Exposure Dose Guidance for Dermal and Ingestion Exposure to Surface Water

Citation:
[ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Exposure Dose Guidance for Dermal and Ingestion Exposure to Surface Water. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Sept 25.

Contents This guidance contains the following topics

Purpose

Based on the availability of updated exposure parameters, many from the 2011 Exposure Factors Handbook (EFH) published by the U.S. Environmental Protection Agency (EPA), it is necessary that assumptions used in calculating doses in our public health evaluations be updated to reflect the best available science.

This exposure dose guidance (EDG) for surface water provides health assessors with updated guidance on how to estimate exposure from ingesting and contacting contaminants in surface water, such as, while swimming.

Refer to the EDG for the Shower and Household Water-use Exposure (SHOWER) model to review guidance on evaluating dermal exposure to contaminants in water while bathing and rinsing hands (ATSDR 2018.)

Background

After a release of chemicals into the environment, health assessors must evaluate all human exposure pathways. Dermal exposure to surface water and ingesting surface water should be evaluated where appropriate.

1. ATSDR's Public Health Assessment Guidance Manual (PHAGM) (ATSDR 2005) provides guidance on evaluating the dermal pathway based on the 2001 Risk Assessment for Superfund (RAGS) Part E document (EPA 2001) and the 1997 Exposure Factor Handbook (EFH) (EPA 1997).

2. The PHAGM recommends that dermal contact with chemicals in surface water be evaluated using the following equation (EPA 2001, EPA 1997). ***The equation below is no longer the most current method for evaluating dermal exposure to water.***

$$D = (C \times P \times SA \times ET \times CF) / BW$$

where:

D = dose (mg/kg/day)
C = contaminant concentration (mg/L)
P = permeability coefficient (cm/hr)
SA = exposed body surface area (cm^2)
ET = exposure time (hours/day)
CF = conversion factor (1L/1,000 cm^3)
BW = body weight (kg)

3. The 2005 ATSDR PHAGM default dermal exposure values (e.g., skin surface area) used in the above equation ***are no longer appropriate to use.***

This EDG provides guidance to health assessors on updated equations and how to determine the best exposure assumptions needed to calculate a dermal dose based on updated EPA guidance:

- RAGS Part E for Dermal Exposure (EPA 2004), and
- Exposure Factors Handbook (EPA 2011) (Appendix A.)

This EDG also provides updated guidance on surface water ingestion rates while swimming. Examples of how to calculate exposure from surface water contact are provided for dermal contact (Appendix C) and for incidental surface water ingestion while swimming (Appendix D.)

Use the default intake parameters in this guidance when calculating contaminant exposure doses. If you modify default intake parameters using site- or situation-specific information, explain the basis of those modifications in your public health documents.

Definitions

Several definitions are important to know in order to discuss dermal and ingestion exposure to surface water. These definitions follow.

Dermal Absorbed Dose (DAD). The amount of chemical absorbed through the skin. The dermal absorbed dose needs to be converted to an administered dose before comparing the dose to health guidelines, such as Minimal Risk Levels (MRLs) and Reference Doses (RfDs) or before using a cancer slope factor (CSF) to estimate cancer risk. This conversion is done using a gastrointestinal absorption factor (ABS_{GI}) to convert the dermal absorbed dose to an administered dose. Equations used to make this adjustment are provided in this EDG.

Administered Dermal Dose (ADD). A dermal absorbed dose that has been adjusted to an administered dermal dose using a GI absorption factor. The ADD can be combined with doses from other routes (e.g., oral doses) and compared directly to oral MRLs and RfDs.

Administered Dose. Health guidelines and slope factors, such as MRLs, RfDs, and CSFs, are provided as administered doses. That is, they reflect the amount of a chemical that is administered per unit time and body weight. Doses derived for oral intake are considered to be administered doses and are compared directly to appropriate health guideline.

Dermal Exposure to Surface Water. Dermal exposure to surface water is defined as exposure to chemicals found in surface water that enters the body though the skin. The amount of chemical that enters the body is dependent on certain properties of the chemical, such as how efficiently it may go through

the skin and enter the bloodstream. Note that this EDG does not address direct impacts to the skin, such as irritant contact dermatitis.

Central Tendency Exposure (CTE). CTE refers to persons who have average or typical dermal exposure to surface water. One dose is derived for dermal contact with surface water. The CTE evaluation reflects exposure for a CTE duration of 12 years.

Reasonable Maximum Exposure (RME). RME refers to persons who are at the upper end of the exposure distribution (approximately the 95th percentile). The RME scenario assesses exposure doses that are higher than average but still within a realistic exposure range. One dose is derived for dermal contact with surface water. The RME evaluation reflects exposure for a RME duration of 33 years.

Exposure Factor (EF): An expression of how often (frequency) and how long (duration) a person may be contacting a substance in the environment. In many instances, the exposure factor (EF) will equal 1, representing a daily exposure to the contaminant. However, some exposures may occur on an intermittent or irregular basis. For these exposures, an EF can be used to average the dose over the exposure interval. The EF is calculated by multiplying the exposure frequency (F) by the exposure duration (ED) and dividing by the time period during which the dose is to be averaged (averaging time—AT). The EF for occupational, school, trespassing, and swimming scenarios is likely to be different than 1 (see examples).

Exposure Duration (ED): The period over which the exposure takes place.

Exposure Frequency (F): How frequently exposure occurs. This parameter is often measured in days per week and weeks per year.

Event Frequency (EV): The number of times swimming occurs each day. The default event frequency is 1 time per day.

Averaging Time (AT): The period over which the exposure is averaged to arrive at a time-weighted exposure factor. For assessing cancer risks, AT is averaged over a lifetime (78 years); for assessing noncancer risks, AT is averaged over the exposure duration (days, weeks, or years), which may or may not be a lifetime.

Surface water. Surface water is natural water that has not penetrated much below the surface of the ground (e.g., ponds, streams, rivers, puddles). Incidental ingestion of surface water occurs when persons contact surface water through recreational activities, such as swimming, boating, and playing in water.

Chronic Exposures: Exposures greater than 365 days. Exposure doses derived for chronic exposure scenarios should be evaluated using chronic ATSDR Minimal Risk Levels (MRL). If MRLs are not available, EPA Reference Doses (RfD), EPA Reference Concentrations (RfC) or another suitable health guidance value may be used for the evaluation.

Intermediate Exposures: Exposures of 15 to 364 days. Exposure doses derived for intermediate exposure scenarios should be evaluated using intermediate MRLs or appropriate toxicity information (e.g. utilizing studies of similar duration if available).

Acute Exposures: Exposures up to 14 days. Exposure doses derived for acute exposure scenarios should be evaluated using acute MRLs or appropriate toxicity information (e.g., utilizing studies of similar duration if available).

Exposure Dose Equations– Dermal Contact

The EPA RAGS Part E (EPA 2004) and the EFH (EPA 2011) recommend updated equations and exposure factors that health assessors should use to estimate dermal dose. Note that estimating the dermal dose using this equation does not address toxicity that may result from direct dermal contact with a contaminant, such as allergic contact dermatitis, hives and chemical irritation.

The following equation for dermal absorbed dose is based on equations and parameters provided in EPA RAGS Part E (EPA 2004) and EPA EFH (EPA 2011).

$$DAD = \frac{DA_{event} \times SA \times EV \times EF}{BW}$$

Table 1. Parameters used to estimate dermal absorbed dose

Parameter	Definition (units)
DAD	= dermal absorbed dose (mg/kg/day)
DA_{event}	= absorbed dose per event (mg/cm^2/event)
EV	= event frequency (events/day)
$EF_{chronic}$	= exposure factor (F x ED)/AT • F = frequency of exposure (d/wk and wk/yr) • ED = exposure duration (yrs) • AT = averaging time o noncancer – 7 d/wk x 52.14 wks/yr x ED o cancer – 7 d/wk x 52.14 wks/yr x 78 yrs
SA	= surface area available for contact (cm^2)
BW	= body weight (kg)

DA_{event}
Different equations are used for organic and inorganic compounds.

Organic Compounds
Health assessors can determine which of the two equations below will be used to calculate DA_{event} by comparing the chemical-specific t* in Table 6 in Appendix A with the site-specific duration (t_{event}).

If $t_{event} \leq t^*$ (i.e., for short-term exposures where the duration of the exposure is shorter than the time it takes to reach steady state), then:

$$DA_{event} = 2\,FA \times K_p \times C_{SW} \sqrt{\frac{6\,\tau_{event} \times t_{event}}{\pi}}$$

If $t_{event} > t^*$ (i.e., for longer-term exposures where the duration of the exposure is longer than the time it takes to reach steady state), then:

$$DA_{event} = FA \times K_p \times C_{SW} \left[\frac{t_{event}}{1+B} + 2\tau_{event}\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

where,

$$B = \frac{K_p}{K_{p,ve}} \approx K_p \times \frac{\sqrt{MW}}{2.6}$$

Inorganic Compounds:

$$DA_{event} = C_{SW}\, x\, K_p\, x\, t_{event}$$

Table 2. Parameters used to estimate *DA_{event}*

Parameter	Definition (units)
DA_{event}	= Absorbed dose per event (mg/cm^2-event)
FA	= Fraction absorbed water (dimensionless)
K_p	= Dermal permeability coefficient of compound in water (cm/hr)
C_{SW}	= Chemical concentration in surface water (mg/cm^3)
τ_{event}	= Lag time per event (hr/event)
t_{event}	= Site-specific event duration (hr/event)
t*	= Chemical-specific time to reach steady state (hr) = 2.4 τ_{event}
B	= Dimensionless ratio of the permeability coefficient of a (dimensionless)

Source: EPA RAGS Part E (EPA 2004) and EPA EFH (EPA 2011).

