transfer into other media. Chemicals can vaporize from soil into indoor or outdoor air and can be entrained into the suspended particle phase. As a default, soil is treated as the source of outdoor suspended particulate matter, but a measured concentration in on-site particulate matter may replace the calculated value. By this means, total particle-bound contaminants from off-site and on-site sources can be included. Vapors can be inhaled indoors or outdoors. Soil can be transported indoors, where it becomes a component of interior dust. Exposure to this dust can be by ingestion or dermal contact, or it can be re-suspended and inhaled.

FIGURE 1: SITE CONCEPTUAL MODEL FOR EXISTING OR PROPOSED SCHOOL SITES

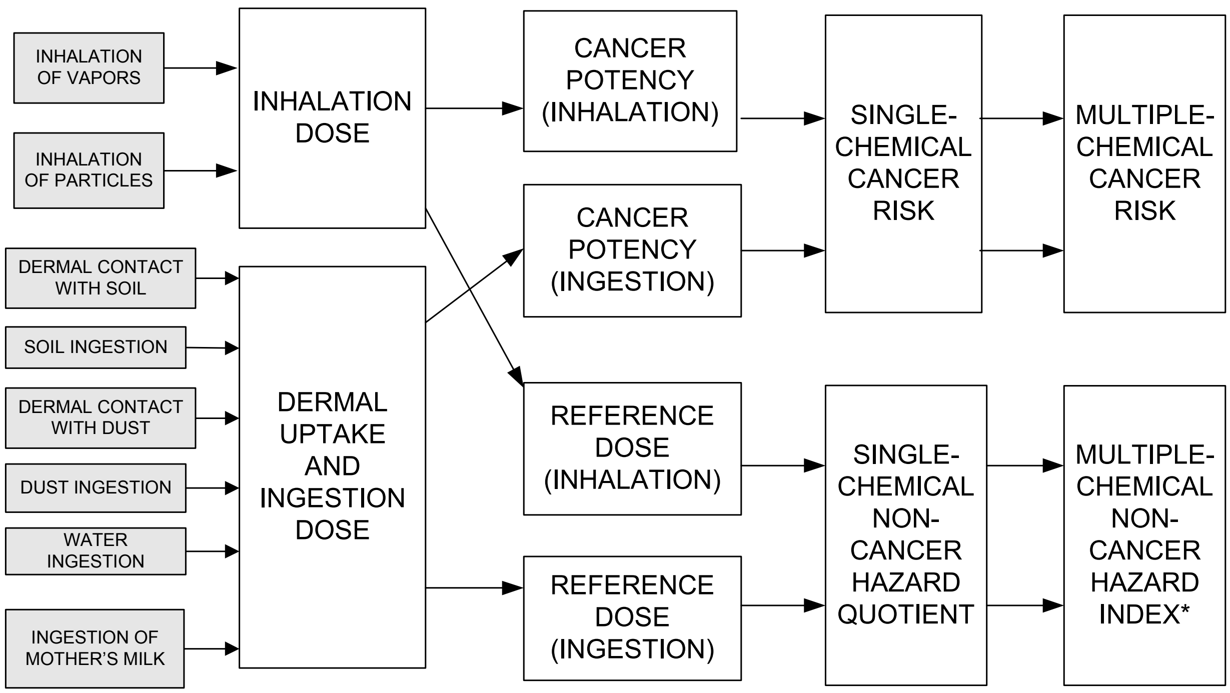


* Available representative measured concentrations in these exposure media may be substituted for the model-based estimates.

Ground water is treated as a source of drinking water (if pathway 12 is selected) and as a source of chemicals that may vaporize and contribute to soil vapors. However, a measured soil vapor concentration may be substituted for the value estimated from soil and ground water concentrations.

As depicted in Figure 2, hazard quotients and incremental risks are estimated for each chemical; then the hazard quotients and incremental risks associated with the individual chemicals are added to arrive at the total hazard index and total risk. If the total hazard index does not exceed one, then it may be assumed that the non-cancer toxic effects are unlikely and further analysis of non-cancer effects is not necessary. If the total hazard index exceeds one, then it may be useful to separate chemicals by target organ and/or mode of action and add the hazard quotients of only those chemicals that are likely to act in an additive manner. This target organ/mode of action analysis should be documented.

FIGURE 2: RISK ESTIMATION FOR EXISTING OR PROPOSED SCHOOL SITES



* Additivity considered as appropriate, depending on target organ and/or mode of action

Potentially Exposed Sub-populations at Schools

The model addresses the following school sub-populations. With the exception of pregnant or nursing women, genders are not separated.

1) Students from kindergarten through high school

2) Staff

3) Pregnant or nursing women

4) Pre-schoolers aged one through four

5) Nursing infants less than one year of age in day care at the school site whose mothers are students or staff. No sources of contaminants other than those associated with the school environment are considered in calculating the concentration in breast milk.

Other groups that may use or visit the school facilities, such as parents and members of the general community are not explicitly considered. Since their visits would be less frequent than the students and staff, their long-term average exposure would be less than that of the groups listed above. Also, it would be possible to assess exposure of nursing infants who did not spend time at the school site, but whose mothers were students or staff. However, these children would be exposed less than infants described above (group #5).

Exposure and Source Media at Schools

Potential Source Media at Schools

Soil
Soil is often the primary environmental medium to be contaminated when toxic materials are spilled or dumped. Soil may be a source medium for contamination of other media such as surface dust or airborne particulate matter or vapors. The model can estimate the concentrations of contaminants in soil gas based on the concentrations in soil matrix and/or ground water, or these concentrations may be measured directly. Soil may be directly contaminated by spills or leaks occurring on the site, or may be contaminated by wet or dry deposition from off-site sources. The model does not explicitly consider deposition; rather it is assumed that this type of contamination will be included in the results of the on-site soil sampling.

Ground water
Ground water may be a source of volatile contaminants in indoor and outdoor air. Off-site ground water plumes may need to be considered if they are likely to move on-site.

Off-site sources
Atmospheric emission sources within ½ mile of the site that have the potential to contaminate on-site air may be important in estimating overall toxic exposures. Examples could include fixed facilities with known emissions and mobile sources such as highways, heavily traveled streets, or vehicle loading areas.

Potential Exposure Media at Schools

Soil
Students and others at school sites may be exposed to soil on the campus. Bare dirt may cover a portion of the campus area. Playgrounds and athletic fields may have patches of bare dirt. Even paved areas may contain a layer of soil. Soil may be ingested or may contaminate the skin.

Dust
Interior surfaces including floors, desks, shelves, and windowsills, may accumulate a layer of dust between cleanings. This dust may come from multiple sources, including tracked-in or blown-in outdoor soil. Dust may be ingested or may contaminate the skin.

Air
Air may contain vapor-phase and/or particulate contaminants. The multiple sources of vapors and particles may include on-site and off-site sources. The model estimates indoor and outdoor concentrations of pollutants in the particulate or vapor phases based on concentrations in on-site soil and/or ground water. Representative measured concentrations of vapor-phase or particulate contaminants in outdoor air may be substituted for estimated values. For existing schools corresponding indoor measurements may also be used.

Drinking Water
Since ground water may be a source of drinking water (RTI, 2003), the model includes an optional equation for assessing exposure via the drinking water pathway. This equation does not predict concentrations of contaminants in ground water, but relies on measured values.

Air contamination by vapor- or particle-phase pollutants originating off-site
Depending on program requirements, modeled on-site concentrations of contaminants originating from off-site sources may be added to estimated concentrations of contaminants from on-site sources. If on-site concentrations are measured under representative

meteorological conditions (as opposed to modeled), contributions from these off-site contamination sources generally should not be added to the resulting measured concentrations, because the measured concentrations should include the off-site component.

Other potential exposure media

In a recent survey, nearly 8 percent of schools reported that produce for human consumption was grown at the site (RTI, 2003). OEHHA considered including food grown in the site soil as an exposure pathway, however, a variety of simulations using an array of chemicals representing various chemical classes (including volatile organic chemicals, lipophilic organic chemicals, and heavy metals) showed that the food pathway never contributed as much as 1 percent of the total risk or hazard, even assuming up to 5 percent of the diet being site-grown produce. Therefore, food is not included as an exposure medium in the schools exposure model.

Building materials and indoor products may be important sources of indoor exposure to toxic constituents at schools. It may be appropriate to include these sources of chemical exposures in the overall assessment of overall hazards and risks at existing schools. Typically these assessments would be based on measured atmospheric concentrations in classrooms and other indoor areas, and estimated risks, using the same exposure parameters, would be added to site-related risks. Hazards would be additive among chemicals sharing a common target organ and/or mode of action.

Background (non-site-related) Exposures

A small incremental dose of a toxic constituent that would otherwise be of no concern, may become a concern if the exposed person is already receiving a background dose of the constituent and the combined exposures may exceed the toxic threshold. For this reason, risk managers may wish to take background exposures into account in their decision-making process. This is of primary importance for non-carcinogenic toxic effects, which are generally thought to exhibit a toxic threshold. Carcinogens, on the other hand are generally treated as exhibiting no threshold. Thus, the incremental risk posed by a given exposure to a carcinogen does not depend on the individual's background exposure to that or any other carcinogen.

Exposure Pathways

Exposure pathways can be direct or indirect. A direct exposure pathway consists of a contaminated environmental medium and an exposure route by which the contaminated medium contacts and enters the body (e.g. ingestion of contaminated soil, pathway 1, below). An indirect exposure pathway consists of a contaminated environmental medium, one or more transfers between environmental media and ultimately an exposure medium, and an exposure route by which the exposure medium contacts and enters the body (e.g. transfer of chemicals from contaminated soil to indoor dust and ingestion of indoor dust, pathway 3, below).

Exposure Pathway Equations

Figure 1 depicts the movements of contaminants into and between environmental and exposure media. These movements and the resulting exposures may be described by a series of mathematical relationships. This model includes up to 12 pathways by which school users could be exposed to chemicals at the school site. Each pathway can be represented by an equation which describes a concentration in the source medium, up to two transfer factors that relate the concentration in the source medium to a concentration in an intermediate or exposure medium, and a contact rate that describes the daily intake of, or contact with, the exposure medium. When the exposure pathway is direct (i.e. the environmental medium and the exposure medium are the same, such as ingestion of outdoor soil), then no transfer factors are required. The annual average daily dose associated with each of these pathways is estimated as follows:

1. **Ingestion of outdoor soil:** $D = C_S * I_S * A_I * F_S * F_O * EF/(BW * 365$ (days/year)), where:
   - D = Pathway-specific annual average daily dose of contaminant (mg/kg_{BW}/day)
   - C_S = Concentration of contaminant in soil (mg/kg_{soil})
   - I_S = daily soil/dust ingestion (kg_{soil}/day)
   - A_I = route-specific absorption factor for ingestion (unitless)
   - F_S = fraction of daily soil/dust ingestion and dermal contact that occurs at school (unitless)
   - F_O = fraction of daily soil/dust ingestion and dermal contact that occurs outdoors (unitless)
   - BW = age-specific body weight (kg)
   - EF = exposure frequency (days/year)

2. **Dermal contact with outdoor soil:** $D = C_S * A_D * F_S * F_O * D_S * EF / 365$ (days/year) where:
   - D = Pathway-specific annual average daily dose of contaminant (mg/kg_{BW}/day)
   - C_S = Concentration of contaminant in soil (mg/kg_{soil})
   - A_D = route-specific absorption factor (unitless)
   - F_S = fraction of daily soil/dust ingestion and dermal contact that occurs at school (unitless)
   - F_O = fraction of daily soil/dust ingestion and dermal contact that occurs outdoors (unitless)
   - D_S = Daily dermal contact with soil/dust (kg_{soil}/kg_{BW}/day) = $\sum(A_{BP} * L_{BP})$, where
   - A_{BP} = body-part-specific area (cm^2/kg)
   - L_{BP} = body-part-specific skin loading (kg_{soil}/cm^2/day)
   - EF = exposure frequency (days/year)

3. **Migration of chemicals from outdoor soil to indoor dust; ingestion of indoor dust:**
   - $D = C_S * TF_{SD} * I_S * A_I * F_S * F_I * EF/(BW * 365$ (days/year)), where:
   - D = Pathway-specific annual average daily dose of contaminant ($\mu g/kg_{BW}$/day)
   - C_S = Concentration of contaminant in soil (mg/kg_{soil})
   - TF_{SD} = Transfer factor from soil to indoor dust ((mg/kg_{dust})/(mg/kg_{soil}))
   - I_S = daily soil/dust ingestion (kg_{soil}/day)
   - A_I = route-specific absorption factor for ingestion (unitless)
   - F_S = fraction of daily soil/dust ingestion and dermal contact that occurs at school (unitless)
   - F_I = fraction of school soil/dust ingestion that occurs indoors (unitless)
   - BW = age-specific body weight (kg)
   - EF = exposure frequency (days/year)

4. **Migration of chemicals from outdoor soil to indoor dust; dermal contact with indoor dust:**
   - $D = C_S * TF_{SD} * A_D * F_S * F_I * D_S * EF / 365$ (days/year), where
   - D = Pathway-specific annual average daily dose of contaminant (mg/kg_{BW}/day)
   - C_S = Concentration of contaminant in soil (mg/kg_{soil})
   - TF_{SD} = Transfer factor from soil to indoor dust ((mg/kg_{dust})/(mg/kg_{soil}))
   - A_D = route-specific absorption factor (unitless)
   - F_S = fraction of daily soil/dust ingestion and dermal contact that occurs at school (unitless)
   - F_I = fraction of daily soil/dust dermal contact that occurs indoors (unitless)
   - D_S = Daily dermal contact with soil/dust (kg_{soil}/kg_{BW}/day) = $\sum(A_{BP} * L_{BP})$, where
   - A_{BP} = body-part-specific area (cm^2/kg_{BW})
   - L_{BP} = body-part-specific skin loading (g/cm^2)
   - EF = exposure frequency (days/year)

5. **Suspension of soil particles in outdoor air; inhalation of suspended particulate matter (PM10) in outdoor air:**

$D = C_S * TF_{PM/S} * PM_{10} * B_O * T_O * A_{In} * EF / 365$ (days/year), where

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_S = Concentration of contaminant in soil (mg/kg_{soil})

PM_{10} = Respirable particle load for outdoor air due to resuspension of site soil (kg_{PM10}/L_{air})

B_O = Body-weight-normalized breathing rate outdoors ($L/min/kg_{BW}$)

T_O = Time outdoors at school daily (min/day)

A_{In} = route-specific absorption factor (unitless)

EF = exposure frequency (days/year)

$TF_{PM/S}$ = Ratio of the concentration of contaminant in outdoor PM_{10} originating from site soils to the concentration of contaminant in soil ($(mg/kg_{PM10})/(mg/kg_{soil})$)

A representative measured value for concentration of a chemical in outdoor PM_{10} may replace the value estimated from soil data; in that case the equation becomes:

$D = C_{PM10} * PM_{10} * B_O * T_O * A_{In} * EF / 365$ (days/year), where

C_{PM10} = Measured concentration in PM_{10} ($\mu g/g$)

6. **Suspension of respirable indoor dust particles (PM10) in indoor air; inhalation of PM10 in indoor air:**

$D = C_S * TF_{S/D} * TF_{PM/D} * S_F * B_I * T_I * A_{In} * EF / 365$ (days/year), where

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_S = Concentration of contaminant in soil (mg/kg_{soil})

S_F = Respirable particle load for indoor air due to resuspension of dust particles (kg_{PM10}/L_{air})

B_I = Weight-normalized breathing rate indoors ($L_{air}/min/kg$)

T_I = Time indoors at school daily (min/day)

A_{In} = route-specific absorption factor (unitless)

$TF_{PM/D}$ = Ratio of the concentration of contaminant in indoor PM_{10} to the concentration of contaminant in indoor surface dust ($(mg/kg_{PM10})/(mg/kg_{dust})$)

TF_{SD} = Transfer factor from soil to indoor dust ($(mg/kg_{dust})/(mg/kg_{soil})$)

EF = exposure frequency (days/year)

7a. **Vaporization of volatile chemicals from the soil; penetration of vapors into building interior; inhalation of vapors mixed with indoor air**:**

$D = C_S * \alpha * VC_S * CF * B_I * T_I * A_{In} * EF / 365$ (days) /year, where:

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_S = Concentration of contaminant in soil (mg/kg_{soil})

α = Ratio of chemical concentration in indoor air to that in soil vapor (unitless)[1]

VC_S = Volatilization factor from soil (g_{soil}/L_{vapor})

CF = Conversion factor (0.001 kg/g)

B_I = Weight-normalized breathing rate indoors (L/min/kg)

T_I = Time indoors at school daily (min/day)

A_{In} = route-specific absorption factor for inhalation (unitless)

EF = exposure frequency (days/year)

A measured soil vapor concentration may be used in place of the value estimated from soil matrix data; in that case the equation becomes:

$D = C_{SV} * \alpha * B_I * T_I * A_{In}$, where:

C_{SV} = concentration in soil vapor (mg/L) and 7a and 7b collapse into a single pathway 7. The decision as to which one to use should be made in consultation with the lead agency for the project.

