Exposure Dose Guidance for Water Ingestion

Citation:
[ATSDR] Agency for Toxic Substances and Disease Registry. 2023. Exposure Dose Guidance for Water Ingestion. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, Jan 31.

Content

This guidance contains the following topics:

Topic	See Page
Purpose	2
Background	2
Definitions	2
Exposure Dose Equation	4
Summary Tables of Water Intake Rates	4
Cancer	6
Noncancer (Annual) Dose and Cancer (Lifetime) Dose Estimates	7
Central Tendency and Upper Percentile Dose Estimates (CTE/ RME)	9
Public Health Assessment Site Tool (PHAST)	9
Impact	10
References	10
Appendices	11
Appendix A—Exposure Dose Calculations	11
Appendix B—Mutagenic Mode of Action (MOA)	14
Appendix C—Derivation of Intake Rates for Standard Age Groups and Special Groups	14

Purpose

Based on the availability of updated exposure parameters, many from the 2019 update of drinking water ingestion values in the Exposure Factors Handbook (EFH) published by the U.S. Environmental Protection Agency (EPA), it is necessary that parameters used in calculating doses in our public health evaluations be updated to reflect the best available science.

This water exposure dose guidance (EDG) provides health assessors with updated guidance on how to estimate water-ingestion related exposures to potential contaminants of concern (COCs). The guidance document for the Shower and Household Water-use Exposure (SHOWER) model addresses inhalation of volatile and semi-volatile organic compounds during household water use, such as while showering (ATSDR 2020).

Background

After a release of chemicals into the environment, health assessors evaluate all relevant human exposure pathways; water ingestion is usually one of the more commonly evaluated pathways.

In ATSDR's 2005 Public Health Assessment Guidance Manual (PHAGM), default daily water intake rates were 2 L/day for adults and 1 L/day for children (ATSDR 2005). This guidance document provides updated age-specific drinking water intake rates for ATSDR's standard and special age groups using the 2019 update of EPA's 2011 Exposure Factor Handbook, Chapter 3, (EPA 2019). ATSDR's standard age groups are based on age ranges for residential scenarios. We also developed intake rates for special groups, such as infants, school age children, workers, pregnant women, and breastfeeding women.

Definitions

Any discussion of water ingestion needs to start with several important definitions:

Intake rate (IR). IR refers to all forms of tap water intake from either municipal or private wells (direct and indirect ingestion). It does not include intake from bottled water.

Direct ingestion is drinking plain water as a beverage at home and away from home from all sources, including

- Tap/fountain water from a community water supply,
- Household well or rain cistern,
- Household or public spring, and
- Bottled.

Direct ingestion does not include water used for preparing beverages such as coffee or tea.

Indirect ingestion includes drinking water added during food preparation but does not include drinking any water included with prepackaged, purchased foods. Thus, indirect ingestion includes water added to prepare, for example, baby formula, cake mix, and concentrated orange juice but does not include the water that is part of, say, pasta sauce.

Community water includes tap water from a community or municipal water supply.

Central tendency exposure (CTE). CTE refers to persons who have average or typical water intake rate. For water ingestion, the dose calculation uses CTE water intake.

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 exposures that are higher than average but still within a realistic exposure range.

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 calculated by averaging 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.

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.

Residential occupancy period (ROP): The time in years between when a person moves into a residence and when the person moves out or dies.

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

$$D = \frac{C * IR * EF}{BW}$$

where

D = exposure dose (mg/kg-day)
C = contaminant concentration (mg/L)
IR = intake rate of contaminated water (L/day)
$EF_{chronic}$ = exposure factor (unitless) = (F x ED)/AT

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

BW = body weight (kg)

Source: Public Health Assessment Guidance Manual, Estimating Site-Specific Ingestion Doses (ATSDR 2022a).

Summary Tables of Water Intake Rates

ATSDR staff reviewed the water intake rates in the previous version of this EDG and updated the intake rates using data from the 2019 update to Chapter 3 in EPA's 2011 Exposure Factors Handbook (EFH) (EPA 2019). The 2019 EFH update has information about adult and child water intake rates based on recent data from the National Health and Nutrition Examination Survey (NHANES) IV (CDC 2012). Unless site-specific conditions warrant using other rates, ATSDR recommends using the default water intake rates in Table 1 to estimate site-specific doses. Table 1 also contains associated time-weighted body weights (For further information, see the EDG for body weight) (ATSDR 2023).