Exposure Parameters for Dermal Contact

Calculating a Dermal Dose for Surface Water

The general equations for calculating a dermal dose are provided in the previous section. An example calculation is provided in Appendix C. Exposure factors, which consist of exposure frequency and exposure duration, are likely to be site-specific. The EDG for Life Expectancy and Exposure Factor should be consulted to select the most appropriate exposure factors (ATSDR 2016c.) Recommended exposure values for surface area (*SA*) and chemical-specific parameters are provided in Appendix A.

Surface Area (*SA*)

- Surface Area (*SA*) in units of cm^2 is the amount of skin surface that is available for contact with contaminants.
- EPA's EFH Chapter 7, (Tables 7-1 and 7-2 of Appendix A), provide a detailed list of the skin surface area for whole body exposure during swimming and for selected body parts to evaluate a wading exposure scenario (e.g., exposure of the head, hands, forearms, lower legs and feet) (EPA 2011).
- **The mean surface area should be used to evaluate both the CTE and RME exposure scenarios since surface area is correlated with the body weight and the mean body weight is used for both scenarios.** The EDG for Body Weight provides the body weight that should be used for ATSDR's standard age group. The infant body weight for evaluating water scenarios is 7.8 kg, which represents exposure of children aged birth to < 1 year (ATSDR 2016b.)

Absorbed Dose Per Event (DA_{event})

- The absorbed dose per event (DA_{event}) in units of mg/cm^2/event represents the dose of a chemical absorbed through the skin per event.
- The absorbed dose is dependent on the duration of exposure and on whether the compound is organic or inorganic.

Fraction Absorbed (FA)

- The fraction absorbed (*FA*) is unitless and accounts for loss of the contaminant on the skin due to desquamation (i.e., the peeling of the outer layer of skin).
- In the absence of chemical-specific information, the default of 1 should be used.

Dermal Permeability Coefficient (K_p)

- K_p is the dermal permeability coefficient of the compound in water in units of cm/hr. *Kp* is an important parameter in estimating the amount of a chemical that permeates the skin and is absorbed into the body.
- Table 6 in Appendix A provides a list of chemical-specific K_p values. K_p values for chemicals not included on the list can be derived using EPA equations (EPA 2004.)

B ratio

- B is the dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis.
- Table 6 in Appendix A of this document provides a list of chemical-specific B values.

Event Duration (t_{event})

- The event duration (t_{event}) in units of hours represents the duration of exposure for each event.
- The value is site-specific and should be defined using the site-specific scenario.

Time to Steady State (t^*)

- The time to reach steady absorption across the skin is represented by t^*.
- For organic contaminants, the equation used to determine DA_{event} depends on the duration of exposure (i.e., the chemical-specific t^* versus the site-specific t_{event}.)
- t_{event} is the site-specific duration of exposure and is based on the exposure scenario.
- Table 6 in Appendix A provides a list of chemical-specific t^* values.
- The chemical-specific t^* values are based on $2.4\tau_{event}$, the lag time per event (hr/event).

Lag time (τ_{event})

- Lag time per event (τ_{event}) accounts for chemical loss due to desquamation as the chemical crosses the stratum corneum during the absorption process.
- Units are hours per event.

Absorption Through the GI Tract (ABS_{GI})

- ABS_{GI} represents the absorption of the chemical through the gastrointestinal tract following ingestion.
- EPA uses the ABS_{GI} value to adjust health guidelines and slope factors (e.g., MRL, RfD, oral CSF) from an administered dose or factor to an absorbed dose or factor. This adjustment allows the health guidelines to be compared to the dermal absorbed dose or the slope factor to be used with the dermal absorbed dose to estimate cancer risk.
- ATSDR will use the ABS_{GI} to adjust the dermal absorbed dose to an equivalent administered dose. This approach allows the dose from skin uptake to be compared directly to health guidelines, such as

MRLs and RfDs without adjusting the guidelines. More importantly, it also allows the dermal dose to be combined with the oral dose determined from incidental surface water ingestion while swimming.

Conversion of Dermal Absorbed Dose to Administered Dose

The dermal dose in mg/kg/day derived using the dermal exposure equations is an absorbed dose. That is, it reflects the amount of a chemical that is absorbed into the body via the dermal exposure route. For this reason, EPA recommends adjusting health guidelines, such as RfDs, MRLs, and oral slope factors, from an administered dose to an absorbed dose. This adjustment is done by using a gastrointestinal (GI) absorption factor (ABS_{GI}), which is the fraction of chemical absorbed by the gastrointestinal tract (EPA 2004).

- $MRL_{\text{absorbed dose or}}$ $RfD_{\text{absorbed dose}}$ = (Oral MRL or RfD) x ABS_{GI}
- Cancer Slope $Factor_{\text{absorbed dose}}$ = Oral Cancer Slope Factor/ABS_{GI}

As with EPA's efforts, ATSDR also agrees that dermal exposure assessments must make adjustments to account for the dermal dose being an absorbed dose. However, ATSDR converts the dermal absorbed dose to an administered dermal dose rather than adjusting the health guideline or CSF. The advantage of ATSDR's approach is that the doses from the oral and dermal pathways can be added together to create a total dose from both pathways. This total dose can then be compared to the unadjusted health guideline or used with the unadjusted CSF to calculate cancer risk.

The following formula is used to convert the absorbed dermal dose to an equivalent administered dose:

Administered Dermal Dose (ADD) = DAD / ABS_{GI}

This results in the full dermal absorption exposure equation being:

$$ADD = \frac{DA_{event} \times SA \times EV \times EF}{BW \times ABS_{GI}}$$

For most chemicals, the absorbed dermal dose is the same as the oral administered dose because we assume 100% of the chemical is absorbed through the GI tract, thus ABS_{GI} equals 1. Therefore, no adjustment from absorbed dermal dose to administered oral dose is needed for organic chemicals including VOCs, SVOCs, pesticides, PAHs, and PCBs. For these chemicals, the absorbed dose calculated from dermal uptake is also an administered dose.

For inorganic compounds where 100% GI absorption is not the case, the absorbed dermal dose must be adjusted using the factor shown in the Table 3. The list of ABS_{GI} factors comes from EPA RAGS, Part E, Exhibit 4-1 (EPA 2004). While the following ABS_{GI} are recommended, site-specific ABS_{GI}, if available, can be used to adjust the dermal dose.

Table 3. ABS_{GI} adjustment factors for inorganic elements and compounds.

Compound	ABS_{GI} Adjustment Factor
Antimony	15%
Arsenic	100% absorption assumed; No adjustment;
Barium	7%
Beryllium	0.7%
Cadmium	2.5% (diet) 5% (water)
Chromium III	1.3%
Chromium VI	2.5%
Copper	57%
Cyanate	100% absorption assumed; No adjustment
Manganese	6%
Mercuric chloride (and other soluble salts)	7%
Metallic mercury	80%
Methyl mercury	100% absorption assumed; No adjustment
Nickel	4%
Selenium	30%
Silver	4%
Thallium	100% absorption assumed; No adjustment
Vanadium	2.6%
Zinc	100% absorption assumed; no adjustment

Surface Water Ingestion

The 2011 EFH reports mean, 97th percentile, and maximum water ingestion rates for children (≤18 years old) and for adults while swimming (USEPA 2011, Dufour et al., 2006). Based on these results, ATSDR recommends using the ingestion rates in Table 4.

Table 4. Recommended Values for Surface Water Ingestion Rates.

Group	*CTE (Liters/hour)*	*RME (Liters/hour)*	*Body Weight+ (kg)*
Children (< 21 years old)	0.049*	0.12**	Age-appropriate
Adults (≥ 21 years old)	0.021*	0.071***	80

*Mean
**97th percentile
***Maximum
+ATSDR 2016b

Because the data used by Dufour et al. is limited (especially for adults), US EPA (2011) suggests using the 97th percentile and maximum values for the RME ingestion rates for children and adults, respectively. This ATSDR guidance suggests that health assessors use a range of values from the CTE to the RME when calculating doses.

Health assessors should use the following equation and ATSDR's standard age ranges for estimating the oral dose (ATSDR 2016a, 2016b.)

$$D = \frac{C \times IR \times t_{event} \times EV \times EF}{BW}$$

where

D = exposure dose (mg/kg-day)
C = contaminant concentration (mg/L)
IR = ingestion rate of contaminated water (L/hr)
t_{event} = site-specific event duration (hr/event)
EV = site-specific event frequency (events/day)
$EF_{chronic}$ = Chronic Exposure Factor (unitless) = (F x ED)/AT)

- F = exposure frequency (d/wk x wk/yr)
- ED = exposure duration (yr)
- AT = averaging time
  - noncancer = F (d/wk x 52.14 wk/yr) x ED (yr)
  - cancer: F (7 d/wk x 52.14 wk/yr) x 78 (yr)

BW = body weight (kg)

Health assessors should consider geographic factors such as proximity or availability of surface water for recreation, seasonal factors, and age when determining the appropriate exposure factor (ATSDR 2005). Activity pattern data from the 2011 EPA EFH can assist with some of these determinations (e.g., swimming frequency/month). However, local and regional knowledge should be considered in determining a reasonable exposure factor.

Appendix D has an example showing how to calculate the exposure dose from incidental ingestion of water while swimming.

Exposure Factors

Most scenarios involving skin contact with surface water will involve swimming or wading in surface water. Similarly, most scenarios involving ingestion of surface water will involve incidental ingestion while swimming. These and other similar scenarios will consist of intermittent exposure that require adjusting the exposure factor (EF) based on a site-specific scenario. Where warm-weather conditions prevail year round, exposure duration can be chronic, intermediate, or acute, or a combination of these durations depending upon the site specific scenario. For example, for scenarios where children are at camp for 1 week a year, only acute exposure is likely. For scenarios where children are visiting a location for the summer, only acute and intermediate duration exposures are likely. However, locations with warm weather year-round, such as southern Florida, Puerto Rico, or southern California, acute, intermediate, and chronic exposure may be possible for certain scenarios.