7b. **Vaporization of volatile chemicals from shallow ground water; penetration of vapors into building interior; inhalation of vapors mixed with indoor air**:**

$D = C_{GW} * \alpha * VC_{GW} * CF * B_I * T_I * A_{In} * EF / 365$ (days/year), where:

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_{GW} = Concentration of contaminant in ground water (mg/L)

α = Ratio of chemical concentration in indoor air to that in soil vapor (unitless)[1]

VC_{GW} = Volatilization factor from ground water (ml_{water}/L_{vapor})

CF = Conversion factor (0.001 L/ml)

B_I = Weight-normalized breathing rate indoors (L/min/kg)

T_I = Time indoors at school daily (min/day)

A_{In} = route-specific absorption factor for inhalation (unitless)

EF = exposure frequency (days/year)

A measured soil vapor concentration may be used in place of the value estimated from ground water data; in that case the equation becomes:

$D = C_{SV} * \alpha * B_I * T_I * A_{In}$, where:

C_{SV} = concentration in soil vapor (mg/L), and 7a and 7b collapse into a single pathway 7. The decision as to which one to use should be made in consultation with the lead agency for the project.

8. **Inhalation of chemicals vaporized from outdoor soil**:**

$D = C_S * 1/VF * CF * (B_O * T_O + B_I * T_I) * A_{In} * EF / 365$ (days/year), where:

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_S = Concentration of contaminant in soil (mg/kg_{soil})

VF = Volatilization Factor (ratio of concentration in air to concentration in soil)(L_{air}/g_{soil})

CF = Conversion factor (0.001 kg/g)

B_O = Weight-normalized breathing rate outdoors (L/min/kg)

T_O = Time outdoors at school daily (min/day)

B_I = Weight-normalized breathing rate indoors (L/min/kg)*

T_I = Time indoors at school daily (min/day)*

A_{In} = route-specific absorption factor (unitless)

EF = exposure frequency (days/year)

* Assumes that HVAC system circulates outdoor air to the indoor spaces.

9. **Inhalation of contaminants in vapors that originate off-site*:**

$D = C_A * (B_I * T_I + B_O * T_O) * A_{In} * EF / 365$ (days/year), where:

D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)

C_{AV} = Concentration of contaminant vapor in site air (mg/L)

B_I = Weight-normalized breathing rate indoors (L/min/kg)

T_I = Time indoors at school daily (min/day)

B_O = Weight-normalized breathing rate outdoors (L/min/kg)

T_O = Time outdoors at school daily (min/day)

A_{In} = route-specific absorption factor for inhalation (unitless)

EF = exposure frequency (days/year)

This pathway accommodates modeled on-site concentrations from off-site sources. It is independent of (and therefore added to) modeled on-site concentrations. However, representative on-site concentrations measured under conditions that would capture contaminants originating both off-site and on-site, should include the contribution from both sources and therefore would replace modeled concentrations based on on- and off-site sources.

10. **Inhalation of contaminants in suspended particles that originate off-site.**
    $D = C_{AP} * (B_I * T_I + B_O * T_O) * A_{In} * EF / 365$ (days/year), where:
    D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)
    C_{AP} = Concentration of particulate contaminant in site air (mg/L)
    B_I = Weight-normalized breathing rate indoors (L/min/kg)
    T_I = Time indoors at school daily (min/day)
    B_O = Weight-normalized breathing rate outdoors (L/min/kg)
    T_O = Time outdoors at school daily (min/day)
    A_{In} = route-specific absorption factor for inhalation (unitless)
    EF = exposure frequency (days/year)
    This pathway accommodates modeled on-site concentrations from off-site sources. It is independent of (and therefore added to) modeled on-site concentrations. However, representative on-site concentrations measured under conditions that would capture contaminants originating both off-site and on-site, should include the contribution from both sources and therefore would replace modeled concentrations based on on- and off-site sources. This pathway may be inappropriate for some programs.

11. **Ingestion of contaminants in breast milk** (only for infants up to one year old)
    $D = C_{BM} * I_{BM} * A_I * EF / 365$ (days/year), where:
    D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)
    C_{BM} = Contaminant concentration in breast milk (mg/kg_{milk}), estimated as:
    $B_{BM} * BW_M$ * maternal annual average daily dose (mg/kg/day) where:
    B_{BM} = breast milk biotransfer factor ((mg/kg)/(mg/day))
    BW_M = Maternal body weight (kg)
    I_{BM} = Age-specific, weight normalized daily breast milk ingestion ($kg_{milk}/kg_{BW}/day$)
    A_I = route-specific absorption factor for ingestion (unitless)
    EF = exposure frequency (days/year)

12. **Ingestion of contaminated drinking water:**
    $D = C_{DW} * I_{DW} * F_S * A_I * EF / 365$ (days/year); where:
    D = Pathway-specific annual average daily dose of contaminant ($mg/kg_{BW}/day$)
    C_{DW} = User-supplied contaminant concentration in school drinking water (mg/L).
    I_{DW} = Age-specific, weight normalized daily drinking water ingestion (ml/day/kg)
    F_S = fraction of daily water ingestion that occurs at school (unitless)
    A_I = Ingestion absorption factor (unitless)
    EF = exposure frequency (days/year)

** Vapor inhalation pathways may be omitted for chemicals whose boiling point exceeds 600ºK

Each of these equations gives a pathway-specific annual average daily dose of the chemical in question. Doses via all pathways that involve the same exposure route (e.g. ingestion) are added together to determine the route-specific annual average daily dose. The latter is divided by the route-specific reference dose (RfD) to arrive at the route-specific hazard quotient (HQ). Dermal exposures are usually combined with ingestion exposures. The route-specific HQs are added to give the chemical-specific HQ. In a screening analysis, the chemical-specific HQs for each chemical are added to give the Hazard Index. In a more detailed (tier 2) analysis, target organs and mechanisms of toxic action may be considered in determining the appropriateness of adding the HQs for individual chemicals.

To compute cancer risk, the route-specific annual average daily dose is converted to a route-specific lifetime average daily dose by multiplying by the fraction of a lifetime represented by each exposure scenario (ED/AT), i.e. 1/70 of a lifetime for each year of exposure. The route-specific lifetime average daily dose is multiplied by the route-specific cancer potency factor to obtain the risk for that pathway. The route-specific risks for relevant pathways are added to give the chemical-specific risk. Finally the chemical-specific risks for each chemical are added to give the total cancer risk. Annual risks may be added for a series of years to obtain the total risk for that period.

Model Parameters

The pathway equations above require numerical values or parameters, which can be divided into "intermedia transfer factors" and "exposure factors," which are described below and summarized in a table at the end of each section:

Intermedia Transfer Factors

When the environmental medium and the exposure medium are not the same, one or more intermedia transfer factors are involved. Transfer factors describe the relationship between the concentration of a chemical in one compartment and the concentration of the chemical in another compartment, or, in some cases, the concentration of one medium in another, such as the amount of suspended particulate matter in the air. Some indirect pathways – such as vaporization of soil contaminants and movement of the vapors into indoor spaces – involve two or more intermedia transfer factors. Some transfer factors are chemical-specific; others are general. Many of the intermedia transfer factors in this guidance have a default value of one. This begs the question, "Why include them if the value is one?" The reasons for their inclusion are 1) including the parameter facilitates incorporating a site-specific value without altering the equation structure, and 2) further research may support a default value other than one in the future.

Transfer factor from soil to indoor dust (TF_{SD})

TF_{SD} is the ratio of the concentration of a chemical in the dust on surfaces inside the school building(s) to its concentration in outdoor soil from the schoolyard. This is important because dust on indoor surfaces may be a significant source of exposure to chemicals originating in soil and transported to the building's interior through open doors and windows, heating, ventilation, and air conditioning (HVAC) systems, building infiltration, and on shoes, clothing, and objects carried into the rooms. OEHHA recommends a default value of 2 for this parameter (see Appendix 1 for further explanation).

Transfer factor from soil to outdoor particulate matter ($TF_{PM/S}$)

$TF_{PM/S}$ is the ratio of the concentration of contaminant in outdoor PM_{10}, resulting from resuspension of on-site soil, to the concentration of contaminant in outdoor soil from the schoolyard. This is important because students and other school users may inhale suspended respirable particles in the outdoor air. OEHHA recommends a conservative default value of one (1). If samples of outdoor PM_{10} are collected and analyzed, this transfer factor is not needed.

Transfer factor from indoor surface dust to indoor respirable particulate matter ($TF_{PM/D}$)

$TF_{PM/D}$ is the ratio of the concentration of a chemical in indoor PM_{10} to its concentration in indoor surface dust. This is important because students and other school users may inhale suspended respirable particles in the indoor air. OEHHA recommends a default value of one, implying that indoor dust is resuspended in indoor air with no change in its chemical contaminant concentration.

Soil vapor to Indoor air (α)

Alpha is the unitless ratio of the concentration of a chemical in indoor air to its concentration in soil vapor. It is a dilution factor for vapors moving from relatively confined spaces in soil pores to the better-ventilated building interior. OEHHA recommends the use of the EPA adaptation of the

Johnson and Ettinger (J&E) model to estimate a value for this parameter. OEHHA recommends a default air exchange rate of 4.7 per hour, based on the lower confidence limit on the weighted mean value from 94 portable and 26 traditional classrooms (see Appendix 1 for further discussion). Default values may be used for the remaining parameters including a sandy soil type. Site-specific parameters may be used when justified.

Volatilization factor from soil (VC_S)

VC_S is the ratio of the concentration of a chemical in soil vapor to its concentration in the soil matrix. This ratio, in g_{soil}/L_{vapor}, depends on the physical and chemical properties of the chemical, and on the properties of the soil. OEHHA recommends the Johnson and Ettinger screening model (EPA, 2003) to estimate this value.

Volatilization factor from ground water (VC_{GW})

VC_{GW} is the ratio of the concentration of a chemical in soil vapor to its concentration in shallow ground water. This ratio, in ml_{water}/L_{vapor}, depends on the physical and chemical properties of the chemical, and on the properties of the soil. OEHHA recommends the Johnson and Ettinger screening model (EPA, 2003) to estimate this value.

Volatilization factor (VF)

VF is the ratio of the concentration of a chemical in soil to its concentration in outdoor breathing zone air. To calculate VF, OEHHA recommends the use of the equations in EPA's Soil Screening Guidance (EPA, 1996) with chemical-specific parameters and one modification: to better represent the possible contaminated area on a school site, EPA's default high-end value of Q/C of 68.8 for a 0.5-acre contaminated site is adjusted to 41.24, corresponding to a 10-acre contaminated site.

Breast milk biotransfer factor (BBM)

B_{BM} (d/kg) of organic chemicals is estimated as 0.0000002 * K_{OW}. The value of 0.0000002 is an empirically determined constant (DTSC, 1994).

Other Constants

Respirable particle load for outdoor air (PM_{10})

OEHHA recommends a default concentration of 1.8 E-12 kg_{PM}/L (1.8 $\mu g_{PM}/m^3$) for site related PM_{10} (particular matter less than 10 microns in diameter) in outdoor air. This value is based on the EPA Soil Screening Levels document (EPA, 1996).

Respirable particle load for indoor air (S_F)

S_F is the concentration in indoor air of particulate material less than 10 microns in diameter (PM_{10}) originating from on-site soil. OEHHA recommends a default value of 1.8E-12 kg_{PM}/L (1.8 $\mu g_{PM}/m^3$). This assumes that indoor PM levels are the same as outdoor PM levels.

Table 1: Transfer Factors and Other Constants

Factor	Units	Value	Discussed on Page
TF_{SD}	Unitless	2	17
$TF_{PM/S}$	Unitless	1	17
PM_{10}	kg PM_{10}/L_{air}	1.8 E-9	18
$TF_{PM/D}$	Unitless	1	17
S_F	kg PM_{10}/L_{air}	1.8 E-9	18
α	Unitless	Chemical-specific	17
VC_S	g_{soil}/L_{vapor}	Chemical-specific	18
VC_{GW}	ml_{water}/L_{vapor}	Chemical-specific	18
VF	g_{soil}/L_{air}	Chemical-specific	18
B_{BM}	d/kg	Chemical-specific	18

Exposure Parameters

Most existing risk assessment guidance is focused on multi-year residential or occupational exposure scenarios. Exposure parameters given in existing guidance are generally long-term averages. This guidance is specifically aimed at school populations, including students, teachers and other staff, and users of on-site day care. Because children are rapidly changing anatomically, physiologically and behaviorally, we recommend a set of exposure parameters for each year until age 18. We believe that it is useful to evaluate the exposure of growing children on a year-by-year basis for several reasons:

(1) Some chemicals may exhibit age-specific toxicity. OEHHA is currently evaluating this aspect, and plans to publish age-specific toxicity criteria in the near future. Age-specific toxicity criteria should be paired with corresponding age-specific exposure estimates, to the extent possible.
(2) If the exposure parameters are given on a year-by-year basis, model users can aggregate the years in a manner that best supports the risk management process. Conversely, if OEHHA were to recommend exposure parameters that were averaged over a multi-year period, that averaging period might not match the existing or proposed school scenario. In that case it would be difficult to disaggregate the exposure parameters then re-aggregate them to match the exposure scenario.

The principal sources of exposure factor data for this guidance were the Technical Support Document for Exposure Assessment and Stochastic Analysis (OEHHA, 2000), the Children's Exposure Factors Handbook (EPA, 2002). When more than one value was available for an exposure parameter, preference was given to values that were reported in a way that conformed to the assessment methodology, such as age-specific or short age intervals, and values reported as a function of body weight. This avoided or reduced the need to interpolate or extrapolate data and to convert data to appropriate units using uncertain conversion factors. When percentile estimates were available, preference was given to the ninetieth percentile to be consistent with the reasonable maximum exposure (RME; EPA, 1989). Where data were considered equally appropriate for the analysis, preference was given to OEHHA values. Consideration was given to entering the data as distributions rather than as point estimates, but distributions were not available for several critical parameters. This approach will be considered in the future if sufficient data become available.

This guidance includes the following parameters. Recommended parameter values are summarized in Table 8, at the end of this section:

Soil Ingestion (I_S)

I_S is the estimated total daily inadvertent soil and dust ingestion. Geophagia or soil pica is not addressed in this document. EPA (2002, Table 5-19) estimated total daily soil and dust ingestion by children 1-6 years of age as 100 mg/day mean, with 400 mg/day as an upper end, adding that 200 mg/day may be taken as a conservative estimate of the mean. EPA (1997) recommended a value of 50 mg/day for adults. OEHHA (2000, page 4-15) recommends default values of 200 mg/day for children 1 - 6, and 100 mg/day for everyone over the age of 6. The estimated daily soil ingestion rates at school, shown in the last column of Table 2, are based on OEHHA recommendations. Soil ingestion is not normalized to body weight because a) it is not related to any physiologic process that would be a function of weight and b) it is not reported in that way in any of the references cited.