Table 1: Recommended Age-Specific Water Intake Rates for ATSDR's Standard Age Groups[a]

Age Range	Mean (mL/day)	95th Percentile (mL/day)	Body Weight (kg)
Birth to < 1 years	595	1,106	7.8
1 to < 2 years	245	658	11.4
2 to < 6 years[b]	337	852	17.4
6 to < 11 years	455	1,258	31.8
11 to < 16 years	562	1,761	56.8
16 to < 21 years	722	2,214	71.6
Adult (21 to 78 years)[b]	1,313	3,229	80

[a]Intake rates for combined direct and indirect water from community water supply (EPA 2019, [b]See Appendix C for derivation of intake rates.

Children, pregnant and breastfeeding women: Table 2 has the recommended water ingestion values for infants and for children in kindergarten as well as for grade school children. Table 2 also provides recommended water ingestion values for pregnant and breastfeeding women. If a review of ATSDR toxicological profiles for potential COCs indicates a critical outcome is based on developmental effects, include the pregnant woman scenario in the health evaluation. Similarly, if information in the toxicological profiles indicates potential COCs might affect breast milk, include breastfeeding women in the health evaluation. For specific questions regarding the evaluation of pregnant and breastfeeding women, contact the Associate Director for Science (ADS).

If needed, EPA's EFH contains more detailed information about water ingestion for specific groups (e.g., sex, region, activity levels) (EPA 2019).

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

Appendix A has sample water-exposure dose calculations. See Appendix C for an explanation of how intake rates were calculated for each age group.

Table 2: Recommended Water Intake Rates for Special Groups

Age Range	Special Group	Mean (mL/day)	95th Percentile (mL/day)	Body [a] (kg)
Birth to < 1 month[b]	Infant	581	938	4.8
1 to < 3 months[b]	Infant	785	1,224	5.9
3 to < 6 months[b]	Infant	649	1,125	7.4
6 to < 12 months[b]	Infant	554	1,104	9.2
3 to < 5 years[c]	Pre-Kindergarten	324	866	17.2
5 to < 6 years[c]	Kindergarten	364	1,006	20.6
6 to < 11 years	1st-5th	455	1,258	31.8
11 to < 14 years[c]	6th-8th grade	553	1,655	50.6
14 to < 16 years[c]	9th-10th grade	621	1,886	63.7
16 to < 18 years[c]	11th-12th grade	675	2,072	67.3
18 ≤ 67 years[c]	Full, part-time worker/educator	1,276	3,270	80.6
15 < 45 year[d]	Pregnant Women	1,158	2,935	73
15 < 45 year[d]	Breastfeeding Women	1,495	3,061	73

[a]See Exposure Dose Guidance for Body Weight (ATSDR 2023); [b]EPA 2019 EFH (update), Chapter 3, Table 3-1; [c]See Appendix C for derivation of intake rates; [d]EPA 2019 EFH (update), Chapter 3, Table 3-3 (EPA 2019)

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 also 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 chemicals, sufficient data are available to derive age-specific cancer slope factors. 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 PHAST and 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 for 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 yr/78 yr and adults (33 yr) using an ED/AT term of 33 yr/78 yr.

- 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.

When occupational exposure duration is unknown, health assessors should use the values reported in Table 3. The basis for these values is described in more detail in the EDG for determining life expectancy and exposure factor (ATSDR 2016).

Table 3. Default assumptions for occupational scenarios[a]

Typical workday, all (hours/day)	Work year (weeks)	Work tenure (years)
Full time: 8.5	RME: 50.0 CTE: 50.0	RME: 20.0 CTE: 5.0
Part time: 5.1	CTE: 50.0	CTE: 3.1

[a]ATSDR 2016

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 2016).

Central Tendency and Reasonable Maximum Exposure Dose Estimates (CTE/ RME)

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 tap water intake rates in children and adults (EPA 2019).

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 (e.g., for drinking water, usually children birth to 1 yr) or for the most sensitive group. If the estimated dose for these groups exceeds the health guideline (e.g., MRL, RfD), then 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, whenever possible.