Thus, health assessors will need to adjust the EF where swimming is involved based not only on the site-specific scenario but also on whether warm weather is likely year-round or only part of the year. When exposure duration approaches 1 year or more, chronic, intermediate, and acute doses can be calculated. When exposure duration is significantly less than a year (e.g., 6 months or less), then only intermediate and acute doses should be calculated unless the toxicology of the chemical supports calculating a chronic dose. The EF for chronic, intermediate, and acute durations follows:

$EF_{chronic}$ = chronic exposure factor (unitless)

- F = exposure frequency (d/wk x wk/yr)
- ED = exposure duration (yr)
- AT = averaging time
  - noncancer = ED (yr) x F (d/wk x 52.14 wk/yr)
  - cancer = 78 yr x F (7d/wk x 52.14 wk/yr)

$EF_{intermediate}$ = Intermediate Exposure Factor (unitless)

- F = exposure frequency (d/wk)
- ED = exposure duration (wk)
- AT = averaging time
  - noncancer = F (d/wk) x ED (wk)

EF_{acute} = Acute Exposure Factor

EF_{acute} = 1 (by default)

More information about EF can be found in the EDG for Life Expectancy and Exposure Factor (ATSDR 2016c.)

Cancer

EPA's approach to quantitative cancer risk estimates includes a cancer slope factor (CSF). It involves multiplying a carcinogen-specific CSF by a duration-specific estimated dose. This approach allows estimation of cancer risk for adults and children as a function of exposure duration.

Special Cancer Considerations

EPA has proposed that risk calculations for chemicals that act with a mutagenic mode of action (MOA) for carcinogenesis can be quantified using one of two possible approaches (EPA 2005):

- For some MOA chemical, sufficient data are available to derive age-specific CSFs. These age-specific CSFs can be used to estimate age-specific and total cancer risk. An example is vinyl chloride, which has two CSFs: one for early life exposure and one for adult only exposure. These two CSFs account for differences in susceptibility between exposure that begins in childhood and exposure that begins in adulthood. Therefore, age-dependent adjustment factors (ADAFs) should not be used for vinyl chloride.

- For MOA chemicals without age-specific CSFs, ADAFs should be applied. EPA suggests using the following ADAFs:

  ✓ Children 0 < 2 years 10
  ✓ Children 2 to < 16 years 3
  ✓ Children and adults 16 and older 1

Mutagenic chemicals are identified in the EPA's Regional Screening Levels (RSL) table [https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016] and include chemicals commonly found at waste sites, such as polycyclic aromatic hydrocarbons, trichloroethylene, and chromium compounds. Additional information about EPA's approach to evaluating early life exposure to mutagenic carcinogens can be found at https://www3.epa.gov/airtoxics/childrens_supplement_final.pdf.

Noncancer (Annual) dose and Cancer (Lifetime) Dose Estimates

For (chronic) non-cancer evaluations, annual doses (or doses averaged over 1-year of exposure) are calculated. This allows the doses to be directly compared with the chronic MRL, which has been developed to be protective for exposures of one year or greater.

Lifetime doses, used to evaluate cancerous effects, can differ depending on exposure duration and are averaged over a lifetime of exposure (i.e., 78 years). For cancer risk evaluations, you can assume either lifetime exposure or some fraction of a lifetime exposure.

You can convert the 1-year annual dose to a lifetime cancer dose by multiplying the annual dose by the site-specific or default exposure duration/averaging time (ED/AT). For default residential scenarios, RME (33 years) and CTE (12 years) residential occupancy periods are used to calculate the RME and CTE cancer risk, respectively. Health assessors have several options available for the presentation of cancer risk estimates, which are discussed below.

Unknown Exposure Duration

When the residential exposure duration is unknown, the 95th percentile residential occupancy period (i.e., 33 years) may be incorporated into the report and presented in several ways:

- Most commonly, adult and childhood cancer risk are presented separately. Calculate and present the combined cancer risk for children (birth to 21 years) using an ED/AT term of 21/78 and for adults (33 years) using an ED/AT term of 33/78.

- Combined childhood and adulthood cancer risk can be presented as one cancer risk estimate**.** This is only appropriate if you are assessing exposures that began at birth and continue into adulthood at the same house or in a house with similar contaminant levels. To incorporate the 33 year default residential occupancy period into this scenario, you should calculate the cancer risk for children exposed from birth to 21 years (using an ED/AT term of 21/78) and calculate an additional 12 years of exposure for adults (using an ED/AT term of 12/78). The childhood and adult cancer risk should be added together to account for 33 years of total exposure.

Known Exposure Duration

When an exposure duration is known, you can incorporate the site-specific exposure duration and present cancer risk (1) separately for children and adults (most common scenario) or (2) combine them (if exposures are

occurring from childhood through adulthood and site-specific information warrants), as discussed above.

Lifetime Exposure Duration

When site-specific information indicates that exposures may have occurred over an entire lifetime (e.g. a small rural or tribal community), the cancer risk for children (birth to 21 years; ED/AT of 21/78) and adults (additional 57 years; ED/AT of 57/78) should be added together to account for an entire lifetime of exposure. Please note that there should be reliable site-specific information available when considering the presentation of cancer risk with a lifetime exposure duration.

For more information about exposure factors, review the EDG for Determining Life Expectancy and Exposure Factor (ATSDR 2016c).

Central Tendency and Reasonable Maximum Dose Estimates

To represent persons with typical and high-end exposures, estimate typical exposure doses for receptors using CTE intake values and rates and high-end doses for receptors using a combination of CTE and RME values and rates. When feasible, you can present the results as a range of doses in the target population. The EPA's EFH is the primary source for CTE and RME intake rates in children and adults (EPA 2011).

Discussion in the public health implications section of your document should include your explanation for estimates for both children and adults. For example, if the risk of harmful effects is only for children with high intake rates (RME), describe the risk of harm for that group and explain that children with typical intake rates (CTE) are not at risk. Likewise, if the risk of harmful effects is for both groups, your estimate explanation should reflect both scenarios.

When evaluating noncancer endpoints, you should estimate doses for the most highly exposed group or for the most sensitive group. If the estimated dose for either or both groups exceeds the health guideline (e.g., MRL, RfD), then estimate and evaluate doses for other groups. Remember that when evaluating cancer risk, you should use site-specific information to identify the age ranges for which you need cancer risk estimates.

Note that for the dermal exposure to water pathway, the chronic (annual) dermal dose is the same for CTE and RME because they are derived using exposure parameters that are correlated (i.e., body weight and skin surface area). CTE and RME cancer risks, however, will differ because the CTE cancer risk uses a CTE residential occupancy period (i.e., 12 years) and the RME cancer risk uses the RME residential occupancy period (i.e., 33 years).

Public Health Assessment Site Tool (PHAST)

When available, health assessors should use the public health assessment site tool (PHAST) to estimate dermal doses from contact with surface water. PHAST provides a *quick summary* of the maximum hazard quotient for chronic, intermediate, and acute exposure as well as the maximum cancer risk for this exposure scenario involving children and adults. The Quick Summary is based on an RME residential scenario using default exposure parameters from ATSDR's Exposure Dose Guidance and is intended to give health assessors an overview of HQs and cancer risks. Until dermal dose equations are coded into PHAST, health assessors may use the Excel dermal dose calculator in the PHAST resource page.

If the HQ exceeds one, review the age-specific dose and hazard quotient calculations to evaluate risk of noncancerous effects in children and adults. If no MRL or RfD is available, compare the maximum site-specific dose directly to NOAELs and LOAELs to determine the possibility of harmful effects. If you decide harmful effects are possible, consider site-specific doses for all age ranges to determine who is at risk of noncancerous harmful effects.

The default cancer risk calculation in the *quick summary* assumes 33 years of residential exposure—the 95th percentile residential-occupancy period. The default 33-year cancer risk assumes 21 years of exposure as a child, followed by 12 years of exposure as an adult at the same residence. If the maximum cancer risk in the *quick summary* exceeds 1E-6, review the cancer risks for children exposed for 21 years and for adults exposed for 33 years. Remember that the quick summary cancer risk is a screen—you should not include it in PHAs/HCs unless you know you have an exposure scenario where children grow up in a house or area and continue to have the same exposure as adults.

Impact

Using the best available science to update the parameters to calculate dermal and ingestion exposure from surface water will improve the consistency of exposure dose estimates in ATSDR- and state-prepared health assessments and consultations.

References

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public Health Assessment Guidance Manual (Update). US Department of Health and Human Services. January. Available at http://www.atsdr.cdc.gov/HAC/phamanual/index.html [Accessed 2018 Sept 19.]

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016a. Exposure Dose Guidance for Water Ingestion. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, October 26.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016b. Exposure Dose Guidance for Body Weight. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016c. Exposure Dose Guidance: Determining Life Expectancy and Exposure Factor to Estimate Exposure Doses. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Exposure Dose Guidance for the Shower and Indoor Water-use Model. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Dufour AP, Evans O, Behymer TD, Cantú, R. 2006. Water ingestion during swimming activities in a pool: a pilot study. J Water Health 4: 425-430.

[EPA] U.S. Environmental Protection Agency. 1997. Exposure Factors Handbook, Volumes 1, 2 and 3. National Center for Environmental Assessment, Washington, DC. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=12464 [Accessed 2018 Sept 19.]

[EPA] U.S. Environmental Protection Agency. 2001. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Interim. Review Draft – For Public Comment. EPA/540/R/99/005. September 2001.

[EPA] US Environmental Protection Agency. 2003. Updated Dermal Exposure Assessment Guidance. Region 3 Technical Guidance Manual, Risk Assessment. Last Updated December 29, 2010. Available online at https://www.epa.gov/risk/updated-dermal-exposure-assessment-guidance [Accessed 2018 Sept 19.]