Table 2: Soil Ingestion

Age (years)	EPA estimates (mg/day)			**Recommended value (mg/day)**
	Mean	Conservative mean	Upper end	
<1				**0**
1-6	100	200	400	**200**
>6	50			**100**

Fraction at school (F_S)

F_S is the estimated fraction of total daily soil and dust ingestion and dermal contact that occurs at school on school days. It is calculated as the total time at school (indoors plus outdoors) divided by 16 hours per day. This is based on the assumptions that soil and dust ingestion and dermal contact are proportional to time spent at a given locale, and that soil and dust ingestion occur only during waking hours, which comprise 16 hours per day.

Body-part-specific skin loading rate (L_{BP})

EPA (2002, chapter 8) recommends the data of Kissel et al. (1996, 1998) and Holmes et al. (1996) as a basis for estimating body-part- and activity-specific soil skin loading (L_{BP}, kg/cm^2/day). Geometric mean body-part-specific loadings ranged from 0.02 to 0.09 mg/cm^2 for the day-care kids (see table below). Although this reference does not provide values for the head and trunk, these body parts are likely to be contaminated by soil at rates less than or similar to the legs. Therefore, OEHHA recommends a value of 0.02 mg/cm^2 for the head and trunk. A “fraction exposed” term is not used, since the studies were based on entire body parts irrespective of whether they were partially clothed or not.

OEHHA considers these data to be the best available because they are based on real-world exposures to young children in day-care centers, (daycare kids #1a, 1b, 2, and 3) an exposure setting similar to that being assessed. The children ranged in age from 1 to 6.5 years and included 17 boys and 4 girls (groups 1a and 1b were the same children, measured in the morning and afternoon). They wore long pants (16) or shorts (5), long sleeves (7) or short sleeves (14). Most children wore low socks and shoes, but 5 were barefoot. Exposure times ranged from 3.5 to 8 hours, with no obvious correlation between time and dermal loading. These data are limited by low numbers of children, high inter-individual variability, limited age range and the need to match their activities with those being assessed. The daycare data are preferred for young children because the setting was most similar to the school setting. Data from other groups of children are available: The indoor kids (3 to 13 years of age) and tae-kwon-do participants (8 to 42 years) playing on a carpeted surface for 1.5 to 2 hours generally had lower dermal exposures to soil than the daycare kids. Nine to 14-year-old kids playing in mud for 10 to 20 minutes had much higher dermal exposures (2 – 3 logs). Thirteen to 15-year-olds playing soccer on grass and bare earth for 40 minutes had a soil exposure that was generally similar to the daycare kids.

Skin Surface area (A_{BP})

As stated above, EPA (2002) recommends using body-part- and activity-specific soil skin loading rates. In order to do this, skin surface area needs to be calculated on a body-part-specific basis. Data on fractional area of various body parts are found in Table 8-3 (EPA, 2002). Age-specific body surface area data are found in tables 8-1 and 8-2 (EPA, 2002). Table 8-4 (EPA, 2002) supplies surface-area to body weight ratios, but these are pooled for ages 2.1 to 19 years. Since it is apparent from analyzing the data in Tables 8-1, 8-2 and 11-1 (EPA, 2002) that surface-area-to-body-weight ratios change markedly with age, OEHHA recommends using the age-specific data in Tables 8-1, 8-2, and 8-3 to calculate these ratios for children 2 years and older. A sample calculation (for a 1-year-old child) is shown below.

Body part	Fraction of Body[a]		Total skin Area[b] **cm^2/kg**		Fractional Area **cm^2/kg**		Skin Loading[d] **g/cm^2**		Skin Loading[e] **g/kg**
Head	**16.5%**	**X**	**641**	=	**105.8**	**X**	**0.000020**[f]	=	**0.0021**
Trunk	**35.5%**	**X**	**641**	=	**227.6**	**X**	**0.000020**[f]	=	**0.0044**
Arms	**13.0%**	**X**	**641**	=	**83.3**	**X**	**0.000023**	=	**0.0019**
Hands	**5.7%**	**X**	**641**	=	**36.4**	**X**	**0.000092**	=	**0.0034**
Legs	**23.1%**	**X**	**641**	=	**148.1**	**X**	**0.000020**	=	**0.0029**
Feet	**6.3%**	**X**	**641**	=	**40.2**	**X**	**0.000065**	=	**0.0026**
Total	**100%**				**641**				**0.0173**

a EPA, 2002, Table 8-3

b Estimated from EPA, 2002, Tables 8-4.

d EPA, 2002, Table 8-13

e Assumes that the school children will be clothed similarly to those in the study (see EPA, 2002, Table 8-12).

f There are no data for trunk and head. OEHHA suggests that the value for the legs, i.e. 0.02, be adopted for the head and trunk.

Fraction outdoors (F_O)

F_O is the estimated fraction of the daily school-related dermal and ingested soil/dust exposure that is acquired outdoors. This is calculated as the time spent outdoors divided by the total time spent outdoors and indoors (see below). The implicit assumption is that indoor and outdoor exposure are proportional to time spent in those environments.

Fraction indoors (F_I)

F_I is the estimated fraction of the daily school-related dermal and ingested soil/dust exposure that is acquired indoors. It is calculated as 1- F_O.

Body weight (BW)

BW for children up to 3 years old is from EPA, 2002, Table 11-1. The 50th percentile values for boys and girls within each year of age were averaged to obtain a representative value. E.g. the body weight for one-year-olds is the average of male and female 50th percentile values at 12, 18, and 24 months. Body weights for children older than 3 years are the means for boys and girls at the beginning and end of each age interval from Table 11-2 (EPA, 2002). E.g. the body weight estimate for four-year-olds is the average of male and female means (including clothing) at 4 and 5 years. Mid-range values for body weight are recommended because this parameter appears only in the denominator of the soil ingestion and dermal contact equations, and since the numerators are thought to be conservative estimates of these parameters, it would be excessively conservative to use a low-end body weight. Estimated body weights for various ages are in Tables 3 and 7.

Table 3: Age Related Body Weights

Age (years)	Weight (kg)	Age (years)	Weight (kg)	Age (years)	Weight (kg)
		6-7	23.75	13-14	53.20
0-1	7.04	7-8	26.50	14-15	57.05
1-2	11.08	8-9	29.80	15-16	60.35
2-3	13.29	9-10	33.90	16-17	62.90
3-4	16.35	10-11	38.70	17-18	64.15
4-5	18.55	11-12	43.20	Nursing moms	63.2
5-6	21.15	12-13	47.85		

Exposure time, outdoors (T_O)

Estimates of daily outdoor exposure time (T_O), shown in Table 4, are from EPA (2002) Table 9-40. The data are based on national activity pattern survey data, and are weighted according to gender, age, race, employment status, region, season, etc, to represent the U.S. population (Klepeis et al., 2001). OEHHA recommends the 75th percentile values (in bold below) because when 75th percentile values for time indoors at school and for time outdoors at school are added, the combined time at school ranks at the 95th to 99th percentile for total time spent at school. Data for infants <1 are not available, so the values for 1-year-olds are recommended as a surrogate.

Table 4: Minutes Spent Outdoors At School Per School Day

Age	50th percentile	**75th percentile**	95th percentile
1-4	65	**140**	175
5-11	60	**120**	220
12-18	55	**105**	225

Exposure time, indoors (T_I)

Estimates of daily outdoor exposure time (T_I), shown in Table ,5 are based on EPA (2002) Table 9-39). OEHHA recommends 75th percentile values (in bold below) because when 75th percentile values for time indoors at school and for time outdoors at school are added, the combined time at school ranks at the 95th to 99th percentile for total time spent at school (EPA, 2002, Table 9-34).

Data for infants less than 1 year of age are not available, so the values for 1-year-olds are recommended as a surrogate.

Table 5: Minutes Spent Indoors At School Per School Day

Age	50th percentile	**75th percentile**	95th percentile
1-4	269	**500**	595
5-11	403	**445**	565
12-18	420	**450**	565

Breathing rate, outdoors (B_O)

B_O is the estimated breathing rate for outdoor school activities like walking and running, estimated from the data of Wiley, et al. in OEHHA, 2000, p. 3-27. This Guidance recommends using a value of 0.75 L/min-kg for all ages. This value assumes that 50 percent of outdoor time is spent in moderate activity like outdoor play, outdoor leisure, and golf with a ventilation rate of 0.6 L/min-kg and 50 percent in is spent in heavy activity like walking and active sports with a ventilation rate of 0.9 L/min-kg. Both sets of descriptors in the Wiley, et al. report (moderate activity and heavy activity) were deemed consistent with outdoor activities at school.

Breathing rate, indoors (B_I) the estimated breathing rate for indoor school activities, were estimated from the data of Wiley, et al. (in OEHHA, 2000, p. 3-25 to 3-26). The light activity category (0.3 L/min-kg) contained activity descriptions compatible with indoor activities at school, such as eating, talking, reading, and homework. The moderate activity category (0.6 L/min-kg) also contained some activity descriptions compatible with indoor school activities for younger children, e.g. indoor play. Therefore we recommend using an average of the ventilation rates for light and moderate activity, i.e. 0.45 L/min-kg, for children up through age 5. For older children the light activity ventilation rate of 0.3 L/min-kg is recommended for indoor activities, since their more vigorous activities typically take place outdoors.

Exposure frequency (EF) is the estimated number of days students or other school users attend school annually. Survey data show that the distribution of days of school per year is bimodal, with 94 percent reporting a school year of 161 to 187 days and another 6 percent reporting a school year of 228 to 238 days (RTI, 2003). Based on these results, the recommended default value for a 9-month school year is 180 days, the modal value for a standard 9-month school year. For year-round schooling, a value of 233 days per year, the midpoint of the upper range is recommended.

Breast milk intake (I_{BM}) This Guidance recommends a daily breast milk ingestion of 130 g/kg/day for the first 12 months of life (OEHHA, 2000, Table 5.13, 90th percentile).

Daily Water Intake (I_{DW})

Daily water intake at school was estimated from EPA, 2000, Table 4-12 and EPA, 1989, Table 3-30. Since OEHHA did not identify any data concerning the proportion of daily water intake that occurs at school, we recommend a value of ½ the 90th percentile daily water intake, based on the proportion of waking hours spent at school on school days (EPA, 2000, Table 9-34). The recommended water intake rates at school in the last column below are ½ the 90th percentile value from EPA, 2000.

Table 6: Water Consumption

Age (years)	EPA Mean (ml/kg-day)	EPA Median (ml/kg-day)	EPA 90th %ile (ml/kg-day)	EPA 95th %ile (ml/kg-day)	Water intake at school (ml/kg-day)
<1	46	19	127	156	63.5
1-3	23	17	51	67	25.5
1-10	19	15	42	56	21
11-19	12	9	26	33	13
Pregnant women	18	16	35	40	17.5
Lactating women	21	21	35	37	17.5
Adults	21	19	34		17

Fraction absorbed, inhalation (A_{In}) is the chemical-specific ratio of the total dose of a chemical absorbed through the respiratory tract to the total amount of the chemical inhaled. In the absence of data to support an alternative value, a default value of one should be used.

Fraction absorbed, ingestion (A_I) is the chemical-specific ratio of the total dose of a chemical absorbed through the gastro-intestinal tract to the total amount of the chemical ingested. In the absence of data to support an alternative value, a default value of one should be used.

Fraction absorbed, dermal (A_D) is the chemical-specific ratio of the total dose of a chemical absorbed through the skin to the total amount of the chemical that is adsorbed onto the skin. Suggested values in Table 7 are from (DTSC, 1994) Table 2. page A-6):

Table 7: Absorption Fractions for Compound Classes

Compound	Absorption	Source
Arsenic	0.04	OEHHA, 2000
Beryllium	0.01	OEHHA, 2000
Cadmium	0.001	OEHHA, 2000
Hexavalent chromium	0.01	OEHHA, 2000
Lead	0.01	OEHHA, 2000
Mercury	0.1	OEHHA, 2000
Nickel	0.04	OEHHA, 2000
Polychlorinated biphenyls	0.14	OEHHA, 2000
Polychlorinated dibenzo-p-dioxins and dibenzofurans	0.02	OEHHA, 2000
Hexachlorocyclohexanes	0.1	OEHHA, 2000
Polynuclear aromatic hydrocarbons,	0.13	OEHHA, 2000
DEHP	0.1	OEHHA, 2000
4,4’ methylene dianiline	0.1	OEHHA, 2000
Organophosphates, pentachlorophenol	0.25	DTSC, 1994
Chlorinated insecticides	0.05	DTSC, 1994
Other organic chemicals	0.1	DTSC, 1994
Other metals and complexed cyanides	0.01	DTSC, 1994

Free cyanide	0.1	DTSC, 1994

Lifetime Exposure Fraction (ED/AT) is the fraction of a lifetime represented by each exposure scenario. It enters into the calculation of cancer risk but not the calculation of the hazard index. Exposures need to be adjusted according to the lifetime exposure fraction because while cancer potency factors are based on lifetime exposure, this model estimates school-related exposure and risk for a series of one-year intervals beginning at birth. Since exposures differ from year to year, risks for each year are unique. For single-year scenarios, ED/AT is 1/70 or 0.014. For staff, the exposure duration is 25 years, standard occupational exposure duration. Annual risks may be added to obtain the aggregate risk for any multi-year period.