Public Health Assessment Site Tool (PHAST)

Health assessors should use the public health assessment site tool (PHAST) to estimate drinking water doses. PHAST provides a quick summary with the maximum hazard quotient for chronic, intermediate, and acute exposure as well as the maximum cancer risk for the typical residential exposure scenario involving children and adults.

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 age-specific dose directly to NOAELs and LOAELs to determine the possibility of harmful effects. If you decide harmful effects are possible, consider 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 and adults from the more detailed cancer risks in the results table. Remember that the quick summary cancer risk is a screen – you should not include it in PHAs/HCs unless 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 exposure doses for water ingestion 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. 2022a. Public health assessment guidance manual. Atlanta: US Department of Health and Human Services. Available at: https://www.atsdr.cdc.gov/pha-guidance/index.html.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2022b. Exposure dose guidance for body weight. Atlanta, GA: US Department of Health and Human Services, Public Health Service, Dec 1.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2020. Exposure dose guidance for the Shower and Household Water-use Exposure (SHOWER) model v2.0. Atlanta, GA: US Department of Health and Human Services, Public Health Service, Feb 3.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016. Exposure Dose Guidance for Determining Life Expectancy and Exposure Factor. Atlanta, GA: US Department of Health and Human Services, Public Health Service, October 26.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public health assessment guidance manual (previous version). Atlanta: US Department of Health and Human Services, Public Health Service.

[CDC] Centers of Disease Control and Prevention. 2012. National Health and Nutrition Examination Survey. Available at: http://www.cdc.gov/nchs/nhanes.htm [accessed 2022 August 11].

[EPA] US Environmental Protection Agency. 2019. Exposure Factors Handbook Chapter 3 (Update): Ingestion of Water and Other Select Liquids. U.S. EPA Office of Research and Development, Washington, DC, EPA/600/R-18/259F. Available at: https://cfpub.epa.gov/ncea/efp/recordisplay.cfm?deid=343661 [accessed 2022 August 17].

[EPA] US Environmental Protection Agency. Exposure Factors Handbook 2011 Edition (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

[EPA] US Environmental Protection Agency. 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens.

Washington, DC, EPA/630/R-03/003F. Available at: https://www.epa.gov/risk/supplemental-guidance-assessing-susceptibility-early-life-exposure-carcinogens [accessed 2016 Oct 19].

Appendices

Appendix A: Exposure Dose Calculations

As discussed previously, health assessors should use PHAST to calculate water ingestion doses, hazard quotients, and cancer risk estimates.

The examples in the appendices detail the dose calculations included in PHAST. We show examples here for children and adults and for noncancer and cancer using the following dose formula for drinking water ingestion:

$$D = \frac{C \; x \; IR \; x \; EF}{BW}$$

D = dose in mg/kg/day
C = water concentration in mg/L
IR = tap water intake rate in L/day
EF = exposure factor
BW = body weight in kg

$EF_{chronic}$ = (F x ED)/ AT

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

- noncancer = ED (yr) x F (d/wk x wk/yr)
- cancer = 78 yr x F (7 d/wk x 52.15 wk/yr)

$EF_{intermediate}$ = (F x ED)/ AT

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

- noncancer = ED (wk) x F (d/wk)

Dose Calculation Examples

What follows are several examples showing how drinking water doses are calculated and the role exposure factor (EF) and intermittent exposure plays in estimating doses. Sample dose calculations are shown for chronic, intermediate, and acute durations.

Scenario #1. Children ages 2 to 6 years old attend preschool 5 days a week for 9 months of the year. Tap water at the school contains 10 mg/L bromoform. What is the chronic dose for children at this school from four years of exposure?

Chronic Dose

$$EF_{\text{chronic}} = 0.493$$

$$\frac{5\ \frac{d}{wk}\ x\ 36\ \frac{wk}{yr}\ x\ 4\ yr}{7\ \frac{d}{wk}\ x\ 52.14\ \frac{wk}{yr}\ x\ 4\ yr}$$

$$\text{Chronic RME Dose}_{2\ \text{to}\ <6\ \text{yr}} = \frac{(10\ \text{mg/L x}\ 0.852\ \text{L/d x}\ 0.493)}{17.4\ \text{kg}}$$

$$\text{Chronic RME Dose}_{2\ \text{to}\ <6\ \text{yr}} = 0.24\ \text{mg/kg/day}$$

Table A1 shows the parameters used to calculate the chronic, noncancer doses for children and adults at the daycare who drank water containing 10 mg/L bromoform. Compare these doses to the chronic, oral MRL of 0.02 mg/kg/day to calculate a hazard quotient (HQ).