[EPA] US Environmental Protection Agency. 2004. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. EPA/540/R/99/005. OSWER 9285.7-02DEP; PB99-963312. Available online at https://www.epa.gov/risk/risk-assessment-guidance-superfund-rags-part-e [Accessed 2018 Sept 19.]

[EPA] US Environmental Protection Agency. 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. U.S. Environmental Protection Agency, Washington, DC, EPA/630/R-03/003F. Available at https://www.epa.gov/risk/supplemental-guidance-assessing-susceptibility-early-life-exposure-carcinogens [Accessed 2018 Sept 19.]

[EPA] US Environmental Protection Agency. 2011. Exposure Factors Handbook: 2011 Final. Washington DC. National Center for Environmental Assessment, Washington, DC. EPA/600/R-090/052A. Available online at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252 [Accessed 2018 Sept 19.]

Appendices

Default Dermal Exposure Factors (Appendix A)
Input Parameters for Organic and Inorganic Contaminants in Water (Appendix B)
Example of Dermal Dose Calculations (Appendix C)
Example of Surface Water Ingestion Calculations (Appendix D)

Appendix A
Default Dermal Exposure Factors

Default Skin Surface Area Tables
Input Parameters for Organic Contaminants in Water

Table 5. Default Skin Surface Area Using Data from EFH (EPA 2011)

Age Interval	Head	Hands	Forearms[b]	Lower Legs[c]	Feet	Combined Scenario SA for Wading (cm^2)[d]	Total Surface Area for Swimming (cm^2)[e]	Associated Body Weight (kg)
Child (birth to < 1 year)[a]	727	211	247	329	258	1,772	3,992	7.8
Child (1 to <2 yr)	870	300	311	488	330	2,299	5,300	11.4
Child (2 to <6 yr)	585	348	457	739	463	2,591	7,225	17.4
Child (6 to <11 yr)	660	510	680	1,244	730	3,824	10,800	31.8
Adolescent (11 to <16 yr)	730	720	1,022	1,932	1,050	5,454	15,900	56.8
Adolescent (16 to <21 yr)	750	830	1,211	2,172	1,120	6,083	18,400	71.6
Adult (≥21 years)	1,250	980	1,240	2,560	1,295	7,325	19,811	80

a - values from Table 7-2 (surface area of body parts) and 7-1 (whole body surface area) of EFH 2011 (EPA, 2011). The skin surface area for the infant was derived using a time-weighted average value from Table 7-2 in the EFH (EPA, 2011).

b - No value is available for the SA of the forearms in females or children, so the value represents approximately 45% of the total SA of the arm (EPA, 2011).

c – No value is available for the lower leg in infants, children, or adolescents so the value represents approximately 40% of the total leg value (calculated from adult values; EPA, 2007).

d - Combined surface area for body parts included in the wading scenarios. It is assumed that children and adults wear a short-sleeved shirt, shorts, and no shoes resulting in exposure of the head, hands, forearms, lower legs, and feet.

e – The total skin surface area is used for a swimming scenario.

Appendix B - Input Parameters for Organic Contaminants in Water
Table 6 – Input Parameters for Organic Contaminants in Water (EPA 2004, Exhibit B-3)

NA: The abbreviation NA (not applicable) in the "Chem Assess" column reflects OSWER's recommendation against quantifying exposure and risk in the body of the risk assessment because these contaminants are outside the effective predictive domain.

Y/N: The abbreviation Y (yes) and N (no) in the "Chem Assess" column refers to whether or not dermal exposure exceeds 10% of drinking water— The actual ratio dermal/oral is given in the column labeled "Derm/Oral," and the next column labeled "Chem Assess" gives the result of the comparison of these two routes of exposure as "Y" (yes) when dermal exposure exceeds 10% of drinking water (ratio of DAD from dermal to oral). The oral route is represented by drinking 2 liters of water per day.

*/** See notes provided at the beginning of Exhibit B-2.

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/ Oral (%)	Chem Assess
1	Acetaldehyde	75070	6.3E-04	0.0	0.19	0.45	1.0	6.1E-07	6.4E-05	1%	N
2	Acetamide	60355	1.1E-04	0.0	0.23	0.55	1.0	1.1E-07	1.2E-05	0%	N
3	Acetylaminofluorene, 2-	53963	1.2E-02	0.1	1.90	4.56	1.0	3.6E-05	3.8E-03	33%	Y
4	Acrolein	107028	6.5E-04	0.0	0.22	0.53	1.0	6.7E-07	7.0E-05	1%	N
5	Acrylamide	79061	2.2E-04	0.0	0.27	0.64	1.0	2.4E-07	2.6E-05	0%	N
6	Acrylonitrile	107131	1.2E-03	0.0	0.21	0.51	1.0	1.2E-06	1.2E-04	1%	N
7	Aldrin	309002	1.4E-03	0.0	11.89	28.54	1.0	1.0E-05	1.1E-03	9%	N
** 8	Allyl chloride	107051	5.4E-03	0.0	0.29	0.69	1.0	6.1E-06	6.4E-04	5%	N
9	Amino-2-methylanthraquinone, 1-	82280	5.3E-03	0.0	2.28	5.48	1.0	1.7E-05	1.8E-03	15%	Y
10	Aminoanthraquinone, 2-	117793	2.4E-03	0.0	1.90	4.56	1.0	6.9E-06	7.2E-04	6%	N
11	Aminoazobenzene, p-	60093	6.8E-03	0.0	1.36	3.26	1.0	1.7E-05	1.8E-03	15%	Y
12	Aminoazotoluene, o-	97563	3.4E-02	0.2	1.96	4.69	1.0	1.0E-04	1.1E-02	91%	Y
13	Aminobiphenyl, 4-	92671	1.3E-02	0.1	0.95	2.27	1.0	2.6E-05	2.8E-03	24%	Y
14	Aniline	62533	1.9E-03	0.0	0.35	0.85	1.0	2.3E-06	2.5E-04	2%	N
15	Anisidine, o-	90040	1.5E-03	0.0	0.69	1.66	1.0	2.6E-06	2.7E-04	2%	N
16	Auramine	492808	1.1E-02	0.1	3.37	8.09	0.9	3.9E-05	4.1E-03	35%	Y
17	Benzene	71432	1.5E-02	0.1	0.29	0.70	1.0	1.7E-05	1.8E-03	15%	Y
18	Benzidine	92875	1.1E-03	0.0	1.15	2.76	1.0	2.6E-06	2.7E-04	2%	N
* 19	Benzo-a-anthracene	56553	4.7E-01	2.8	2.03	8.53	1.0	1.4E-03	1.5E-01	1283%	NA
* 20	Benzo-a-pyrene	50328	7.0E-01	4.3	2.69	11.67	1.0	2.4E-03	2.6E-01	2186%	NA
* 21	Benzo-b-fluoranthene	205992	7.0E-01	4.3	2.77	12.03	1.0	2.5E-03	2.6E-01	2221%	NA
22	Benzoic acid	65850	5.7E-03	0.0	0.51	1.24	1.0	8.6E-06	9.1E-04	8%	N
23	Benzotrichloride	98077	1.1E-02	0.1	1.32	3.17	1.0	2.7E-05	2.8E-03	24%	Y
24	Benzyl chloride	100447	1.0E-02	0.0	0.55	1.32	1.0	1.6E-05	1.7E-03	14%	Y
25	Bis(2-chloroethyl)ether	111444	1.8E-03	0.0	0.68	1.62	1.0	3.1E-06	3.3E-04	3%	N
** 26	Bromodichloromethane	75274	4.6E-03	0.0	0.88	2.12	1.0	9.2E-06	9.7E-04	8%	N
** 27	Bromoform	75252	2.2E-03	0.0	2.79	6.70	1.0	7.9E-06	8.4E-04	7%	N
** 28	Bromomethane	74839	2.8E-03	0.0	0.36	0.87	1.0	3.6E-06	3.8E-04	3%	N