Table 8: Summary of Recommended Exposure Parameters

Parameter	Abbre-viation	See page	Units	Recommended values for age																			
				<1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	Mothers	Staff
Soil Ingestion[a]	I_S	19	mg/day	0	200	200	200	200	200	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Fraction at school[b]	F_S	19	unitless	0.67	0.67	0.67	0.67	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Fraction outdoors[c]	F_O	21	unitless	0.22	0.22	0.22	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.11
Body weight[d]	BW	22	Kg	7.04	11.1	13.3	16.4	18.6	21.2	23.8	26.5	29.8	33.9	38.7	42.3	47.9	53.2	57.1	60.4	62.9	64.2	64.2	70
Surface area, head[e]	SA	20	Cm^2/kg	117	106	63	55	54	50	47	45	42	38	33	29	25	28	26	23	21	20	20	20
Loading rate, head[f]	L_{BP}	19-20	g/cm^2/day	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5
Surface area, trunk[e]	A_{BP}	20	Cm^2/kg	229	228	171	128	122	124	126	122	116	107	104	101	99	91	91	89	87	85	82	85
Loading rate, trunk[f]	L_{BP}	19-20	g/cm^2	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5
Surface area, arms[e]	A_{BP}	20	Cm^2/kg	88	83	53	58	54	50	47	45	42	39	39	39	39	34	34	35	35	47	45	47
Loading rate, arms[f]	L_{BP}	19-20	g/cm^2	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5
Surface area, hands[e]	A_{BP}	20	Cm^2/kg	34	36	24	24	22	19	17	17	17	17	16	16	15	14	15	15	15	14	13	14
Loading rate, hands[f]	L_{BP}	19-20	g/cm^2	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5	9e-5
Surface area, legs[e]	A_{BP}	20	Cm^2/kg	132	148	103	108	108	102	98	97	95	90	89	88	87	89	90	90	90	82	79	82
Loading rate, legs[f]	L_{BP}	19-20	g/cm^2	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5	2e-5
Surface area, feet[e]	A_{BP}	20	Cm^2/kg	42	40	32	29	28	26	25	25	25	24	23	21	20	22	21	20	19	19	19	19
Loading rate, feet[f]	L_{BP}	19-20	g/cm^2	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5	7e-5
Breathing rate, outdoors[g]	B_O	23	L/min-kg	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.7
Exposure time, outdoors[h]	T_O	22	min/day	140	140	140	140	140	120	120	120	120	120	120	120	105	105	105	105	105	105	105	60
Breathing rate, indoors[i]	B_I	23	L/min-kg	0.45	0.45	0.45	0.45	0.45	0.45	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Exposure time, indoors[i]	T_I	23	min/day	500	500	500	500	500	445	445	445	445	445	445	445	450	450	450	450	450	450	450	480
Exposure frequency[n]	EF	23	days/yr	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	
Exp. freq. (year-round)[o]	EF	23	days/yr	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	250
Breast milk intake[p]	I_{BM}	23	g/kg/day	130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Intake	I_{DW}		ml/kg/da	63.5	25.5	25.5	25.5	21	21	21	21	21	21	13	13	13	13	13	13	13	13	17.5	17.5
Exposure duration[q]	ED	24	Years	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	25
Averaging time[r]	AT	24	Years	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70

[a] The estimated total daily inadvertent soil and dust ingestion, based on OEHHA 2000, page 4-15. Geophagia or soil pica is not addressed in this document.
[b] Fraction of daily soil and dust ingestion and dermal loading that occurs at school, based on the number of hours at school daily divided by 16. OEHHA recommends default values of 0.67 for infants <1 and 0.563 (9 of 16 hours daily) for staff.
[c] Fraction of daily site-related dermal and ingested soil/dust load that is acquired outdoors. Calculated as the time spent outdoors divided by the time spent outdoors plus the time spent indoors.
[d] Body weight data for children up to 3 years old were taken from EPA, 2002: Table 11-1 (50th percentile; mean of boys and girls). For older children, values were taken from Table 11-2, the mean for boys and girls and the average of the beginning and end of the interval.
[e] EPA, 2002, Table 8-13 (Assumes that the school children will be clothed similarly to those in the study; see EPA, 2002, Table 8-12).
[f] Estimated from EPA, 2002, Tables 8-1, 8-2 and 8-3 OEHHA suggests that the value for the legs, i.e. 0.02, be adopted for the head and trunk
[g] Based on (OEHHA, 2000, p. 3-27).
[h] Based on 75^{th} percentile values from EPA, 2002, Tables 9-39 and 9-40. Since data for adult staff are not available, OEHHA recommends a default value of 60 minutes daily
[i] OEHHA recommends a value of 0.45 L/min-kg for children up through age 5, and a value of 0.3 L/min-kg for older children and adults based on (OEHHA, 2000, p. 3-25 to 3.26).
[j] Based on 75^{th} percentile values from EPA, 2002, Tables 9-39 and 9-40. Since data for adult staff are not available, OEHHA recommends a default value of 480 minutes daily.
[n] The recommended default value for a 9-month school year is 180 days, the standard school-year length in California.
[o] For year-round schooling, a value of 223 days may be used.
[p] Based on (OEHHA, 2000, Table 5.13, 90th percentile).
[q] Exposure Duration is the number of consecutive years of exposure represented by the exposure scenario under evaluation.
[S] OEHHA recommends a default value of 70 years.

Risk Assessment

Chemicals of Concern

Chemicals of concern should be determined in consultation with the lead regulatory agency on the project. Suggested guidance includes DTSC, 1994, section 2.4.6.7.

Exposure Point Concentration

Exposure point concentration should be determined in consultation with the lead regulatory agency on the project. Suggested guidance includes DTSC, 1992, Chapter 2.

Toxicity Criteria

OEHHA cancer potency values and reference exposure levels, which are available at (http://www.oehha.ca.gov/risk/ChemicalDB/index.asp) should be preferentially used. Child-specific reference doses (chRD) should be used when available. When OEHHA criteria are not available, U.S. EPA criteria found in the Integrated Risk Information System (IRIS) database (http://www.epa.gov/iriswebp/iris/index.html) should be used when available. If criteria for a given chemical are not available either from OEHHA or in IRIS, criteria from other published sources may be used, subject to approval by the reviewing agency.

Risk and Hazard Calculation

Hazard quotients and incremental risks from all exposure routes are estimated and summed for each chemical. The hazard quotients and incremental risks for the individual chemicals are then added to calculate the total hazard index and total risk. For screening assessment, the default assumption is that hazards posed by individual chemicals are additive. Some non-cancer toxic effects of individual chemicals are unlikely to be additive. In those cases, a statement to that effect, with documentation based on target organ and/or mode of action, should be included.

Dose (route a) /RfD (route a) = Hazard Quotient (route a)

Dose (route b) /RfD (route n) = Hazard Quotient (route n)

Hazard Quotient (chemical a) = ∑Hazard Quotient (route a…n)

Hazard Index = ∑Hazard Quotient (chemical a…n)*
* For chemicals acting by a similar mode of action or affecting the same target organ

Dose (route a) * CPF (route a) = Risk (route a)

Dose (route b) * CPF (route n) = Risk (route n)

Risk (chemical a) = ∑Risk (route a…n)

Total Risk = ∑Risk (chemical a…n)

Risk Characterization

Following the methodology described herein will produce age-specific estimates of hazard and risk. At a minimum, the risk characterization should present risk and hazard for each year or group evaluated. In order to calculate the risk for a multi-year period, the risks for individual years must be added. Hazards are not usually considered to be additive from year to year (i.e. the chemical exerts its full effect of within one year). It may be useful to show contributions of individual chemicals and/or individual pathways to total risk and hazard.

Sensitivity Analysis

The calculated risk or hazard may be relatively sensitive or insensitive to changes in various input parameters. Sensitivity analysis is important because it can help direct research or data gathering toward those parameters that will have the most effect on the outcome. For example it would not be highly productive to measure indoor PM_{10} levels at a site where the primary contaminant of concern is trichloroethylene. Local sensitivity is the percent change in the total risk or hazard index corresponding to a small change in the value of a specific parameter divided by the percent change in that parameter. It is investigated by changing the input parameter values one at a time and measuring the effect on the risk or hazard. The local sensitivity is dependent on how the parameter is mathematically related to the result. However, it can change, depending on other inputs. For example, the model is very sensitive to changes in soil ingestion rate when soil contamination is the primary problem at a site, but relatively insensitive to changes in soil ingestion rate when ground water contamination is the primary problem at the site. The local sensitivity is also heavily influenced by the properties of the contaminant. For example, risk from volatile chemicals is sensitive to changes in breathing rate and hours spent indoors daily, while risk from non-volatile chemicals is relatively insensitive to changes in these parameters. Because of this variation in sensitivity, we focused on the maximum sensitivity observed under the conditions of our simulations.

For this analysis, representative conditions were selected. The only inputs were 0.15 mg/kg of the chemical in soil and 0.1 μg/L in shallow ground water. The following table shows the results of the analysis for 1-year-olds. The ratio of change in output/change in input has been converted to percentages, i.e. a 1:1 ratio would be shown as 100%. Some parameters (e.g. those that appear in the denominator) change the output in the opposite direction; these are shown as negative percentages. Four chemicals were selected to represent a range of physical and chemical characteristics. They include a volatile chemical, a relatively non-volatile lipophilic organic chemical, a metal and a metal that is carcinogenic by inhalation but not by ingestion. Each chemical was evaluated based on its most sensitive endpoint: For the first three the most sensitive endpoint was carcinogenicity; for the fourth, non-carcinogenic toxicity was limiting.

Table 9: Local Sensitivity

Parameter	Local Sensitivity*					Parameter Uncertainty
	Vinyl chloride	DDT	Cadmium	Chromium VI	Maximum	
Indoor dust/outdoor soil	0.10%	74.00%	77.34%	77.29%	77.34%	High
Outdoor PM10/outdoor soil	0.00%	0.00%	0.00%	0.000%	0.000%	High
Outdoor PM10	0.00%	0.00%	0.00%	0.000%	0.000%	High
Indoor PM10	0.00%	0.00%	0.00%	0.000%	0.000%	Moderate
Indoor vapor/Soil vapor (α)	93.90%	3.00%	0.00%	0.000%	93.900%	High
Kow	-0.028%	0.00%	0.00%	0.000%	-0.028%	Moderate
Fraction absorbed, resp	97.30%	4.10%	0.00%	0.000%	97.30%	Moderate
Fraction absorbed, ingest	0.20%	94.90%	99.19%	99.40%	99.40%	Moderate
Fraction absorbed, dermal	2.50%	1.20%	1.05%	0.73%	2.500%	High
Soil vapor/soil matrix (VC_S)	91.10%	0.00%	0.00%	0.00%	91.10%	High

Soil vapor/groundwater (VC_{GW})	2.90%	3.00%	0.00%	0.00%	3.00%	High
Volatilization Factor (VF)	-5.40%	-1.00%	0.00%	0.00%	-5.40%	High
Soil Ingestion	0.20%	93.20%	98.50%	98.74%	98.74%	High
Fraction at school	0.20%	94.40%	98.50%	98.74%	98.74%	High
Surface area	0.00%	0.80%	0.81%	0.567%	0.81%	Moderate
Fraction outdoors	0.00%	0.50%	0.54%	0.38%	0.54%	Moderate
Body weight	-0.20%	-85.80%	-89.54%	-89.77%	-89.77%	Low
Breathing rate, outdoors	3.40%	1.60%	0.00%	0.00%	3.40%	Moderate
Exposure time, outdoors	3.40%	1.50%	0.41%	0.29%	3.40%	Moderate
Exposure time, indoors	93.90%	2.60%	-0.39%	-0.27%	93.90%	Moderate
Breathing rate, indoors	93.90%	3.00%	0.00%	0.00%	93.90%	Moderate
Exposure frequency	100.00%	100.00%	100.00%	100.00%	100.00%	Moderate
Exposure duration	100.00%	100.00%	100.00%	0.000%	100.00%	High
Averaging time	-90.90%	-90.90%	-90.90%	0.00%	0.00%	Low
Area fraction Head	0.00%	0.30%	0.07%	-0.044%	0.30%	Low
area fraction Trunk	0.00%	0.10%	0.15%	-0.076%	0.15%	Low
area fraction Arms	0.00%	0.00%	0.06%	-0.050%	0.062%	Low
area fraction Hands	0.00%	0.10%	0.11%	0.052%	0.11%	Low
Area fraction Legs	0.00%	0.10%	0.09%	-0.019%	0.10%	Low
area fraction Feet	0.00%	0.10%	0.08%	0.027%	0.10%	Low
Loading Head	0.00%	0.30%	0.07%	0.069%	0.30%	High
loading Trunk	0.00%	0.10%	0.15%	0.15%	0.15%	High
loading Arms	0.00%	0.00%	0.06%	0.062%	0.062%	High
loading Hands	0.00%	0.10%	0.11%	0.109%	0.11%	High
Loading Legs	0.00%	0.10%	0.09%	0.094%	0.10%	High
loading Feet	0.00%	0.10%	0.08%	0.084%	0.10%	High
Reference Dose	0.00%	0.00%	0.00%	100.00%	100.00%	High
Cancer potency	100.00%	100.00%	100.00%	0.00%	100.00%	High

* Change in risk or hazard divided by change in the input parameter

Parameters that are well characterized (i.e. possessing low uncertainty) are not large contributors to uncertainty in the outcome, regardless of the sensitivity of the outcome to the parameter. Therefore, if either the local sensitivity or the range of uncertainty for any given parameter is small, changes in that parameter are unlikely to have appreciable impact on risk or hazard. In turn, research to reduce the uncertainty in that parameter will be a lower priority because the results will have less effect on the outcome than those with greater local sensitivity or uncertainty. For example for a parameter with a local sensitivity of less than 1 percent, a 10-fold error in the parameter value would change the hazard or risk by less than 10 percent. A change of less than 10 percent is not likely to change the result expressed to one significant figure. Risk assessors generally acknowledge that their results are good to only one significant figure at best. Therefore, the analysis of parameter uncertainty below is focused on those with 1 percent or greater local sensitivity and moderate to high uncertainty.

Uncertainty Analysis

Model Uncertainty

In time-dependent models, concentrations, flow rates, and dose rates change with time. Time-independent models like the one described herein assume that conditions are at equilibrium and do not change over time. They do not account for source depletion. This could result in overestimating risk, particularly if multi-year exposures are considered.

This model does not consider all possible transport mechanisms or all possible factors affecting environmental fate and transport of environmental contaminants. For example, it does not consider transport of soil contaminants to ground water, transfer from soil or air into edible plants, or redeposition of particulate matter. However, the authors believe it considers the principal determinants of chemical exposures at schools.

Exposure Pathway Uncertainty

This model does not consider all possible exposure pathways. For example, crops could be grown in site soil and contaminated ground water could be used to irrigate site-grown crops, thereby transferring contaminants to produce eaten by students and staff. Inhalation of volatile chemicals while showering is not included. The contribution of these pathways to the overall risk or hazard is minimal.

Parameter Uncertainty

In addition to a unique exposure scenario, exposure assessment for schools requires a unique set of exposure parameters. For example, building parameters, and age distribution and activity patterns of the school users differ from typical residential, recreational, and occupational settings. As discussed above, under the heading "Sensitivity Analysis," parameters with a local sensitivity of 1 percent or greater and those that have a high level of uncertainty are the primary focus of this discussion.

Transfer factor from soil to indoor dust (TF_{SD})

Interior dust is an important exposure medium in school site exposure assessment because students typically spend much of their time at school in classrooms and other indoor areas. The fraction of dust that comes from site soil is poorly characterized, but significant, inasmuch as other sources of interior dust are less affected by site selection. This parameter was considered a good candidate for further study because it has high local sensitivity (77 percent) and there are no published values for this parameter in the school setting. The recommended default dust/soil transfer factor (2) is based on relative concentrations of several elements in outdoor soil and interior dust at California schools (RTI. 2003b, see Appendix 1).

Soil vapor to Indoor air (α)

The ratio of chemical concentration in indoor air to that in soil vapor parameter (alpha) is a good candidate for further study because it has a high local sensitivity for some chemicals (up to 94 percent) and because there are limited data for ventilation rates at schools. Site-specific factors such as operation of the HVAC system (positive or negative pressure, ventilation rates, etc.), type of foundation, and use of doors and windows will substantially affect alpha. The recommended default ventilation rate for use in the Johnson and Ettinger model (4.7 changes/hr) is based on ventilation rate data from California schools (RTI, 2003a, see Appendix 1).

Volatilization factor from soil (VC_S)

The ratio of the contaminant concentration in soil vapor to that in soil matrix depends on the physical and chemical properties of the chemical, as well as soil properties. This ratio, in $\mu g/L_{vapor}/(\mu g/g_{soil})$ (or g_{soil}/L_{vapor}), has a high local sensitivity (up to 91 percent for volatile chemicals) and is relatively uncertain. However, the uncertainty can be partially offset by sampling soil vapors in addition to soil matrix. Since there is no reason to believe that $\mathbf{VC_S}$ would be different in a school environment than in other environments, OEHHA recommends the Johnson and Ettinger model (EPA, 2000 (2)) to estimate this value.

Volatilization factor from ground water (VC_{GW})

The ratio of the contaminant concentration in soil vapor to that in shallow groundwater depends on the physical and chemical properties of the chemical, as well as soil properties. This ratio, in $\mu g/L_{vapor}/(\mu g/ml_{water})$ (or ml_{water}/L_{vapor}), has a moderate local sensitivity (up to 3 percent for volatile chemicals) and is relatively uncertain. However, the uncertainty can be partially offset by sampling soil vapors in addition to ground water. Since there is no reason to believe that this factor would be different in a school environment than in other environments, OEHHA recommends the Johnson and Ettinger model (EPA, 2000 (2)) to estimate this value.