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/Oral (%)	Chem Assess
29	Bromophenol, p-	106412	8.8E-03	0.0	1.00	2.39	1.0	1.9E-05	2.0E-03	17%	Y
30	Butadiene, 1,3-	106990	1.6E-02	0.0	0.21	0.51	1.0	1.6E-05	1.7E-03	15%	Y
31	2,3-Butanediol	513859	1.2E-04	0.0	0.34	0.82	1.0	1.5E-07	1.6E-05	0%	N
32	n-Butanol	71363	2.3E-03	0.0	0.28	0.67	1.0	2.6E-06	2.7E-04	2%	N
33	Butoxyethanol, 2-	111762	1.2E-03	0.0	0.49	1.17	1.0	1.8E-06	1.9E-04	2%	N
34	Captan	133062	1.2E-03	0.0	5.13	12.32	1.0	5.7E-06	6.0E-04	5%	N
35	Carbon disulfide	75150	1.7E-02	0.1	0.30	0.72	1.0	2.0E-05	2.1E-03	18%	Y
** 36	Carbon tetrachloride	56235	1.6E-02	0.1	0.78	1.86	1.0	3.0E-05	3.2E-03	27%	Y
37	Chlordane	57749	3.8E-02	0.3	21.21	50.91	0.7	2.6E-04	2.7E-02	231%	Y
38	Chlordane (cis)	5103719	3.4E-02	0.3	21.27	51.05	0.7	2.3E-04	2.4E-02	208%	Y
39	Chlordane (trans)	5103742	3.4E-02	0.3	21.27	51.05	0.7	2.3E-04	2.4E-02	208%	Y
40	Chlorobenzene	108907	2.8E-02	0.1	0.46	1.09	1.0	4.0E-05	4.2E-03	36%	Y
41	4-Chlorocresol	59507	2.9E-02	0.1	0.67	1.61	1.0	4.9E-05	5.2E-03	44%	Y
** 42	Chlorodibromomethane	124481	3.2E-03	0.0	1.57	3.77	1.0	8.5E-06	9.0E-04	8%	N
** 43	Chloroethane	75003	6.1E-03	0.0	0.24	0.59	1.0	6.3E-06	6.7E-04	6%	N
** 44	Chloroform	67663	6.8E-03	0.0	0.50	1.19	1.0	1.0E-05	1.1E-03	9%	N
** 45	Chloromethane	74873	3.3E-03	0.0	0.20	0.49	1.0	3.3E-06	3.4E-04	3%	N
46	2-Chlorophenol	95578	8.0E-03	0.0	0.56	1.34	1.0	1.3E-05	1.3E-03	11%	Y
47	4-Chlorophenol	106489	1.2E-02	0.1	0.56	1.34	1.0	1.8E-05	1.9E-03	16%	Y
48	Chlorothalonil	1897456	1.9E-02	0.1	3.30	7.93	0.9	6.4E-05	6.8E-03	58%	Y
* 49	Chrysene	218019	4.7E-01	2.8	2.03	8.53	1.0	1.4E-03	1.5E-01	1283%	NA
50	Cresidine, p-	120718	3.4E-03	0.0	0.63	1.50	1.0	5.7E-06	6.0E-04	5%	N
51	m-Cresol	108394	7.8E-03	0.0	0.43	1.03	1.0	1.1E-05	1.1E-03	10%	N
52	o-Cresol	95487	7.7E-03	0.0	0.43	1.03	1.0	1.1E-05	1.1E-03	10%	N
53	p-Cresol	106445	7.7E-03	0.0	0.43	1.03	1.0	1.1E-05	1.1E-03	10%	N
* 54	DDD	72548	1.8E-01	1.2	6.65	25.99	0.8	7.8E-04	8.3E-02	703%	NA
* 55	DDE	72559	1.6E-01	1.1	6.48	25.08	0.8	6.7E-04	7.1E-02	602%	NA
* 56	DDT	50293	2.7E-01	1.9	10.45	42.51	0.7	1.3E-03	1.4E-01	1156%	NA
* 57	n-Decanol	112301	2.2E-01	1.1	0.82	3.18	1.0	4.2E-04	4.5E-02	380%	NA
58	Di-2-ethylhexyl phthalate	117817	2.5E-02	0.2	16.64	39.93	0.8	1.7E-04	1.8E-02	155%	Y
59	Diaminoanisole, 2,4-	615054	2.2E-04	0.0	0.63	1.52	1.0	3.7E-07	3.9E-05	0%	N
60	Diaminotoluene	95807	5.4E-04	0.0	0.51	1.24	1.0	8.3E-07	8.7E-05	1%	N
61	Diaminotoluene, 2,4-	101804	2.8E-03	0.0	1.41	3.38	1.0	6.9E-06	7.3E-04	6%	N
* 62	Dibenzo(a,h)anthracene	53703	1.5E+00	9.7	3.88	17.57	0.6	3.8E-03	4.0E-01	3388%	NA
63	Dibutyl phthalate	84742	2.4E-02	0.2	3.86	9.27	0.9	9.0E-05	9.5E-03	81%	Y
64	Dichlorobenzene, 1,2-	95501	4.1E-02	0.2	0.71	1.71	1.0	7.4E-05	7.8E-03	66%	Y
65	Dichlorobenzene, 1,3-	541731	5.8E-02	0.3	0.71	1.71	1.0	1.0E-04	1.1E-02	93%	Y
66	Dichlorobenzene, 1,4-	106467	4.2E-02	0.2	0.71	1.71	1.0	7.5E-05	7.9E-03	67%	Y

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2 -event)	DAD (mg/kg -day)	Derm/ Oral (%)	Chem Assess
67	Dichlorobenzidine, 3,3'	91941	1.3E-02	0.1	2.80	6.72	1.0	4.5E-05	4.8E-03	41%	Y
** 68	Dichlorodifluoromethan	75718	9.0E-03	0.0	0.51	1.22	1.0	1.3E-05	1.4E-03	12%	Y
** 69	Dichloroethane, 1,1-	75343	6.7E-03	0.0	0.38	0.92	1.0	8.8E-06	9.3E-04	8%	N
** 70	Dichloroethane, 1,2-	107062	4.2E-03	0.0	0.38	0.92	1.0	5.5E-06	5.8E-04	5%	N
** 71	Dichloroethylene, 1,1-	75354	1.2E-02	0.0	0.37	0.89	1.0	1.5E-05	1.6E-03	14%	Y
** 72	Dichloroethylene, 1,2-	540590	7.7E-03	0.0	0.37	0.89	1.0	9.9E-06	1.0E-03	9%	N
73	2,4-Dichlorophenol	120832	2.1E-02	0.1	0.87	2.10	1.0	4.1E-05	4.3E-03	37%	Y
** 74	Dichloropropane, 1,2-	78875	7.8E-03	0.0	0.46	1.10	1.0	1.1E-05	1.2E-03	10%	N
** 75	Dichloropropene, 1,3-	542756	4.3E-03	0.0	0.45	1.07	1.0	6.1E-06	6.4E-04	5%	N
76	Dichlorvos	62737	8.5E-04	0.0	1.85	4.44	1.0	2.5E-06	2.6E-04	2%	N
77	Dieldrin	60571	1.2E-02	0.1	14.62	35.09	0.8	7.9E-05	8.3E-03	71%	Y
78	Diepoxybutane	1464535	3.1E-05	0.0	0.32	0.78	1.0	3.7E-08	3.9E-06	0%	N
79	Diethyl phthalate	84662	3.9E-03	0.0	1.87	4.50	1.0	1.1E-05	1.2E-03	10%	Y
80	Diethyl sulfate	64675	1.2E-03	0.0	0.78	1.87	1.0	2.3E-06	2.4E-04	2%	N
81	Dimethoxybenzidine,	119904	9.3E-04	0.0	2.85	6.84	1.0	3.3E-06	3.5E-04	3%	N
82	Dimethyl phthalate	131113	1.4E-03	0.0	1.31	3.13	1.0	3.4E-06	3.5E-04	3%	N
83	Dimethyl sulfate	77781	1.8E-03	0.0	0.54	1.30	1.0	2.8E-06	3.0E-04	3%	N
84	Dimethylamine, n-	62759	2.5E-04	0.0	0.28	0.67	1.0	2.8E-07	3.0E-05	0%	N
85	Dimethylaminoazobenze	60117	9.5E-02	0.5	1.95	4.68	1.0	2.8E-04	2.9E-02	251%	Y
86	Dimethylbenzidine, 3,3'-	119937	3.6E-03	0.0	1.65	3.97	1.0	9.8E-06	1.0E-03	9%	N
87	Dimethylcarbamyl	79447	3.9E-04	0.0	0.43	1.02	1.0	5.4E-07	5.7E-05	0%	N
88	Dimethylhydrazine, 1,1-	57147	7.3E-05	0.0	0.23	0.55	1.0	7.6E-08	8.0E-06	0%	N
89	Dimethylphenol, 2,4-	105679	1.1E-02	0.0	0.52	1.24	1.0	1.7E-05	1.7E-03	15%	Y
90	Dimethylphenol, 3,4-	95658	9.8E-03	0.0	0.51	1.24	1.0	1.5E-05	1.6E-03	13%	Y
91	Dinitrophenol, 2,4-	51285	1.5E-03	0.0	1.15	2.76	1.0	3.5E-06	3.7E-04	3%	N
92	Dinitrotoluene, 2,4-	121142	3.1E-03	0.0	1.12	2.69	1.0	6.9E-06	7.3E-04	6%	N
93	Dinitrotoluene, 2,6-	606202	2.1E-03	0.0	1.12	2.69	1.0	4.6E-06	4.9E-04	4%	N
94	Dioxane, 1,4-	123911	3.3E-04	0.0	0.33	0.80	1.0	4.0E-07	4.3E-05	0%	N
95	Diphenylamine, n-	86306	1.5E-02	0.1	1.38	3.31	1.0	3.6E-05	3.8E-03	32%	Y
96	Diphenylhydrazine, 1,2-	122667	1.3E-02	0.1	1.15	2.76	1.0	3.0E-05	3.1E-03	27%	Y
97	Dipropylamine, n-	621647	2.3E-03	0.0	0.57	1.37	1.0	3.7E-06	3.9E-04	3%	N
98	Endrin	72208	1.2E-02	0.1	14.62	35.09	0.8	7.9E-05	8.3E-03	71%	Y
99	Epichlorohydrin	106898	3.5E-04	0.0	0.35	0.84	1.0	4.3E-07	4.6E-05	0%	N

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/Oral (%)	Chem Assess
100	Ethanol	64175	5.4E-04	0.0	0.19	0.46	1.0	5.2E-07	5.5E-05	0%	N
101	Ethanol, 2-(2-butoxyethoxy)-	112345	4.7E-05	0.0	0.86	2.07	1.0	9.3E-08	9.8E-06	0%	N
102	Ethanol, 2-(2-ethoxyethoxy)-	111900	2.5E-04	0.0	0.60	1.44	1.0	4.0E-07	4.2E-05	0%	N
103	Ethanol, 2-(2-methoxyethoxy)-	111773	1.7E-04	0.0	0.50	1.20	1.0	2.6E-07	2.8E-05	0%	N
104	2-Ethoxy ethanol (Cellosolve)	110805	3.0E-04	0.0	0.34	0.82	1.0	3.7E-07	3.9E-05	0%	N
105	Ethoxyethyl acetate, 2-	111159	7.7E-04	0.0	0.59	1.41	1.0	1.2E-06	1.3E-04	1%	N
106	Ethyl acrylate	140885	3.2E-03	0.0	0.39	0.93	1.0	4.3E-06	4.5E-04	4%	N
107	Ethyl carbamate	51796	3.9E-04	0.0	0.34	0.81	1.0	4.8E-07	5.1E-05	0%	N
108	Ethyl ether	60297	2.3E-03	0.0	0.28	0.67	1.0	2.6E-06	2.8E-04	2%	N
109	Ethylbenzene	100414	4.9E-02	0.2	0.42	1.01	1.0	6.7E-05	7.1E-03	61%	Y
110	Ethylene oxide	75218	5.6E-04	0.0	0.19	0.45	1.0	5.4E-07	5.7E-05	0%	N
**111	Ethylenedibromide	106934	2.8E-03	0.0	1.21	2.90	1.0	6.4E-06	6.8E-04	6%	N
112	Ethyleneimine	151564	1.6E-04	0.0	0.19	0.45	1.0	1.5E-07	1.6E-05	0%	N
113	Ethylenethiourea	96457	1.7E-04	0.0	0.37	0.88	1.0	2.1E-07	2.2E-05	0%	N
114	4-Ethylphenol	123079	1.7E-02	0.1	0.52	1.24	1.0	2.5E-05	2.7E-03	23%	Y
* 115	Fluoranthene	206440	2.2E-01	1.2	1.45	5.68	1.0	5.7E-04	6.0E-02	512%	NA
116	Formaldehyde	50000	1.8E-03	0.0	0.16	0.38	1.0	1.6E-06	1.7E-04	1%	N
117	Glycerol	56815	3.2E-05	0.0	0.35	0.84	1.0	4.0E-08	4.3E-06	0%	N
118	Heptachlor	76448	8.6E-03	0.1	13.27	31.85	0.8	5.3E-05	5.6E-03	48%	Y
119	n-Heptanol	111706	1.9E-02	0.1	0.48	1.15	1.0	2.8E-05	3.0E-03	25%	Y
* 120	Hexachlorobenzene	118741	1.3E-01	0.9	4.22	16.21	0.9	5.2E-04	5.5E-02	469%	NA
**121	Hexachlorobutadiene	87683	8.1E-02	0.5	3.09	7.42	0.9	2.7E-04	2.9E-02	243%	Y
**122	Hexachloroethane	67721	3.0E-02	0.2	2.27	5.44	1.0	9.6E-05	1.0E-02	86%	Y
123	Hexamethylphosphoramide	680319	1.6E-04	0.0	1.08	2.58	1.0	3.6E-07	3.8E-05	0%	N
124	n-Hexanol	111273	9.3E-03	0.0	0.40	0.96	1.0	1.2E-05	1.3E-03	11%	Y
* 125	Hydrazine/Hydrazine sulfate	302012	4.4E-05	0.0	0.16	0.39	1.0	3.9E-08	4.2E-06	0%	NA
* 126	Indeno(1,2,3-CD)pyrene	193395	1.0E+00	6.7	3.78	16.83	0.6	2.6E-03	2.7E-01	2307%	NA
127	Isophorone	78591	3.4E-03	0.0	0.63	1.52	1.0	5.7E-06	6.0E-04	5%	N
128	Lindane	58899	1.1E-02	0.1	4.57	10.97	0.9	4.4E-05	4.6E-03	40%	Y
129	Mechlorethamine	51752	1.1E-03	0.0	0.80	1.92	1.0	2.0E-06	2.1E-04	2%	N
130	Methanol	67561	3.2E-04	0.0	0.16	0.39	1.0	2.9E-07	3.0E-05	0%	N
131	Methoxyethanol, 2-	109864	1.8E-04	0.0	0.28	0.68	1.0	2.0E-07	2.1E-05	0%	N
132	Methoxypropan-2-ol, 1-	107982	3.7E-04	0.0	0.34	0.82	1.0	4.6E-07	4.8E-05	0%	N
133	Methyl ethyl ketone	78933	9.6E-04	0.0	0.27	0.65	1.0	1.1E-06	1.1E-04	1%	N

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/Oral (%)	Chem Assess
134	Methyl-4-hydroxy	99763	4.4E-03	0.0	0.76	1.82	1.0	8.1E-06	8.6E-04	7%	N
**135	Methyl iodide	74884	2.5E-03	0.0	0.67	1.60	1.0	4.3E-06	4.6E-04	4%	N
136	Methylaziridine, 2-	75558	3.0E-04	0.0	0.22	0.53	1.0	3.1E-07	3.3E-05	0%	N
137	Methylene	101144	2.1E-02	0.1	3.36	8.06	0.9	7.2E-05	7.6E-03	65%	Y
138	Methylene	101611	8.4E-02	0.5	2.83	6.80	1.0	3.0E-04	3.2E-02	270%	Y
**139	Methylene chloride	75092	3.5E-03	0.0	0.32	0.76	1.0	4.2E-06	4.5E-04	4%	N
140	Methylenedianiline, 4,4'-	101779	1.4E-03	0.0	1.37	3.30	1.0	3.4E-06	3.6E-04	3%	N
141	Michler's ketone	90948	2.5E-02	0.2	3.41	8.19	0.9	8.7E-05	9.2E-03	78%	Y
**142	Mustard Gas	505602	4.5E-03	0.0	0.83	2.00	1.0	8.6E-06	9.1E-04	8%	N
143	Naphthalene	91203	4.7E-02	0.2	0.56	1.34	1.0	7.4E-05	7.8E-03	66%	Y
144	2-Naphthol	135193	1.9E-02	0.1	0.69	1.64	1.0	3.3E-05	3.5E-03	30%	Y
145	Naphthylamine, 1-	134327	7.7E-03	0.0	0.68	1.62	1.0	1.3E-05	1.4E-03	12%	Y
146	Naphthylamine, 2-	91598	8.1E-03	0.0	0.68	1.62	1.0	1.4E-05	1.5E-03	13%	Y
147	Nitrilotriacetic acid	139139	1.0E-04	0.0	1.26	3.01	1.0	2.4E-07	2.5E-05	0%	N
148	Nitro-o-anisidine, 5-	99592	2.1E-03	0.0	0.77	1.84	1.0	3.8E-06	4.0E-04	3%	N
149	Nitrobiphenyl, 4-	92933	3.8E-02	0.2	1.40	3.35	1.0	9.5E-05	1.0E-02	86%	Y
* 150	Nitrofen	1836755	1.9E-01	1.2	4.18	16.33	0.9	7.3E-04	7.7E-02	660%	NA
151	Nitrophenol, 2-	88755	4.0E-03	0.0	0.64	1.54	1.0	6.8E-06	7.2E-04	6%	N
152	Nitrophenol, 2-amino-4-	99570	1.7E-03	0.0	0.78	1.87	1.0	3.2E-06	3.4E-04	3%	N
153	3-Nitrophenol	554847	5.5E-03	0.0	0.64	1.54	1.0	9.4E-06	9.9E-04	8%	N
154	4-Nitrophenol	100027	4.8E-03	0.0	0.64	1.54	1.0	8.2E-06	8.6E-04	7%	N
155	Nitrophenol, 4-amino-2-	119346	9.3E-04	0.0	0.78	1.87	1.0	1.7E-06	1.8E-04	2%	N
156	Nitropropane, 2-	79469	8.8E-04	0.0	0.44	1.06	1.0	1.2E-06	1.3E-04	1%	N
157	Nitroso-di-n-butylamine,	924163	3.8E-03	0.0	0.82	1.97	1.0	7.3E-06	7.7E-04	7%	N
158	Nitroso-N-ethylurea, n-	759739	4.9E-04	0.0	0.48	1.16	1.0	7.2E-07	7.6E-05	1%	N
159	Nitroso-N-methylurea, n-	684935	3.9E-04	0.0	0.40	0.97	1.0	5.3E-07	5.6E-05	0%	N
160	Nitrosodiethanolamine,	1116547	2.5E-05	0.0	0.60	1.44	1.0	4.0E-08	4.3E-06	0%	N
161	Nitrosodiethylamine, n-	55185	1.0E-03	0.0	0.33	0.80	1.0	1.3E-06	1.3E-04	1%	N
162	Nitrosodiphenylamine,	156105	2.6E-02	0.1	1.38	3.31	1.0	6.4E-05	6.7E-03	57%	Y
163	Nitrosomethylvinylamin	4549400	5.1E-04	0.0	0.32	0.78	1.0	6.2E-07	6.5E-05	1%	N