Volatilization factor (VF)

The volatilization factor has a moderate local sensitivity – up to 5.4 percent. It is based on a well-reviewed document. However, OEHHA recommends adjusting the contaminated area to 10 acres (compared to the default value of 0.5 acres) to more closely reflect the size of a school site. This reduces VF by approximately 40 percent, which increases the atmospheric concentration by about 67 percent, since atmospheric concentration is a function of 1/VF.

Soil Ingestion (I_S)

Soil and dust ingestion is a good candidate for further study because it has a high local sensitivity (up to 99 percent) and high parameter uncertainty. U.S. EPA has estimated soil/dust ingestion by children and adults, and these values are widely applied in the residential setting. There are no estimates specific to the school environment; however, some of the data, collected in day care facilities, may be relevant to a school environment. Research in the area of soil and dust ingestion in schools could reduce uncertainty in this parameter. Since the recommended value is equivalent to U.S EPA's conservative estimate of central tendency, the model is unlikely to underestimate soil ingestion for most children and adults. However a few children at the upper end of the distribution may ingest more soil than the 200 mg/day default.

Fraction at School (FS)

The fraction of the daily soil ingestion and dermal contact that occurs at school on school days is another parameter with a high local sensitivity (up to 99 percent). The recommended values are based on the estimated fraction of the waking hours that are spent at school, and the assumption that these exposure pathways are proportional to time spent in an environment (i.e., that soil ingestion and dermal contact do not occur preferentially at school or at home). The uncertainty is in both directions, but the maximum underestimate is less than two-fold, since the recommended values range from 58 to 67 percent and the true value could not exceed 100 percent.

Body Weight (BW)

Body weight has a high local sensitivity (up to -90 percent) for chemicals whose exposure is primarily by soil ingestion. This is because soil ingestion is not normalized to body weight in this model. The negative sign indicates that risk decreases as body weight increases. However, body weight is not particularly uncertain.

Breathing Rate, Outdoors and Indoors (B_O, B_I)

Outdoor breathing rate has a moderate local sensitivity (up to 3.4 percent for volatile chemicals). Indoor breathing rate has a high local sensitivity (up to 94 percent for volatile chemicals). The recommended breathing rates are based on studies involving 52 children ranging in age from 3 to 12 years and another 160 children and adults from age 6 to 77 (OEHHA, 2000, p. 3-8 to 3-13). Since activity-specific breathing rates are not available for children in a school environment, we assigned average breathing rates for indoor and outdoor activities based on breathing rates for similar activities that were reported in those studies. Detailed observations of pre-school and school children of various ages could help to reduce the uncertainty in these parameters. However, even with more data, variation between schools and between individuals is likely to be considerable, and inferences would still have to be made concerning which measured respiration rates correspond to the observed activities.

Exposure Time, Outdoors and Indoors (T_O, T_I)

The outdoor exposure time has a moderate local sensitivity (up to 3.4 percent for volatile chemicals). Indoor exposure time has a high local sensitivity (up to 94 percent for volatile chemicals). Data from EPA, 2002, Table 9-40 (used to estimate time spent outdoors on school grounds) may overestimate actual time spent outdoors on school grounds since they include time spent at playgrounds as well as at school grounds. The sum of the recommended 75th percentile exposure times indoors and outdoors is 555 to 620 minutes per day. California law requires a minimum of 50,400 minutes of instructional time per year for grades 1-8. Based on a typical 180-day schedule, this translates to 280 minutes per day. Even allowing another 90 minutes for lunch, recesses, and/or between-class time brings the total to 370 minutes, considerably less than the recommended 75th percentile estimates. Part of the difference could be explained by other time spent at school such as participation in before- or after-school activities. Surveys focused specifically on the school environment could help to narrow this range of uncertainty.

Exposure Frequency (EF)

Exposure frequency has a high local sensitivity (100 percent) because this value enters into every calculation of risk and hazard. While it is not particularly uncertain, it is quite variable, ranging from the minimum days per year required by law to a maximum for a student, staff member, or day-care child who attends the school year-round. Table 10 shows the reported number of planned school days for the current school year for the 54 California schools that interpreted the question correctly (RTI, 2003). The bimodal distribution suggests that a single value may not adequately represent the data.

Table 10: Frequency Distribution of Annual School Days

Number of Days	Number of Schools	Percent
Less than 180 days	9	16.7
180 days	34	63.0
181 to 187	8	14.8
188 to 227	0	0
228 to 238	3	5.6

Lifetime Exposure Fraction (ED/AT)

Lifetime exposure fraction is the fraction of a lifetime represented by each exposure scenario. It has a local sensitivity of 100 percent for carcinogenicity but does not enter into the calculation of the hazard index. For single-year scenarios, ED/AT is 1/70 or 0.014. Averaging time (in effect, the expected life span) has a relatively low uncertainty and is a widely applied value. Exposures need to be adjusted according to the lifetime exposure fraction because while cancer potency factors are based on lifetime exposure, this model estimates school-related exposure and risk for a series of one-year intervals beginning at birth. This involves interpolation and therefore introduces uncertainty. Since exposures differ from year to year, risks for each year are unique. Because the risks are calculated on a year-by-year basis, annual risks may be added to obtain the aggregate risk for any multi-year period.

Reference Dose (RfD)

Reference dose has a high local sensitivity (100 percent for non-carcinogenic effects). The uncertainty varies from minimal (when the RfD is based on data from sensitive humans) to considerable (when multiple uncertainty factors are involved such as when the RfD is based on laboratory animals and/or inadequate studies). The need for reference doses reflecting the potentially greater sensitivity of children to toxic effects of some chemicals is under evaluation by OEHHA.

Cancer Potency

Cancer potency has a high local sensitivity (100 percent for carcinogenic effects). The uncertainty varies from moderate (when the potency is based on human cancer incidence data) to high (when extrapolated from high-dose rodent data). There is additional uncertainty in extrapolating carcinogenic potency determined in a full lifetime study to less-than-lifetime exposure scenarios. The typical approach is to assume linearity, i.e. half the exposure is equivalent to half the risk. However, there is evidence that less-than-lifetime exposure of some carcinogens to children and infants may be more potent in inducing cancer than the same exposure later in life. Methodology to evaluate carcinogenic potency of early-in-life exposures is the subject of an ongoing OEHHA project. Because exposures at school sites are changing from year to year, and because they may be for shorter time periods than residential or occupational exposures, OEHHA deems it beneficial to assess risks on a year-by-year basis. Year-by-year exposure estimates have the potential to be used in conjunction with future age-specific exposure estimates.

Fraction Absorbed, Resp (AIn), Fraction Absorbed, Ingest (AI)

The fraction absorbed by the respiratory and ingestion routes has a high local sensitivity (up to 99 percent). The recommended default value of one implies that absorption is the same in the exposure situation as in the study(s) that are the basis for the toxicity criteria, an assumption widely accepted in the risk assessment community. In reality, the rats may have been fed or dosed with the test chemical mixed into a vehicle that enhances absorption compared to the form to which humans will be exposed. Conversely, the rats may have been exposed to a poorly absorbed form while humans are exposed to a readily absorbed form, though this seems less likely. Route-specific absorption is an important issue for inter-route extrapolation. The uncertainty is in both directions but is not likely to exceed a two- or three-fold error, since most compounds are readily absorbed the gastro-intestinal or the respiratory mucosa. OEHHA has no current plans for research on these parameters.

Fraction Absorbed, Dermal (AD)

Although the fraction absorbed by the dermal route has a moderate local sensitivity (up to 2.5

percent), it is potentially an important parameter because data on chronic toxicity or carcinogenicity by the dermal route are generally not available and therefore inter-route extrapolation is the rule. Current estimates, based on models and experiments using laboratory animals and cadaver skin, are relatively uncertain for some chemicals. However, there is no reason to believe that dermal uptake would be different in a school environment than in other exposure scenarios, and OEHHA has no current plans for dermal uptake research. The uncertainty is in both directions.

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Appendix 1: Summary and Interpretation of Results of RTI Study

OEHHA-recommended values for three exposure parameters in the schools risk assessment model are based on RTI (2003):
1) Composition of interior surface dust with respect to outdoor soil
2) Classroom ventilation rates
3) Days of instruction per year

Composition of interior surface dust with respect to outdoor soil

RTI investigated the relationship of the concentration of nine elements, (As, Cd, Cr, Cu, Pb, Ni, Se, Vd, Zn) in soil at 67 school sites to the concentration of those elements in classroom floor dust (RTI, 2003). The concentrations of three of the nine elements, chromium, nickel, and vanadium, were significantly correlated ($r = 0.55–0.64$, $p<0.001$) between these two media. The 95 percent upper confidence limits (UCL_{95}) on the median dust/soil concentration ratios for these three elements were 1.90, 2.54, and 1.53, respectively (Table A-1). OEHHA, therefore, recommends a default value of 2 for the "transfer factor from soil to indoor dust" (TF_{SD}), based on the mean of the three median UCL_{95}s.

Table A-1: Indoor Dust to Soil Ratios

	Correlation	Significance	Median Ratio	95% C.I.
Arsenic	0.19	0.10	1.88	1.62-2.05
Cadmium	0.06	0.58	2.95	2.51-4.00
Chromium	0.64	**<0.001**	**1.71**	1.48-1.90
Copper	0.03	0.81	2.95	2.39-3.48
Lead	0.17	0.13	3.07	2.27-3.81
Nickel	0.58	**<0.001**	**2.18**	1.81-2.54
Selenium	0.19	0.09	0.20	NA[1]-0.73
Vanadium	0.55	**<0.001**	**1.37**	1.26-1.53
Zinc	0.07	0.55	9.67	7.05-13.64

1 LCL on ratio not calculated due to values below the detection limit.

Other elements studied had lower correlations, but with the exception of selenium and zinc, still had similar median dust/soil ratios in the range of 1.88 to 3.07. The ratio for selenium is not reliable because of failure to detect selenium in some samples. The high dust/soil ratio for zinc is unclear, but could be the result of some (unknown) indoor source of zinc.

Classroom Ventilation Rates

RTI (2003a) reported average outdoor airflow into the classrooms of 0.8737 c.f.m. per ft^2 of floor area (95% C.I. = 0.7894-0.9579)(Table A-2). No data were collected on classroom volume. Assuming a ceiling height of 10 feet, this would yield an average classroom ventilation rate of 0.087 (95% C.I. = 0.079-0.096) c.f.m. per ft^3 (i.e. changes per minute). Multiplying by 60 min/hr yields a mean exchange rate of 5.2 changes per hour (95% C.I. =

4.7-5.7). OEHHA recommends a default air exchange rate of 4.7/hr, based on the 95 percent LCL on the mean.

Table A-2: Classroom Ventilation Rates

Parameter	units	mean	95% C.I.	5-95 percentile
Outdoor air flow/sq.ft.	cfm/ft^2	0.8737	0.7894-0.9579	0.3179-1.3854

Days of Instruction per year

Table A-3 shows the reported number of planned school days for the current school year for the 54 California schools that interpreted the question correctly (RTI, 2003b). The bimodal distribution suggests that a single value may not adequately represent the data. Therefore OEHHA recommends 180 days per year for traditional 3-season schools and 232 days per year for year-round schools.

Table A-3: Days of Instruction per year

Number of Days	Number of Schools	Percent	Cumulative Percent
Less than 180 days	9	16.7	16.7
180 days	34	63.0	79.6
181 to 187	8	14.8	94.4
188 to 227	0	0	94.4
228 to 238	3	5.6	100.0

Appendix 2: Comments and Responses

UNIVERSITY OF CALIFORNIA PEER REVIEWER COMMENTS

William W Nazaroff
Department of Civil and Environmental Engineering
University of California, Berkeley

OVERALL SUMMARY COMMENT

Overall, I found the document clear, generally well organized and easy to follow. The goals, methods, and limitations of the approach are well expressed. The document is also concise, which is a virtue. I have a concern about the overall scope of the document. Some potentially important exposures are not being considered and the justification for the omission is unclear. See below for detailed discussion.

Technically, the equations for assessing exposure and analyzing risk are generally appropriate for a screening-level assessment. Some improvement in how the parameters are presented and discussed would strengthen the report. I like that a sensitivity analysis was conducted and is presented. I think that the identification of parameters that contribute most to uncertainty should be expanded. A few concerns and several specific suggestions for improvement are described in greater detail in the following section of this review.

DETAILED COMMENTS

1. Comment - Scope of Guidance (page 8)

"Exposures to chemicals in building materials and furnishings and chemicals used in schools are beyond the scope of this guidance." It is not clear that excluding such exposures is responsive to the legislation that mandated this document. I find nothing in Health and Safety Code Section 900-901 that justifies such exclusion. Even if this can be justified, some other exposures could be of considerable concern and are neither addressed in the document nor specifically excluded. In particular, exposure to emissions from diesel school buses and to herbicides or pesticides used on the school grounds should be considered.

Response

Health and Safety Code Section 901(f) states that OEHHA is to develop guidance for assessing exposures and risks at existing and proposed schoolsites. OEHHA interprets the term "schoolsites" to mean site-related contamination as opposed to contamination related to school operations. However, in some instances it may be important to estimate health risks at existing schools from all sources. The following text has been added to the Guidelines to clarify this issue (see page 12): "Building materials and indoor products may be important sources of indoor exposure to toxic constituents at schools. It may be appropriate to include these sources of chemical exposures in the overall assessment of overall hazards and risks at existing schools. Typically these assessments would be based on measured atmospheric concentrations in classrooms and other indoor areas, and estimated risks, using the same exposure parameters, would be added to site-related risks. Hazards would be additive among chemicals sharing a common target organ and/or mode of action."

Comment

In the section "Schools Conceptual Site Model" it is stated that "this model considers contaminated soil and shallow ground water as primary source media." In fact, the exposure assessment equations include inhalation exposure to contaminants that originate offsite (such as at an upwind freeway or industrial facility). The inclusion of these sources should be clarified in this section.

Response

The wording on page 8 has been revised to include the following sentence: "As depicted in Figure 1, this model considers contaminated soil, shallow ground water, and unspecified off-site sources as primary source media."

Comment

Table 1 — Exposure Pathways (p. 11) Pathways 9 and 10 can lead to exposures by inhalation of indoor air as well as outdoor air. The equations incorporate this pathway. The column "exposure medium" should be modified to reflect this.

Response

Figure 1 is revised to reflect this change: an arrow now indicates that outdoor particulate and vapor-phase contaminants can move indoors.

Comment

3. The term "Fraction of school soil/dust ingestion that occurs indoors" (FI p. 12) appears in a few pathway equations, but is not explicitly defined in the later section on Exposure Parameters.

Response

The text on page 21 has been revised to include the following definition: Fraction indoors (FI) is the estimated fraction of the daily school-related dermal and ingested soil/dust exposure that is acquired indoors. It is calculated as 1- FO.

Comment

Concentration of PM10 in outdoor air, PM10 (p. 12). In the pathway equations, this parameter needs to be more carefully defined. It is the PM10 concentration on-site because of emissions from site soil. In fact, this will be a small fraction of the total PM10 concentration. Failure to clarify the distinction could cause important confusion. Also, below the equation for pathway 5, the CPM10 parameter should have its units specified.

Response

The definition of PM_{10} has been revised as follows:
PM_{10} = Respirable particle load for outdoor air due to resuspension of site soil (gPM/Lair).
The units "µg/g" have been added to the definition of CPM10 in equation 5.

Comment

5. Respirable particle load for indoor air, SF (p. 12 and p. 15). The definition of this parameter should be more carefully delimited. It refers to the indoor air concentration of crustal materials that originated on the site.

Response

The equation has been revised to treat indoor suspended particles as a function of indoor dust, which is, in turn, a function of outdoor soil. The default transfer factors are one (1) and two (2), respectively (See pathway 8 page 15).

Comment

6. Pathway 8 should include inhalation of indoor air (p. 13). If a chemical is vaporized from soil into outdoor air, then that chemical can enter indoor air with ventilation and be inhaled there. This is a distinct pathway from direct intrusion of the vapor into the building from the soil (as addressed by the Johnson & Ettinger model). This pathway, therefore, should have a term (BI*TI + BO*TO) in place of (BO*TO).

Response

The term (BI*TI + BO*TO) has been added to pathway 8 (See page 15).

Comment

7. Clarify that penultimate paragraph on p. 14 refers to the case of noncarcinogens only.

Response

We presume that the comment refers to the following paragraph:

Each of these equations gives a pathway-specific annual average daily dose of the chemical in question. The pathway-specific annual average daily dose is divided by the route-specific reference dose (RfD) to arrive at the pathway-specific hazard quotient (HQ). The pathway-specific HQs are added to give the chemical-specific HQ. In a screening analysis, the chemical-specific HQs for each chemical are added to give the Hazard Index. In a more detailed (tier 2) analysis, target organs and mechanisms of toxic action may be considered in determining the appropriateness of adding the HQs for individual chemicals.

The paragraph refers to non-carcinogenic effects of both carcinogenic and non-carcinogenic chemicals. Carcinogenicity is handled separately.

Comment

8. Provide a logical ordering of Intermedia Transfer Coefficients and Exposure Parameters (p. 15-21). It would be easier to follow the developments if the presentation and discussion of the parameters had a transparent logical structure. For example, a table could be provided that listed all of the parameters in alphabetical order (according to the symbols), defined them in words (1 line), and listed the page number on which the parameter value is discussed.

Response

A column has been added to tables 1 and 2 to indicate where each parameter is discussed.

Comment

9. Clarification of transfer factor from soil to outdoor particulate matter, TFPM/S (p. 15). The text should make clear that this is the transfer factor that relates the contaminant concentration in soil to the contaminant concentration in the outdoor PM that results from suspension of site soils. Because of windborne transport, the total PM10 level on site would often be much larger than that resulting from releases on site.

Response

The $TF_{PM/S}$ has been re-defined as the ratio of the concentration of contaminant in outdoor PM_{10} originating from site soils to the concentration of contaminant in soil (see page 13).

Comment

10. Default parameters for Johnson and Ettinger model (p. 15): I believe that the default conditions for the J&E model are appropriate for residential construction but may not be for schools. Details like the height of the building, the land area it covers, and the ventilation rate may be different between schools and residences. This issue requires some attention, at least at the level of further discussion in the document.

Response

The air exchange rate has been increased to 4.9 changes per hour (6.13e+5 cm^3/sec) based on (RTI, 2003)

Comment

11. Fraction at school, FS (p. 17): Clarify that this parameter represents the fraction of a school day (as opposed to an average day) that an exposed individual spends at school.

Response

Revisions on pages 13 and 20 indicate that FS represents the fraction of a school day.

Comment

12. Update NHAPS data and reference? (p. 19): Assuming that the appropriate information is contained there, the reference to Tsang and Klepeis (not “Klepis”) should be updated to the

following archival report: Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, Behar JV, Hern SC, Engelmann WH, The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants, JOURNAL OF EXPOSURE ANALYSIS AND ENVIRONMENTAL EPIDEMIOLOGY, 11 (3): 231-252 MAY-JUN 2001.

Response

The reference has been changed.

Comment

13. Table 3 typgraphical error: Change “Cm” to “cm2” in 6 places in the second column.

Response

The error has been corrected.

Comment

14. Strengthen Uncertainty Analysis: The sensitivity and uncertainty analysis is a welcome part of this report. Table 4 presents an important, but only partial picture of the degree to which different parameters affect the outcome, by indicating the change in intake per unit change in each parameter. The other important factor, recognized in the text, is how variable and how uncertain the parameters are themselves. Certain parameters vary only over narrow ranges, e.g. a factor or two or less. Other parameters can vary over orders of magnitude. The parameters that are narrowly variable and well characterized (so possessing low uncertainty) are not large contributors to uncertainty in the outcome, regardless of the sensitivity of the outcome to the parameter. I would like to see Table 4 complemented by another table that provides some indication of the variability of each parameter, and the likely degree of uncertainty in its determination. The combination of all of these would provide an overall sense of which of the parameters is most important in the overall uncertainty of the risk assessment.

Response

An ‘uncertainty” column has been added and the discussion revised (see page 28).

Comment

15. Improve reference list: Wherever possible, web links should be provided to government reports.

Response

Web links have been provided where appropriate.

Michael T. Kleinman

Department of Community and Environmental Medicine

University of California, Irvine

General Comments:

This guidance is intended to:

- Support assessment of chemical exposures and health risks at existing and proposed school sites,
- Characterize uncertainty in assessing exposure and risk in the school setting,
- Suggest which areas are most in need of further research.

To this end, the guidance addresses the differences between children and adults, and between the school setting and other settings. Recognition is given to the concept that children differ from adults anatomically, physiologically, and behaviorally in ways that affect their exposure to environmental contaminants. A modeling approach is used to predict exposures and risks to preschoolers, students, teachers and other school personnel, and their offspring, from chemicals in the soil, shallow ground water, and air at the school site. A spreadsheet is provided which facilitates the application of the model to estimating exposures. Overall the guidance provides and integrated exposure assessment approach, and achieves many of the objectives for the guidance. There are, however, some areas in which the guidance could have been improved. Some examples of these are provided below.

Comment

Other sources – the document states "in some cases, it may be appropriate to add in additional sources of chemicals in the environment. For example there may be off-site emissions that may impact on-site concentrations". It is not clear what those sources might be and some concrete examples would be helpful.

Response

The following language has been added to the Guidelines to clarify this issue (see page 11): "*Atmospheric emission sources within ½ mile of the site which have the potential to contaminate on-site air may be important in estimating overall toxic exposures. Examples could include fixed facilities with known emissions and mobile sources such as highways, heavily traveled streets, or vehicle loading areas*."

Comment

1. In addition, it is stated that "Exposures to chemicals in building materials and furnishings and chemicals used in schools are beyond the scope of this guidance" No justification is given as to why these on-site sources would not be considered while some unspecified off-site sources would be included. An example that comes to mind would be radon from building materials, formaldehyde from floor coverings etc. The guidance should provide a generalized approach as to how these factors could be included in a total exposure assessment.

Response

The following text has been added to the Guidelines to clarify this issue (see page 12): "Building materials and indoor products may be important sources of indoor exposure to toxic constituents at schools. It may be appropriate to include these sources of chemical exposures in the overall assessment of overall hazards and risks at existing schools. Typically these assessments would be based on measured atmospheric concentrations in classrooms and other indoor areas, and estimated risks, using the same exposure parameters, would be added to site-related risks. Hazards would be additive among chemicals sharing a common target organ and/or mode of action."

Comment

2. Target Organs – The document states "Hazard quotients and incremental risks are estimated for each chemical; then the hazard quotients and incremental risks associated with the individual chemicals are added to arrive at the total hazard index and total risk. If the total hazard index does not exceed one, then it may be assumed that the non-cancer toxic effects are unlikely and further analysis of non-cancer effects is not necessary. If the total hazard index exceeds one, it may be useful to separate chemicals by target organ and/or mode of action and add the hazard quotients of only those chemicals that are likely to act in an additive manner. This target organ/mode of action analysis should be documented.". Having said that it would have been useful for the document to specify precisely how such a target organ approach might be addressed, at least in general terms. Thus it would be very useful if the worksheet of potential contaminants could be indexed with respect to target organs to facilitate the computation of target organ specific hazard indices as suggested in USEPA OAQPS 2001.

Response

We agree that it would be useful if the worksheet of potential contaminants were indexed with respect to target organs to facilitate the computation of target organ specific hazard indices; this is something we will address as resources permit.

Comment

3. The approach taken to distinguish between characteristics of children in different age groups is reasonable and appropriate.

Response

No response

Comment

4. The factor that lowers enthusiasm for this guidance the most is that it treats school exposure for the most part in a vacuum, i.e. personal exposure of individuals also includes exposures incurred away from school and from other sources. The risks from the school exposures, if any, are only a part of the overall risk. While it may be beyond the scope of this specific document to estimate these risks, it should be clearly expostulated within the document that children in different parts of California have different background exposures. It would seem to be important that these be considered at least in part before determining that exposures to be incurred in a school setting are

acceptable. Some suggestions should be included as to how these background risks can be estimated – at least on some average level. There are some modeling approaches (ASPEN) and emissions inventories (Toxic Release Inventory) that could be used to establish and update potential community background levels for specific chemicals found on the school site so that the school exposure does not represent the "straw that breaks the camel's back".

Response

A given incremental dose of a toxic constituent that would otherwise be of no concern, may be a concern if the receptor is already receiving a background dose of the constituent near the toxic threshold. For this reason, risk managers may wish to take background exposures into account in their decision-making process. This is suggested in new language added to the Guidelines (see page 12). The "camel's back" phenomenon would impact only those sites where risk management decisions are driven by non-carcinogenic effects. Since carcinogens are treated as exhibiting no threshold, background exposure levels would not affect the incremental risk posed by the contamination at the school site.

Comment

5. The document states "Concentration of site-related particulate material less than 10 microns in diameter in outdoor air (PM_{10}). OEHHA recommends a default value of 1.8 E-9 g PM/L (1.8 $\mu g/m^3$). This value is based on the EPA Soil Screening Levels document (EPA, 1996)". This value seems to be very low when contrasted with measurements of resuspended dust in California made by the Air Quality Management District. On an annual basis resuspended surface material contributes about 20-30 percent of PM10. Given the average PM10 concentration in California is higher than that in most communities in the US, a more realistic default value would be on the order of 5 to 10 $\mu g/m^3$. The authors should consider increasing this default value and re-estimating the sensitivity to this parameter.

Response

The proposed value is for respirable particulate matter resuspended *from the site*. If the suggested value of 5 to 10 $\mu g/m^3$ represents total resuspended surface material, then the proposed value of 1.8 $\mu g/m^3$ would represent 18 to 36 percent of the total, which we believe is a conservative estimate of the fraction of total resuspended surface material that would be from the site.

Comment

The use of the spreadsheet was mentioned but it would be extremely helpful to provide the documentation and instructions as a appendix to the guidance document.

Response

A new sheet "User's Guide" has been added to the spreadsheet, in order to clarify how the spreadsheet should be used. We have avoided making the spreadsheet part of the Guidance in order to avoid the implication that the spreadsheet must be used in order to comply with the guidance.

Comment

I attempted to use the spreadsheet, and inserted Soil Cleanup Levels for several toxic compounds. I estimated that at a benzene level of 60 µg/kg soil the exposure produced a cancer risk of 2.5 x 10^{-5}. Other toxic compounds produced higher values. I presume that I did the calculations incorrectly but it would be useful to check the spreadsheet's output with values taken form some set of soil cleanup guidelines.

Response

The spreadsheet gives a single-highest-year risk estimate of 1.6e-8 for 1-2 year-olds **at a benzene level of 60 µg/kg soil**. There is reason to expect that the estimated risk at a soil concentration corresponding to a Soil Cleanup Levels would not be 10^{-6} if the Soil Cleanup Level is based on a scenario other than the school scenario. The legislature mandated that we develop methodology for estimating risk at schools based on the assumption that risk at schools would be different from risk associated with residential, commercial, and other scenarios.

PUBLIC COMMENTS

Dr. Mark C. Rigby, Tetra Tech

Comment

"The purpose of this [PEA] screening evaluation is to provide the risk manager with an estimate of the potential chronic health hazard from contamination at the site. The anticipated use of this screening evaluation is to assist the risk manager in deciding whether further site characterization, risk assessment, or remediation is necessary." The objective of the PEA at a proposed school site is to provide a timely and health-protective screening level evaluation, as stated in the quote above from the PEA manual.

Response

The draft guidance document was prepared to comply with California Health and Safety Code Section 901(f), which requires OEHHA to develop and publish a guidance document for use by the Department of Toxic Substances Control (DTSC) and other state and local environmental and public health agencies to assess exposures and health risks at existing and proposed school sites. Although DTSC may choose to use the Guidance within the PEA framework, there is no such requirement in the law. Other agencies may use the Guidance in other contexts such as CEQA. The law mandates the use of "appropriate child-specific routes of exposure unique to the school environment, in addition to those in existing exposure assessment models" and the "identification of uncertainties in the risk assessment guidance and those actions that should be taken to address those uncertainties."

Comment

The exposure equations are not in the standard form given in U.S EPA's RAGS and use a different terminology.

Response

While some minor aspects may differ, the general form of the equations is consistent with U.S EPA's RAGS, i.e. the concentration in a contact medium times a contact rate with that medium times an absorption rate to give a daily dose, which, when multiplied by an exposure frequency (expressed as a fraction of a year) gives an annual average daily dose. The annual average daily dose, multiplied by exposure duration divided by averaging time gives a lifetime average daily dose.

Comment

The dermal exposure equation provided in the draft guidance is more complicated than that given in RAGS.

Response

The draft guidance follows the methodology found in the EPA Children's Exposure Factors Handbook, which more accurately describes the way soil adheres to skin in a "real-world" situation.

Comment

Several exposure parameters not in RAGS are used, for which the default factor is assumed to be 1. Eliminating these exposure factors would simplify and expedite the use of the guidance and would not change the outcome from the default scenario. The exposure parameters that with a default of 1 are: AI AD TFSD TFPM/S TFI/O Ain. The indoor dust pathway, as provided in the default form given in the draft guidance, does not differ from the outdoor dust/soil exposure pathway. As such, it is redundant.

Response

A guiding principle in developing this guidance was that implicit assumptions should be made explicit. Besides making the methodology more transparent, this allows for replacing the value of one (1) with a chemical-specific value other than one, when new data support an alternative value. The legislative mandate requires identification of uncertainties in the risk assessment guidance and those actions that should be taken to address those uncertainties. These transfer factors are uncertain and therefore must be included in order to capture the uncertainty. A discussion of the factors mentioned in the comment follows:

TFSD, TFPM/S, and TFI/O are transfer factors, not exposure parameters. Since RAGS does not deal with intermedia transport, these parameters would not be expected to be in RAGS.

TFSD - OEHHA currently recommends a default value of 2 for TFSD, based on the results of recent research.

AD - Absorption by the dermal route is found in RAGS and chemical-class-specific values are proposed.

AIn and AI - Absorption by the inhalation and ingestion routes have implicit values of unity in RAGS. This guidance makes the value of unity explicit.

Comment

Exposure parameters are given for 1 year intervals for children. This requires that the consultant derive appropriate exposure parameters for each site de novo, demonstrate that they are appropriate, and that DTSC approve them. This may lengthen the PEA process for each site. To expedite the process, default exposure parameters could be provided for the most frequent types of schools, e.g. pre-schools, Kindergartens, Elementary schools, Middle schools w/elementary schools, Middle schools, High schools w/middle schools, and High Schools. Providing the yearly exposure parameters in an Appendix would allow consultants to derive specific exposure parameters for those cases that did not fit into the defaults given above.

Response

Default exposure parameters are provided for each year from birth through age seventeen and for adults. The burden of gathering this information is not placed on the user. Default parameters for multi-year periods were considered and rejected because this method would base the hazard index on an average exposure for a multi-year time period and would not capture the single highest year. Furthermore, the use of individual years gives the assessor and the reviewing agency more flexibility. While individual years can be aggregated into groups to match a proposed exposure scenario, multi-year bins can not be easily disaggregated. Disaggregation would be necessary if the assessment period did not match the exposure scenario. For example some districts have elementary schools covering grades K-6, while others have primary schools from K-3 and middle schools from 4-6 on different sites.

Comment

The draft guidance provides a simplified equation for determining outdoor air concentrations of volatiles that have migrated from subsurface soil or shallow groundwater sources. The consultant need only supply the chemical concentration in soil/groundwater and the chemical-physical properties. For indoor air, however, the draft guidance states that the Johnson and Ettinger model from USEPA should be used, but no defaults are supplied. The PEA process would be greatly expedited if default building and soil properties, as well as contaminant depths, were supplied. If this were done, a simplified model could be derived (akin to the VF emissions model) that only requires the input of chemical concentration in soil/groundwater and chemical-physical properties.