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/Oral (%)	Chem Assess
164	Nitrosomorpholine, n-	59892	1.8E-04	0.0	0.48	1.14	1.0	2.6E-07	2.7E-05	0%	N
165	Nitrosonornicotine, n-	16543558	1.7E-04	0.0	1.05	2.52	1.0	3.6E-07	3.8E-05	0%	N
166	Nitrosopiperidine, n-	100754	2.9E-05	0.0	9.83	23.60	1.0	1.9E-07	2.1E-05	0%	N
167	n-Nonanol	143088	7.8E-02	0.4	0.69	1.65	1.0	1.4E-04	1.4E-02	122%	Y
168	n-Octanol	111875	2.7E-02	0.1	0.57	1.37	1.0	4.4E-05	4.6E-03	39%	Y
169	Parathion	56382	1.3E-02	0.1	4.57	10.97	0.9	5.2E-05	5.5E-03	47%	Y
* 170	PCB-chlorobiphenyl, 4-	2051629	7.5E-01	4.9	4.63	20.27	0.6	2.0E-03	2.2E-01	1844%	NA
* 171	PCB-hexachlorobiphenyl	26601649	4.3E-01	3.2	11.29	47.90	0.5	1.5E-03	1.6E-01	1378%	NA
**172	Pentachloronitrobenzene	82688	4.2E-02	0.3	4.83	11.60	0.9	1.7E-04	1.8E-02	157%	Y
* 173	Pentachlorophenol	87865	3.9E-01	2.5	3.33	13.82	0.9	1.4E-03	1.4E-01	1226%	NA
174	n-Pentanol	71410	5.5E-03	0.0	0.33	0.80	1.0	6.6E-06	7.0E-04	6%	N
175	Pentanone, 4-methyl-2-	108101	2.7E-03	0.0	0.39	0.93	1.0	3.5E-06	3.7E-04	3%	N
* 176	Phenanthrene	85018	1.4E-01	0.7	1.06	4.11	1.0	3.1E-04	3.3E-02	283%	NA
177	Phenol	108952	4.3E-03	0.0	0.36	0.86	1.0	5.5E-06	5.8E-04	5%	N
178	Phenol, 4,6-dinitro-2-methyl-	534521	3.1E-03	0.0	1.38	3.30	1.0	7.7E-06	8.1E-04	7%	N
179	n-Propanol	71238	1.1E-03	0.0	0.23	0.56	1.0	1.1E-06	1.2E-04	1%	N
180	Propiolactone, beta-	57578	3.1E-04	0.0	0.27	0.65	1.0	3.4E-07	3.5E-05	0%	N
181	Propylene oxide	75569	7.7E-04	0.0	0.23	0.54	1.0	8.0E-07	8.5E-05	1%	N
182	Resorcinol	108463	1.3E-03	0.0	0.44	1.06	1.0	1.8E-06	1.9E-04	2%	N
183	Safrole	94597	1.1E-02	0.1	0.87	2.08	1.0	2.2E-05	2.3E-03	20%	Y
184	Styrene	100425	3.7E-02	0.1	0.41	0.98	1.0	5.0E-05	5.3E-03	45%	Y
185	Styrene oxide	96093	3.9E-03	0.0	0.50	1.20	1.0	5.8E-06	6.2E-04	5%	N
* 186	TCDD	1746016	8.1E-01	5.6	6.82	30.09	0.5	2.2E-03	2.4E-01	2003%	NA
**187	Tetrachlorethylene	127184	3.3E-02	0.2	0.91	2.18	1.0	6.7E-05	7.1E-03	60%	Y
**188	Tetrachloroethane, 1,1,2,2-	79345	6.9E-03	0.0	0.93	2.24	1.0	1.4E-05	1.5E-03	13%	Y
189	Thioacetamide	62555	1.8E-03	0.0	0.28	0.67	1.0	2.0E-06	2.1E-04	2%	N
190	Thiodianiline, 4,4'-	139651	2.1E-03	0.0	1.73	4.16	1.0	6.0E-06	6.3E-04	5%	N
191	Thiourea	62566	1.4E-04	0.0	0.28	0.68	1.0	1.5E-07	1.6E-05	0%	N
192	Thymol	89838	3.7E-02	0.2	0.74	1.78	1.0	6.8E-05	7.2E-03	61%	Y
193	Toluene	108883	3.1E-02	0.1	0.35	0.84	1.0	3.9E-05	4.1E-03	35%	Y
194	Toluidine hydrochloride, o-	636215	1.8E-03	0.0	0.68	1.62	1.0	3.1E-06	3.3E-04	3%	N
195	Toluidine, o-	95534	3.0E-03	0.0	0.42	1.02	1.0	4.1E-06	4.3E-04	4%	N
196	Toxaphene	8001352	1.2E-02	0.1	22.40	53.75	0.8	9.5E-05	1.0E-02	85%	Y
197	Trichlorobenzene, 1,2,4-	120821	6.6E-02	0.3	1.11	2.66	1.0	1.5E-04	1.6E-02	133%	Y

Table 6 (con't) – Input Parameters for Organic Contaminants in Water

	CHEMICAL	CAS No.	K_p (cm/hr)	B	τ (hr)	t* (hr)	FA	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	Derm/ Oral (%)	Chem Assess
**198	Trichloroethane, 1,1,1-	71556	1.3E-02	0.1	0.60	1.43	1.0	2.1E-05	2.2E-03	19%	Y
**199	Trichloroethane, 1,1,2-	79005	6.4E-03	0.0	0.60	1.43	1.0	1.0E-05	1.1E-03	9%	N
**200	Trichloroethylene	79016	1.2E-02	0.1	0.58	1.39	1.0	1.9E-05	2.0E-03	17%	Y
**201	Trichlorofluoromethane	75694	1.3E-02	0.1	0.63	1.51	1.0	2.1E-05	2.3E-03	19%	Y
202	2,4,6-Trichlorophenol	88062	3.5E-02	0.2	1.36	3.27	1.0	8.5E-05	9.0E-03	77%	Y
* 203	Tris(2,3-dibromopropyl) phosphate	126727	3.9E-04	0.0	874.39	2098.53	1.0	2.4E-05	2.6E-03	22%	NA
204	Tris(aziridinyl)-para-benzoquinone	68768	1.0E-05	0.0	2.11	5.07	1.0	3.1E-08	3.3E-06	0%	N
* 205	Urea	57136	2.9E-05	0.0	0.23	0.55	1.0	3.0E-08	3.2E-06	0%	NA
**206	Vinyl bromide	593602	4.3E-03	0.0	0.42	1.02	1.0	6.0E-06	6.3E-04	5%	N
**207	Vinyl chloride	75014	5.6E-03	0.0	0.24	0.57	1.0	5.9E-06	6.3E-04	5%	N
* 208	Water	7732185	1.5E-04	0.0	0.13	0.32	1.0	1.3E-07	1.4E-05	0%	NA
209	Xylene, m-	108383	5.3E-02	0.2	0.42	1.01	1.0	7.3E-05	7.7E-03	65%	Y

Table 7. Input Parameters for Inorganic Contaminants in Water (Exhibit B-4 in Rags Part E

	CHEMICAL	K_p (cm/hr)	Source of K_p (exp or default)	DA_{event} (mg/cm^2-event)	DAD (mg/kg-day)	ABS_{GI} (chemical specific)	Derm/ Oral (%)	Chemical to be assessed
1	Antimony	1.0E-03	default	5.8E-07	6.2E-05	15%	3.50%	N
2	Arsenic (arsenite)	1.0E-03	default	5.8E-07	6.2E-05	95%	0.55%	N
3	Barium	1.0E-03	default	5.8E-07	6.2E-05	7%	7.50%	N
4	Beryllium	1.0E-03	default	5.8E-07	6.2E-05	0.7%	75.00%	Y
5	Cadmium	1.0E-03	experimental	5.8E-07	6.2E-05	2.5%	21.00%	Y
6	Cadmium	1.0E-03	experimental	5.8E-07	6.2E-05	5%	10.50%	Y
7	Chromium (III)	1.0E-03	experimental	5.8E-07	6.2E-05	1.3%	40.38%	Y
8	Chromium (VI)	2.0E-03	experimental	1.2E-06	1.2E-04	2.5%	42.00%	Y
9	Copper	1.0E-03	default	5.8E-07	6.2E-05	57%	0.92%	N
10	Cyanate	1.0E-03	default	5.8E-07	6.2E-05	47%	1.12%	N
11	Manganese	1.0E-03	default	5.8E-07	6.2E-05	6%	8.75%	N
12	Mercuric chloride (other soluble salts)	1.0E-03	experimental	5.8E-07	6.2E-05	7%	7.50%	N
13	Insoluble or metallic mercury	1.0E-03	experimental	5.8E-07	6.2E-05	7%	7.50%	N
14	Nickel	2.0E-04	experimental	1.2E-07	1.2E-05	4%	2.63%	N
15	Selenium	1.0E-03	default	5.8E-07	6.2E-05	30%	1.75%	N
16	Silver	6.0E-04	experimental	3.5E-07	3.7E-05	4%	7.88%	N
17	Thallium	1.0E-03	default	5.8E-07	6.2E-05	100%	0.53%	N
18	Vanadium	1.0E-03	default	5.8E-07	6.2E-05	2.6%	20.19%	Y
19	Zinc	6.0E-04	experimental	3.5E-07	3.7E-05	highly variable		

Appendix C
Dermal Dose from Wading in Surface Water

Example 1. Dermal exposure to benzene from wading in surface water

Children between 6 and 11 years old are assumed to wade in a small pond that is contaminated with benzene. The pond is located in a state with warm weather year-round thus wading is assumed to occur 12 months/year. Local knowledge and information from nearby residents indicate that children wade in the pond approximately 3 times/week for an hour each time. This age range is assumed to be the most highly exposed group for this exposure scenario. The child is assumed to wade in surface water located along the shoreline, thereby exposing their heads, forearms, hands, lower legs and feet to the impacted surface water along the shoreline. The state environmental agency has collected and tested two surface water samples from the pond. Benzene was found at 50 and 75 ug/L in the two samples. Incidental surface water ingestion is not assumed for wading scenarios.