Response

OEHHA is proposing a default air exchange of 4.5 changes per hour (613,426 cm3/sec in the EPA indoor air model), based on recent studies of California classrooms (RTI, 2003).(see Guidance page 17). Default parameter values will be considered for other parameters. DTSC's indoor air working group is developing recommended default values for some parameters.

Comment

To expedite the PEA process as much as possible, default simplified risk assessment equations could be provided. Such equations were provided in the original PEA manual (DTSC 1999) and only require the input of chemical concentrations and toxicity values (in addition to any modeling necessary to calculate concentrations).

Response

Default risk assessment equations are provided. They are not simplified, but they only require the input of chemical concentrations in selected media and toxicity values (which are provided for some chemicals). These risk assessment equations have been incorporated into a spreadsheet, which can be recalculated virtually instantaneously by most computers. While it would be possible to further simplify the equations by collapsing all exposure parameters into a single pathway exposure factor as the PEA does, this would sacrifice transparency and the ability to substitute case-specific parameters in a tier 2 assessment when appropriate.

Comment

The draft guidance includes the assessment of risks from the migration of offsite dusts and vapors to the school site. This is more appropriately addressed in an EIA/EIS. Risk assessments normally evaluate the risks from contaminants that originate at the site.

Response

This guidance may be used in a variety of contexts including environmental impact analysis. For some purposes, some pathways in the model may not be appropriate. Pathways may be eliminated with the approval of the reviewing agency.

Comment

If local background is evaluated in the risk assessment, it is to subtract the risks from local background from the site-specific risks

Response

The guidance addresses methodology for estimation of dose and risk from environmental contamination at a proposed or existing school site. Contaminant source allocation, and management of contamination are in the domain of risk management, and are outside the scope of this guidance.

Comment

Draft USEPA guidance is cited as the source of some of the information. However, by its very nature, draft guidance is rather labile.

Response

The guidance referred to is now interim final.

Bill Piazza, LAUSD

Comment

In general, the District agrees with the refined methodology recommended in the draft assessment protocol which allows consideration of "reasonable" exposures anticipated to occur at school sites. Nevertheless, the methodology is unnecessarily specific in its attempt to quantify risk. The District contends that until toxicity factors are developed for school aged children, the quantification of risk for each grade level will not reveal a significant difference over the risk value predicted with average exposure factors for a given occupancy.

Response

For some chemicals, the estimated dosage in the first year of life is as much as 2.7 times the average for birth through age seventeen. OEHHA considers a 2.7-fold difference worth considering. And once the algorithms are incorporated into a spreadsheet, the extra calculations are little, if any, extra effort.

Comment

In addition, the methodology is not consistent with existing assessment methodologies utilized for the Safe Drinking Water and Toxic Enforcement Act (Proposition 65), Air Toxic "Hot Spots" Information and Assessment Act (AB 2588) and related California Air Resources Board (ARB) assessment activities prepared under the auspices of the Toxic Air Contaminant Identification and Control Act (AB 1807). The District's concern is exemplified with the pending adoption of ARB's Regulation Order to limit school bus idling and idling at schools. The purpose of the air toxic control measure is to "reduce public exposure, especially school aged children's exposure" to pollutants by "limiting unnecessary idling" of specified vehicular sources "at and around schools and while riding school buses and other types of school transportation." Please note that the ARB utilized the assessment methodology outlined in OEHHA's Air Toxic Hot Spot Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Assessment and Stochastic Analysis to establish a set of defined control measures. The specific exposure assumptions are presented in ARB's Staff Report: Initial Statement of Reasons (ISOR), Appendix C: Idling Diesel School Bus Health Risk Assessment Methodology. The District believes that due to the regulatory nature of the assessment, which identifies operational controls for school bus owner/operators to actually reduce school-based exposures, justifies its use as an appropriate methodology. Nevertheless, the District is aware that one may argue that the various State agencies and their associated regulatory programs require different methodologies to assess risk. As such, assumptions such as exposure frequency and duration may differ producing varying risk values for a given exposed population. However, the District believes that a school is a school regardless of the specific regulatory program. To argue that one agency should assess school exposures with one set of assumptions while another consider different exposure variates for the same occupancy, promotes a lack of consistency between the various State boards and departments and does little to encourage the harmonization in the practice of risk assessment within Cal/EPA. As a result, the assessment of a school-based occupancy must be consistent with all programs which quantify risk for this sensitive subpopulation.

Response

This Guidance also utilizes some of the assessment methodology and parameter values outlined in OEHHA's Air Toxic Hot Spot Program Risk Assessment Guidelines, Part IV, Technical Support Document for Exposure Assessment and Stochastic Analysis. To the extent that there are differences, these reflect the different mandate for this program.

Comment

1. Units of measure are not consistent with industry standard. This may present an unnecessary source of error upon unit conversion and present some difficulty in reviewing empirical data and related workbook calculations. For example:

- Soil concentration (e.g., ug/g to mg/kg)
- Particulate airborne concentrations (e.g., ug/l to ug/m3)
- Volatile airborne concentrations (e.g., ug/l to ug/m3))
- Cancer Potency Factors (e.g., ug/kg/day to mg/kg/day)

Response

- Soil concentration units have been changed to mg/kg
- Particulate and volatile airborne concentrations have been changed to mg/l
- Cancer Potency Factors units have been changed to (mg/kg/day)-1

Comment

2. Calculation of the hazard index does not consider toxicological endpoints. This is not consistent with existing guidance (OEHHA, 2000). The inclusion of this refinement is most relevant as many removal actions currently undertaken by the District are based upon screening values. As such, unity may be exceeded necessitating an unwarranted response action. The ability to readily identify and quantify the hazard index should be included in the proposed methodology. The following excerpt from U. S. EPA's Risk Assessment Guidance for Superfund Volume I - Human Health Evaluation Manual (RAGS) underscores the viability of the District's concern regarding dose additivity. Another limitation with the hazard index approach is that the assumption of dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action. Consequently, application of the hazard index equation to a number of compounds that are not expected to induce the same type of effects or that do not act by the same mechanism could overestimate the potential for effects, although such an approach is appropriate at a screening level. This possibility is generally not of concern if only one or two substances are responsible for driving the HI above unity. If the HI is greater than unity as a consequence of summing several hazard quotients of similar value, it would be appropriate to segregate the compounds by effect and by mechanism of action and to derive separate hazard indices for each group.

Response

Calculation of the hazard index does consider toxicological endpoints. See pages 8 and 25.

Comment

3. Several exposure variates differ from existing guidance (OEHHA, 2000). Many are taken from a draft guidance document (U.S. EPA, 2000). If these values are more appropriate, then OEHHA should revise current guidance for consistency. For example:

- Skin surface area (U-S- EPA, 2000)
- Breathing Rates (not consistent with OEHHA recommended values)
- Body Weights (U.S. EPA, 2000)

Response

The Child-Specific Exposure Factors Handbook is now a citable Interim Report

The skin surface area data were generated in a setting similar to a school environment (day care) and are therefore relevant for school exposure estimation.

The OEHHA-recommended breathing rates (Table 3.22, in Technical Support Document for Exposure Assessment and Stochastic Analysis, OEHHA, September 2000) are for assessment of long-term average exposures. They are not activity-specific as required.

The recommended body weights have been revised to agree with Tables 10.1 (staff) and 10.3 in (Technical Support Document for Exposure Assessment and Stochastic Analysis, OEHHA, September 2000).

Comment

4. Exposure times should be reviewed and revised, as appropriate, following input from school district personnel. Stakeholder input, rather that U.S. EPA's draft documentation, should be utilized to develop viable exposure times. For example, OEHHA assumes most kindergarten students spend over nine hours per day at school. To the contrary, most kindergarten students spend no more than 4 hours per day at school.

Response

The guidance has been revised to reflect recent survey data (RTI, 2003) with respect to exposure frequency. Children 0-6 may be in day care for a full school or work day.

Comment

5. Uncertainty with the use of the Johnson and Ettinger Model should be discussed. OEHHA should address concerns raised regarding the model's accuracy before recommending its use.

Response

Uncertainty associated with the use of the Johnson and Ettinger Model is discussed in the Uncerainty section.

Comment

If utilized, the model must be programmed to account for vapor intrusion into institutional (e.g., Department of Education approved) buildings and not a single-family residence. For example, a default air exchange rate of 0.45 per hour is inappropriate for institutional buildings with markedly higher ventilation rates which range from 4 to 7 air changes per hour (e.g., 50 CFM per person).

Response

The guidance has been revised to reflect recent survey data (RTI, 2003) with respect to default air exchange rates.

Comment

6. The school's conceptual site model must be further defined. School-based exposures must be plausible and likely to occur for a given occupancy. A discussion similar to U.S. EPA guidance must be included to further define "reasonable" exposure pathways. The District's recommendation is exemplified by the following excerpt from RAGS. There are two steps required to determine whether risks or hazard indices for two or more pathways should be combined for a single exposed individual or group of individuals. The first is to identify reasonable exposure pathway combinations. The second is to examine whether it is likely that the same individuals would consistently face the "reasonable maximum exposure" (RME) by more than one pathway. Identify exposure pathways that have the potential to expose the same individual or subpopulation at the key exposure areas evaluated in the exposure assessment, making sure to consider areas of highest exposure for each pathway for both current and future land uses (e.g., nearest downgradient well, nearest downwind receptor). For each pathway, the risk estimates and hazard indices have been developed for a particular exposure area and time period; they do not necessarily apply to other locations or time periods. Hence, if two pathways do not affect the same individual or subpopulation, neither pathway's individual risk estimate or hazard index affects the other, and risks should not be combined. Once reasonable exposure pathway combinations have been identified, it is necessary to examine whether it is likely that the same individuals would consistently face the RME as estimated by the methods described in Chapter 6. Remember that the RME estimate for each exposure pathway includes many conservative and upper-bound parameter values and assumptions (e.g., upper 95th confidence limit on amount of water ingested, upper-bound duration of occupancy of a single residence). Also, some of the exposure parameters are not predictable in either space or time (e.g., maximum downwind concentration may shift compass direction, maximum ground-water plume concentration may move past a well). For real world situations in which contaminant concentrations vary over time and space, the same individual may or may not experience the RME for more than one pathway over the same period of time. One individual might face the RME through one pathway, and a different

individual face the RME through a different pathway. Only if you can explain why the key RME assumptions for more than one pathway apply to the same individual or subpopulation should the RME risks for more than one pathway be combined.

Response

All pathways included in the guidance may affect the same child with two exceptions: The breast milk pathway does not affect children above one year of age, and the soil ingestion pathway does not affect children less than one year of age. Thus, these pathways are not additive. A column has been added to Table 2 indicating for each exposure parameter whether it is mid-range or upper end, and some discussion of upper end versus mid-range has been added to the uncertainty section on page 30.

Comment

Some discussion on acceptable level of risk should be introduced. OEHHA administers Proposition 65 which supports the State's "level posing no significant risk" of one in one hundred thousand (I.0E-05), not the value of one in one million (I 0E-06) as used in Environmental Assessment screening guidance and adopted as the Department of Toxic Substances Control's acceptable level of risk. As noted above, removal actions currently undertaken by the District are based upon these screening evaluations. The District contends that the "no significant risk levels" established by the State are relevant and appropriate and should be considered when refined assessment activities are conducted.

Response

Acceptable or target risk levels are in the risk management domain. The guidelines cover risk assessment and exclude risk management.

Comment

Please note that the District considers all relevant and appropriate exposures to assess risk for its existing school occupancies. As such, the District has developed a guidance document and associated Excel spreadsheet to quantify school-based risk. The methodology is based upon the above referenced technical support document (OEHHA, 2000) with exposure parameters assigned by occupancy (e.g., kindergarten through the 6 grade). The District believes it is consistent with OEHHA's existing assessment methodology. The program's format allows for quick data entry and is robust in its computational ability to quantify risk for a suite of identified compounds. The guidance document is included for your review and consideration. Staff is currently finalizing the Excel spreadsheet for distribution and will forward an electronic copy for your review the week of February 3rd.

Response

OEHHA has received and reviewed LAUSD’s guidelines.

Lee Shull and Mark Bowland, Montgomery Watson Harza

As a follow up to recent discussions, this letter presents MWH's review comments on OEHHA's draft (File date 10/3/02, header date August 20, 2002) Schools Risk Screen Model (Model). The Model we reviewed was provided by OEHHA to Mr. Ernest Silva of the Coalition for Adequate School Housing (CASH). Our review has been performed on behalf of CASH. Both CASH and MWH greatly appreciate the opportunity to review the Model and provide these comments, and look forward to assisting OEHHA however we can as the agency continues its development of the schools program. Whereas this letter provides substantively technical comments, we will provide our comments on the Model as it relates to policy and implementation issues in a separate letter.

For practical purposes, we have organized our comments on the Model and the associated guidance document into four basic areas: (1) identification of potentially fatal flaws/errors/omissions in the Model, (2) critical flaws/errors/omissions in the Model, (3) suggested user interface improvements, and (4) general/editorial comments.

Comment

1. Input-output sheet. Results include a "0-18 + staff' endpoint. This endpoint assumes that a child spends the entirety of his/her education (preschool through high school) at a single campus, and then post college teaches an entire career at the same campus. This essentially assumes 43-year exposure duration (ED), which is greater than the current residential default assumption. We believe this endpoint is an unreasonable point of departure for decision making. We encourage OEHHA to develop a more reasonable ED value for inclusion in the model.

Response

Which years are aggregated is a case-specific, user/reviewer decision. We have removed the cells labeled "0-18 + staff” to avoid the implication that any particular exposure duration is "approved" by OEHHA.

Comment

2. Groundwater and soil vapor input cell. If a value of "0" is placed in both the groundwater and soil vapor concentration input cells, calculation errors (#value!) Prevent production of useful risk or hazard values.

Response

This error has been corrected.

Comment

3. <u>J&E</u> model database. If a chemical that is not part of the J&E model database is selected, calculation errors occur due to J&E malfunction. Documentation instructs the user to add the chemical to the database, but gives no procedure for performing this function (the sheet is password protected).

Additionally, no guidance is given to direct the user when it is essential to add a volatile chemical to the database, or what data must be entered into all the relevant "vlookups" sheets for all three J&E model components (i.e., soil, soil gas, groundwater). Additional text should be added to the model documentation and model spreadsheets outlining the procedures necessary for adding these features. Also, we suggest a single "vlookups" sheet for all three model components to reduce the potential for user entry error.

Response

The duplicate "vlookup" and "chemprops" sheets have been eliminated, so that the relevant information needs to be added in only one place. Guidance has been added as to when and how to add chemicals to the database.

Comment

4. *Route-to-route extrapolation*. In cases where route-to-route extrapolation is rejected in Input-Output (cells B 13 and/or B 18 given values of "0"), all exposure sheets do not reference the user supplied RfD or CSF values for soil direct contact.

Response

This error has been corrected.

Comment

5. Input-Output Sheet. If a user allows the model to perform route-to-route extrapolation of oral and dermal toxicity criteria from inhalation toxicity criteria, the model may use an inappropriate toxicity metric for the oral and dermal pathways. For example, the inhalation cancer slope factor for 1,4-dichlorobenzene is 4×10^{-2}. The oral cancer slope factor is 5.4×10^{-3}, or 7 times lower. Similarly, the inhalation cancer slope factor for 1,3-butadiene is 0.6, whereas the oral cancer slope factor is 3.4, or six times higher. An additional issue with this procedure is the implication that use of inhalation toxicity factors as surrogates for oral and dermal exposures is appropriate. For numerous inorganic chemicals (nickel, chromium 6+, cadmium) this implication has potentially enormous ramifications, as these inorganics are not currently considered carcinogens by the oral routes. We suggest adding a toxicity criteria table containing both oral/dermal and inhalation toxicity criteria, or defaulting to a user input toxicity criteria for each route and for each chemical for the oral and dermal pathways.

Response

The intent is not to automatically default to inter-route extrapolation. In order to make this intent clearer, the spreadsheet now uses an exclusive user-supplied CPF and RfD as an alternative when these parameters are not in the database. The reviewer should ensure that the assessor documents any user-supplied CPFs or RfDs.

Comment

6. Input-Output Sheet. Results for cancer risk for scenario 0-4 sums 0-5 results, 5-10 scenarios sums 0-6 results, not 5-10 results.

Response

The error for 5-10 year olds has been corrected. The sum for ages 0-4 should include 4-5, since these are four-year-olds.

Comment

7. Volatilization assumption It is doubtful that DDT (and similar semi-volatile compounds) would actually volatilize in appreciable concentrations. It is our opinion that semi-volatiles such as DDT should not be modeled to indoor air.

Response

We agree that DDT and similar semi-volatile compounds will not volatilize in appreciable concentrations, because of the low volatility of these compounds. For example, the indoor air pathway contributes 0.04 percent of total risk for DDT.

Comment

8. Fate. Cell C22 contains a reference error that prevents a breast milk pathway calculation.

Response

This error has been corrected.

Comment

9. Input-Output sheet + Fate. Units for chemical concentration in PM10 are different between these sheets (ug/L versus ug/g).

Response

This error has been corrected.

Comment

10. Fate. Toggles don't function when a chemical is not in the database (e.g., metals) because an error message is created. Logic equations rather than simple arithmetic equations would prevent this from occurring. Also, see comment #3.

Response

I was unable to replicate the problem

Comment

11. Fraction at school is used to partition daily soil ingestion. Guidance documents indicate that this fraction should also be incorporated into dermal dose calculations as indicated by the equation on page 4 of the guidance document. We agree with this conclusion. However, this fraction appears only to be included in the age 3-4 exposure spreadsheet and in none of the other dermal dose calculations.

Response

This error has been corrected.

Comment

12. Dermal exposure assessment. The approach for dermal exposure assessment represents a departure from current OEHHA, DTSC, and USEPA dermal assessment protocols. Additional discussion highlighting the need/utility of this new protocol should be included in the guidance document.

Response

The selected approach is recommended by EPA, and is based on data relevant to the school scenario. The Guidance discusses the salient arguments for selection of this approach.

Comment

13. *Fate.* Cell H7. The on-site soil-to-indoor dust Transfer Coefficient (dermal) does not appear to be used in the calculation.

Response

This error has been corrected.

Comment

14. Indoor air modeling. Default indoor air modeling is based on Johnson and Ettinger model parameters for residential homes, which clearly do not apply to schools. The model and model documentation do not provide adequate guidance on what model parameters may be modified or how such modifications may be incorporated. We suggest, for screening, applying conservative but non-residential parameters.

Response

OEHHA proposes a default air exchange rate of 4.9 per hour, the lower confidence limit on the weighted mean value from 94 portable and 26 traditional classrooms (RTI, 2003). This and other parameters may be changed from default values when justified and documented.

Comment

15. Age-specific exposure sheets. Soil Ingestion. P. 11. Of the OEHHA school model guidance document cites OEHHA *(2000)* guidance for soil ingestion. OEHHA (2000) recommends 200 mg/day soil ingestion for children age 1-6 and 100 mg/day for "everyone else." This approach is inconsistent with the available data, which indicate adults, and especially adults in non-soil intensive exposure work environments, do not consume 100 mg/day. This approach is also inconsistent with other Cal/EPA guidance for worker soil and dust exposures, and is also inconsistent with USEPA's recommended *50* mg/day for adults.

Response

The soil ingestion rate in question (100 mg/day) is partioned such that only 58 percent of that amount (58 mg/day) is assumed to occur at school. Since most estimates of occupational exposure consider only the fraction of total exposure that occurs in the occupational setting, the assumptions are not far apart (50 mg/day versus 58 mg/day).

Comment

16. Potential users of the spreadsheet. It is critical that OEHHA state that the spreadsheet and guidance document are `expert tools' and not intended to be layperson tools.

Response

The follosing sentence has been added on page 8: " This guidance assumes that the user is familiar with the principles of chemical risk assessment; it is not intended to provide basic instruction in risk assessment."

Comment

17. Dust exposure. The utility of differentiating indoor dust from outdoor dust in the model is uncertain. Most schools will go through the assessment process prior to construction and performing any measurement of chemical concentrations in indoor dust. Separating soil ingestion, dermal and inhalation pathways in this fashion may lead to more confusion than clarity.

Response

Recent field studies have demonstrated a concentrating effect for several elements in indoor dust compared to school-yard soil (RTI, 2003). OEHHA is now recommending a default value of 2 for the soil/dust transfer factor (see page 17).

Comment

18. Toxicologic endpoints. No discussion or delineation in the model/model documentation is presented that addresses assessment of specific toxicologic endpoints (also referred to as target organ toxicity). This is an important subject and should be explicitly addressed in the guidance, and where possible, in the model itself.

Response

The additivity of hazard quotients for different chemicals based on their target organ and/or mode of action is discussed on page 9: "If the total hazard index does not exceed one, then it may be assumed that the non-cancer toxic effects are unlikely and further analysis of non-cancer effects is not necessary. If the total hazard index exceeds one, it may be useful to separate chemicals by target organ and/or mode of action and add the hazard quotients of only those chemicals that are likely to act in an additive manner. This target organ/mode of action analysis should be documented." Similar language is in the sheet "user's guide." Chemical-specific information on additivity is available elsewhere.

Comment

19. Stakeholder involvement in Model development. No indication is provided in the guidance documents that stakeholders have been included in the development of key exposure parameters such as exposure time and exposure frequency. This lack of involvement increases uncertainty as to whether the values used in the model for these parameters are representative of California school conditions. CASH is in a unique position to provide data specific to public schools for these parameters.

Response

The opportunity for stakeholder involvement was open through May 2003. All recommendations for parameter values that were supported by documentation were considered.

Comment

20. Annual risk estimations. The assessment of theoretical upper-bound cancer risk and non-cancer hazard indices on a year-by-year basis is a new risk assessment approach. Hopefully, OEHHA has carefully considered the propriety of this approach. We assume that this approach is used in consideration of the new age-specific toxicity criteria (OEHHA, 2002 draft, p.11) under development by OEHHA. Until these criteria are developed, we are uncertain of this approach.

Response

The language in HSC Section 901 suggests that the legislators were concerned that typical risk assessment paradigms (which use longer-term average exposure rates) fail to consider the specific exposures and sensitivities of children. OEHHA took this as a mandate to look specifically at the exposure parameters of young children. To do this effectively required using age-specific exposure parameters. As noted in the comment, this approach is also anticipates development of age-specific toxicity criteria by OEHHA.

Comment

21 Consistency with other OEHHA guidance. The model incorporates assumptions that vary from other currently available OEHHA risk assessment guidance (OEHHA, 2000) without defining the need for the variation. Variations from published agency guidance should be discussed including rationale as to why OEHHA believes the approach/assumptions in the model is more applicable to the schools risk assessments.

Response

Though it is not further described in the comment letter, we assume that "(OEHHA, 2000)" refers to the "Technical Support Document for Exposure Assessment and Stochastic Analysis" (TSD). The TSD was created for a different purpose than the Schools Guidance. and the differences in mission and mandate require some differences between the two. For example, the Schools Guidance must include "Appropriate child-specific routes of exposure unique to the school environment in addition to those in existing exposure assessment models." This requires a different approach, focusing on the rapidly changing exposure patterns of young children and the unique features of the school environment as they affect exposures. Because children are rapidly changing anatomically, physiologically and behaviorally, we recommend a set of exposure parameters for each year until age 18. In contrast, the TSD presents methodology for estimating long-term average exposures in a 24-hour-per-day exposure setting. Nonetheless, internal consistency to the extent possible was a consideration in developing this guidance. Exposure parameters are discussed below in the context of internal consistency.

The proposed value for ***Soil Ingestion***, 200 mg/day is the value recommended in the TSD, and ie equivalent to EPA's "conservative estimate of the mean.

Fraction at school: There is no equivalent parameter in the TSD.

Body-part-specific skin loading rate and ***body-part-specific skin surface area*** differ from the methods and parameters recommended in the TSD. These methods and parameters are from EPA (2002) guidance which antedates the TSD. OEHHA considers these data to be the best available for the ***Guidance*** because they are based on real-world exposures to young children in day-care centers, an exposure setting similar to the School setting addressed in the ***Guidance***

Fraction outdoors and ***Fraction indoors*** also have no equivalent parameter in the TSD. However, these parameter values are based on time-activity studies reported in the TSD.

Body weight data for children 1 to 18 years are from OEHHA, 2000, Table 10.3. For pregnant or nursing women, and for staff the data are from OEHHA, 2000, Table 10.1. The value for children up to 1 year old is from EPA, 2002, because there is no equivalent value in the TSD (OEHHA, 2000).

Exposure time, outdoors and ***Exposure time, indoors:*** Although OEHHA (2000) considered activity-related breathing rates and time spent at those activities, the focus was to develop an amalgamated breathing rate over time. The ***Guidance*** differs in that it considers indoor and outdoor breathing rates separately, since these environments may have different contaminant loadings. Again, OEHHA believes that this approach is consistent with the legislative mandate.

Breathing rate, outdoors and ***Breathing rate, indoors*** were estimated from the data of Wiley, et al in OEHHA, 2000, pp. 3-25 to 3-27. These ventilation rates are based on the activity descriptors in the Wiley, et al. report, that were deemed consistent with outdoor and indoor activities at school, respectively

Exposure frequency, the estimated number of days students or other school users attend school annually is based on California DHS and ARB survey data. There is no equivalent parameter in the TSD.

The recommended ***Breast milk intake*** of 130 g/kg/day for the first 12 months of life is based on (OEHHA, 2000, Table 5.13, 90th percentile).

Lifetime Exposure Fraction (ED/AT) The TSD recommends an exposure duration of 70 years (ED/AT = 1). This is not relevant for a schools exposure scenario.

Fraction absorbed, inhalation and ***Fraction absorbed, ingestion*** are not found in the TSD. The ***Guidance*** does not at present suggest values other than unity. Indeed, some commentors have suggested that a factor with a value of one is pointless, and should be omitted. HSC Section 901 requires consideration of uncertainty in the model. To omit these absorption fractions would be to ignore a source of uncertainty.

Fraction absorbed, dermal: In order to maximize consistency with the TSD, OEHHA now recommends the following dermal absorption fractions:

Compound	Absorption fraction	Source
Arsenic	0.04	OEHHA, 2000
Beryllium	0.01	OEHHA, 2000
Cadmium	0.001	OEHHA, 2000
Hexavalent chromium	0.01	OEHHA, 2000
Lead	0.01	OEHHA, 2000
Mercury	0.1	OEHHA, 2000
Nickel	0.04	OEHHA, 2000
Polychlorinated biphenyls	0.14	OEHHA, 2000
Polychlorinated dibenzo-p-dioxins and dibenzofurans	0.02	OEHHA, 2000
Hexachlorocyclohexanes	0.1	OEHHA, 2000
Polynuclear aromatic hydrocarbons,	0.13	OEHHA, 2000
DEHP	0.1	OEHHA, 2000
4,4’ methylene dianiline	0.1	OEHHA, 2000
Organophosphates, pentachlorophenol	0.25	DTSC, 1994
Chlorinated insecticides	0.05	DTSC, 1994
Other organic chemicals	0.1	DTSC, 1994
Other metals and complexed cyanides	0.01	DTSC, 1994
Free cyanide	0.1	DTSC, 1994

Comment

22. Acceptable risk. No indicators in the guidance or in the model are provided as to what metrics OEHHA is applying for judging what is an "acceptable risk."

Response

Acceptable or target risk levels are in the risk management domain. The guidelines cover risk assessment and not risk management.

Comment

23. Model parameters. All model parameters that can be changed should be clearly and plainly listed on the input-output sheet. This would include all pathway toggles, dermal, oral, and inhalation absorption parameters, chemical properties, exposure frequency, etc.

Response

Use of the model in screening mode with all defaults involves entering data only in the shaded cells in “Input-output” column B. Changing values outside that range will move the user into tier 2 and will require justification of all proposed changes from the default condition.

Comment

24. Input-Output Sheet. For hazard results, no indication is provided as to which hazard estimate to use. We suggest a "=max (range)" formula be inserted for each scenario.

Response

This suggestion has been adopted. See Input-output cell H25.

Comment

25. Equations. We suggest locking cells containing equations that should not be modified.

Response

Sheets other than “Input-output” will be locked when the spreadsheet is released, to prevent inadvertent changes to formulas and parameter values. However, reviewers should still verify the calculations against their own (unmodified) copy of the workbook.

Comment

26. Chemical properties. We suggest adding chemical property input cells on Input Output sheets that are activated only when a chemical is not in the database.

Response

Chemical properties can be entered in the “Vlookup” sheet.

Comment

27. Input-Output Sheet. Currently no dermal absorption fractions are defined in the "database", but are presented in the guidance document. We suggest adding a table of values from the guidance into the model. See comment #21 above.

Response

This has been done.

Comment

28. Fate sheet. Q/C value based on 10-acre site for LA. Meteorological conditions are different for Northern and Southern California. We suggest a table containing a range of *Q/C* values, with a toggle to allow the user to define what region of California in which the site is located.

Response

Regional Q/Cm ratios would make a minor change in a minor pathway. It is not clear that the added complexity brings commensurate benefit.

Comment

29. Age-specific exposure sheets. Dividing soil ingestion rate by body weight to create a soil ingestion per kilogram body weight rate implies that soil ingestion is directly correlated with body weight, which is not consistent with the exposure equations listed in the guidance document. These two parameters are not directly correlated.

Response

Cell H18 is now changed to g/day, then divided by body weight in the "contact rate" cell, in order to avoid the appearance that soil ingestion and body weight are treated as correlated.

Comment

30. *J&E Model parameters.* We suggest including pertinent Johnson & Ettinger model parameters in the Input-Output sheet.

Response

This will be considered for future spreadsheet enhancements.

Comment

31. *Grammatical errors.* Numerous spelling and grammatical errors exist throughout the model spreadsheets, and associated documentation.

Response

We will correct these as we identify them.

Comment

32. Fate. Breast milk BCF reference should be University of California (1994), not DTSC (1994).

Response

This has been corrected.

Comment

33. *Fate + individual age range calculation spreadsheets.* We suggest adding additional clarification for each pathway delineated by a number. When printed, there is no indication which pathway is soil ingestion or dermal contact (1 vs. 2 vs. 3).

Response

Widening column 1 to accommodate the pathway name would make the sheet will be too wide to display on a single screen and would duplicate information in column B (exposure medium) and column E (exposure route).

Comment

34. Units. Input output sheet does not specify units for user defined CSF or RfD.

Response

This has been corrected.

Comment

35. Fate sheet. Units of M8 & M9 should be µg/L.

Response

This has been corrected.

Comment

36. *Age-specific intake spreadsheets.* The water intake parameter is not used in any calculations.

Response

This has been eliminated

Comment

37. Guidance document, p.10. Outdoor air PM10 levels. The document states OEHHA recommends 1.8E-9, but the spreadsheet uses 5.0E-8.

Response

This has been corrected.

REFERENCES

1. RTI, 2003, Final Report, OEHHA Soil Sampling Augmentation, RTI International Project #RTI/08381-01F, April 2003

2. OEHHA, 2000 Technical Support Document for Exposure Assessment and Stochastic Analysis, Air Toxics Hot Spots Program Risk Assessment Guidelines Part IV, September, 2000