The dermal exposure dose is calculated from the following equations (RAGS Part E, 2004 – Equations 3.11 and 3.12):

Step 1: Calculate DA_{event} for Dermal Dose
Determine if t_{event} is greater than or less than t^*.

t_{event} = 1 hour, which is greater than t^* of 0.7 hours (Table 6, benzene)

Therefore, use the following equation:

$$DA_{event} = FA \times K_p \times C_{SW} \left[\frac{t_{event}}{1+B} + 2\tau_{event} \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

where,

$$B = \frac{K_p}{K_{p,ve}} \approx K_p \times \frac{\sqrt{MW}}{2.6}$$

Table 8. DA_{event} parameters for example 1 (exposure to benzene from wading in surface water)

Parameter	Definition (units)	Default/Site-Specific Values
DA_{event}	= Absorbed dose per event (mg/cm^2-event)	calculated
FA	= Fraction absorbed water (dimensionless)	1
K_p	= Dermal permeability coefficient of compound in water (cm/hr)	1.5E-2
C_{SW}	= Chemical concentration in surface water (mg/L) × (L/1000 cm^3)	0.075 mg/L × 1/1000 = 0.000075 mg/cm^3
τ_{event}	= Lag time per event (hr/event) (Table 6)	0.29
t_{event}	= Event duration (hr/event)	1
t^*	= Time to reach steady state (hr) (Table 6)	0.7
B	= Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless)	= 1.5E-2 × $\frac{\sqrt{78.11}}{2.6}$ = 0.051
MW	= Chemical-specific MW	78.11 g/mol

$$DA_{event} = FA\ x\ K_p \times C_{SW}\left[\frac{t_{event}}{1+B} + 2\tau_{event}\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

$$DA_{event} = 1 \times 1.5\text{E}-2\ \frac{cm}{hr} \times 0.000075 \frac{mg}{cm3} \cdot \left[\frac{1}{1+0.051} + (2 \times 0.29) \times \left(\frac{1+3(0.051)+3(0.051)^2}{(1+0.051)^2}\right)\right]$$

$$DA_{event} = 1.76\text{E-}06$$

Step 2: Calculate dermal dose for noncancer

Table 9. DAD parameters for example 1 (exposure to benzene from wading in surface water)

Parameter	Definition	Default/Site-specific Value
DAD	= Dermal Absorbed Dose (mg/kg/day)	calculated
ADD	= Administered Dermal Dose (mg/kg/day)	calculated
DA_{event}	= Absorbed dose per event (mg/cm^2/event)	1.76E-6
EV	= Event Frequency (events/day)	EV = 1 event/day
$EF_{chronic}$	= Exposure Factor (F x ED)/AT	
F	= Frequency of Exposure (d/wk, wks/yr)	F = 3 d/wk x 52.14 wks/yr
ED	= Exposure Duration (yr)	ED = 5 years
$AT_{noncancer}$	= Averaging Time (d/wk, wks/yr, yrs)	AT = (7 d/wk x 52.14 wks/yr, 5 yr)
AT_{cancer}	= Averaging Time (d/wk, wks/yr, yrs)	AT = (7 d/wk x 52.14 wks/yr, 78 yr)
SA	= Surface Area available for contact (cm^2)	3,824 cm^2 (see Table 5, Appendix A)
BW	= Body Weight (kg)	31.8 kg – (ATSDR 2016b)

(a) Best Professional Judgment – based on site-specific conditions
(b) Surface area represents mean surface area for the head, hands, forearms, lower legs and feet of a child aged 6 to <11 years old.

Step 2a: Calculate noncancer EF for Dermal Dose

$$EF_{noncancer} = \frac{F \times ED}{AT_{noncancer}}$$

$$EF_{noncancer} = \frac{3\ \frac{d}{wk} \times\ 52.14\ \frac{wk}{yr} \times 5\ yr}{7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 5\ yr} = 0.429$$

Step 2b: Calculate noncancer DAD

$$DAD_{noncancer} = \frac{DA_{event} \times EV \times EF_{noncancer} \times SA}{BW}$$

$$DAD_{noncancer} = \frac{1.76E-6 \times 1 \times 0.429 \times 3{,}824\ cm^2}{31.8\ kg}$$

$DAD_{noncancer}$ = 9.1E-05 mg/kg/day

Step 2c: Convert the DAD $_{noncancer}$ to an ADD $_{noncancer}$

$$ADD_{noncancer} = \frac{DAD_{noncancer}}{ABS_{GI}}$$

$$ADD_{noncancer} = \frac{9.1E-5}{1}\frac{mg}{kg}/day$$

$$ADD_{noncancer} = 9.1E-5\frac{mg}{kg}/day$$

Step 3: Compare ADD $_{noncancer}$ to the chronic oral MRL or RfD and calculate Hazard Quotient (HQ)

$$HQ = \frac{ADD_{noncancer}(\frac{mg}{kg}/day)}{Chronic\ Oral\ MRL\ (\frac{mg}{kg}/day)} = \frac{9.1E-05\ \frac{mg}{kg}/day}{5E-4\ \frac{mg}{kg}/day}$$

$$HQ = 0.18$$

Step 4: Calculate Cancer Risk from Dermal Uptake
Children are assumed to be exposed for 5 years from ages 6 to 11 years old.

Step 4a: Calculate DA_{event}

Use DA_{event} calculated in Step 1

DA_{event} = 1.76E-06

Step 4b: Calculate cancer EF for Dermal Dose

$$EF_{cancer} = \frac{F \times D}{AT_{cancer}}$$

$$EF_{cancer} = \frac{3\ \frac{d}{wk} \times\ 52.14\ \frac{wk}{yr} \times 5\ yr}{7\ \frac{d}{wk} \times 52.14\ \frac{wk}{yr} \times 78\ yr} = 0.0275$$

Step 4c: Calculate cancer DAD

$$DAD_{cancer} = \frac{DA_{event} \times EF_{cancer} \times SA}{BW}$$

$$DAD_{cancer} = \frac{1.76E-6 \times 1 \times 0.0275 \times 3{,}824\ cm^2}{31.8\ kg}$$

DAD_{cancer} = 5.8E-06 mg/kg/day

Step 4d: Convert DAD_{cancer} to ADD_{cancer}

$$ADD_{cancer} = \frac{DAD_{cancer}}{ABS_{GI}}$$

$$ADD_{cancer} = \frac{5.8E-6\,mg}{1}\frac{}{kg}/day$$

$$ADD_{cancer} = 5.8E-6\,\frac{mg}{kg}/day$$

Step 4d: Calculate Cancer Risk for Dermal Uptake

$$Cancer\ Risk = ADD_{\ cancer} \times cancer\ slope\ factor$$

$$Cancer\ Risk = \ 5.8E-6 \ \times 5.5E-2 \text{ (mg/kg/day)}^{-1}$$

$$Cancer\ Risk = \ 3.2E-7$$

Appendix D
Incidental Ingestion of Surface Water from Swimming

Children 6 years and older attend a month-long swimming camp 5 days a week where they participate 2 hours a day in swimming activities. Several water samples from the pool contain acrylamide, and the EPC has been determined to be 500 ppb. Calculate the oral dose in these children.

Step 1: Calculate EF for Swimming Scenario

Because children are exposed only for 1 month, a chronic dose is not calculated. Health assessors should calculate an intermediate and acute dose.

Intermediate duration EF

$$EF_{intemediate} = \frac{F \times ED}{AT}$$

$$EF_{intemediate} = \frac{5\frac{d}{wk} \times 3\ months}{7\frac{d}{wk} \times 3\ months}$$

$$EF_{intemediate} = 0.714$$

Acute duration EF

$$EF_{acute} = \frac{5\ days}{5\ days}$$

$$EF_{acute} = 1$$

Step 2: Calculate incidental ingestion dose from swimming
Calculations are shown for children 11 to < 16 years with RME intake rates for surface water.

Step 2a: Identify parameters for swimming scenario

Children incidental ingestion rate of surface water: 0.049 L/hour (CTE) and 0.12 L/hour (RME) (See Table 4.)

Table 10. ATSDR-Recommended Body Weights in Health Evaluations (ATSDR 2016b.)

Age Group	Mean Body Weight in kg
6 to < 11 years	31.8
11 to < 16 years	56.8
16 to < 21 years	71.6

Step 2b: Calculate RME incidental surface water doses for intermediate and acute exposures for swimming scenario

$$Incidental\ Surface\ Water\ Dose_{intemediate\ or\ acute} = \frac{C\ \times IR \times EV\ \times t_{event} \times EF_{intemediate\ or\ acute}}{BW}$$

D = exposure dose (mg/kg-day)
C = contaminant concentration (mg/L)
IR = ingestion rate of contaminated water (L/hr)
t_{event} = site-specific event duration (hr/event)
EV = site-specific event frequency (events/day)
EF = exposure factor (unitless) = (F x ED)/AT
BW = body weight (kg)

Intermediate surface water dose for children ages 11 to <16 years.

$$\boldsymbol{RME}\ Incidental\ Surface\ Water\ Dose_{intemediate} = \frac{0.5\frac{mg}{L} \times \frac{0.12L}{hr} \times 2\frac{hr}{event} \times 1\frac{event}{day} \times 0.714}{56.8\ kg}$$

$$\boldsymbol{RME}\ Incidential\ Surface\ Water\ Dose_{intemediate} = 0.0015\ mg/kg/day$$

Acute surface water doses

$$\boldsymbol{RME}\ Incidental\ Surface\ Water\ Dose_{acute} = \frac{0.5\frac{mg}{L} \times \frac{0.12L}{hr} \times 1\frac{event}{day} \times 2\frac{hr}{event} \times 1}{56.8\ kg}$$

$$\boldsymbol{RME}\ Incidental\ Surface\ Water\ Dose_{acute} = 0.0021\ mg/kg/day$$

Step 3. Calculate RME Hazard Quotient for Swimming Scenario

Intermediate, oral MRL = 0.001 mg/kg/day
Acute, oral MRL = 0.01 mg/kg/day

Intermediate Duration HQ

$$HQ_{intermediate} = \frac{RME\ Incidental\ Surface\ Water\ Dose_{intemediate}\ (\frac{mg}{kg}/day)}{Intermediate\ Oral\ MRL\ (\frac{mg}{kg}/day)}$$

$$HQ_{intermediate} = \frac{0.0015\ (\frac{mg}{kg}/day)}{0.001\ (\frac{mg}{kg}/day)}$$

$$HQ_{intermediate} = 1.5$$

Acute Duration HQ

$$HQ_{acute} = \frac{RME\ Incidential\ Surface\ Water\ Dose_{acute}\ (\frac{mg}{kg}/day)}{Acute\ Oral\ MRL\ (\frac{mg}{kg}/day)}$$

$$HQ_{intermediate} = \frac{0.0021\ (\frac{mg}{kg}/day)}{0.01\ (\frac{mg}{kg}/day)}$$

$$HQ_{intermediate} = 0.2$$