Age Group	CTE Intake Rate L/day	RME Intake Rate L/day	Exposure Factor Unitless	Body Weight Kg	Chronic CTE Dose mg/kg/day	Chronic RME Dose mg/kg/day	Chronic CTE Hazard Quotient	Chronic RME Hazard Quotient
2 to < 6 yr	0.337	0.852	0.493	17.4	0..095	0.24	5	12
Adult (21 to 78 yr)	1.313	3.229	0.493	80	0.081	0.20	4	10.5
Pregnant Women	1.158	2.935	0.493	73	0.08	0.20	4	10
Breastfeeding Women	1.495	3.061	0.493	75	0.10	0.20	5	10

When exposure occurs every day throughout the year, the chronic, intermediate, and acute EF are 1. However, when exposure is intermittent, which is the case for this scenario, the EF for chronic, intermediate, and acute durations are different as can be seen in the examples below. For more information about determining the EF for chronic, intermediate, and acute exposures, review the EDG for determining life expectancy and exposure factor (ATSDR 2016).

Intermediate Dose

$$EF_{\text{intermediate}} = 0.714 = \frac{5\ \frac{d}{wk}\ x\ 36\ \frac{wk}{yr}}{7\ \frac{d}{wk}\ x\ 36\ \frac{wk}{yr}}$$

$$\text{Intermediate RME Dose}_{2\text{ to }<6\text{ yr}} = \frac{(10\text{ mg/L x }0.852\text{ L/d x }0.714)}{17.4\text{ kg}}$$

$$\text{Intermediate RME Dose}_{2\text{ to }<6\text{ yr}} = 0.35\text{ mg/kg/day}$$

Table A2 shows the parameters used to calculate the intermediate, noncancer doses for children and adults at the daycare who drank water containing 10 mg/L bromoform. Compare these doses to the intermediate, oral MRL of 0.2 mg/kg/day.

Age Group	CTE Intake Rate L/day	RME Intake Rate L/day	Exposure Factor Unitless	Body Weight Kg	Chronic CTE Dose mg/kg/day	Chronic RME Dose mg/kg/day	Chronic CTE Hazard Quotient	Chronic RME Hazard Quotient
2 to < 6 yr	0.337	0.852	0.714	17.4	0.14	0.35	0.69	1.8
Adult (21 to 78 yr)	1.313	3.229	0.714	80	0.12	0.29	0.59	1.4
Pregnant Women	1.158	2.935	0.714	73	0.11	0.29	0.57	1.4
Breastfeeding Women	1.495	3.061	0.714	75	0.14	0.29	0.71	1.5

Acute Dose

$$EF_{acute} = \frac{5\text{ d}}{5\text{ d}} = 1$$

When evaluating acute exposures for drinking water, the EF always will be one.

Table A3 shows the parameters used to calculate the acute, noncancer doses for children and adults at the daycare who drank water containing 10 mg/L bromoform. Compare these doses to the acute, oral MRL of 0.7 mg/kg/day.

Age Group	CTE Intake Rate L/day	RME Intake Rate L/day	Exposure Factor Unitless	Body Weight Kg	Chronic CTE Dose mg/kg/day	Chronic RME Dose mg/kg/day	Chronic CTE Hazard Quotient	Chronic RME Hazard Quotient
2 to < 6 yr	0.337	0.852	1	17.4	0.19	0.49	0.28	0.70
Adult (21 to 78 yr)	1.313	3.229	1	80	0.16	0.42	0.23	0.60
Pregnant Women	1.158	2.935	1	73	0.16	0.40	0.23	0.57
Breastfeeding Women	1.495	3.061	1	75	0.20	0.41	0.28	0.58

Appendix B: Exposure Dose Calculations — Mutagenic Mode of Action (MOA)

Typically, when calculating the cancer risk for a carcinogen, the chronic dose is adjusted for a lifetime exposure by multiplying the chronic (annual) dose by the number of years of exposure divided by 78 years (the average human life span).

$$\text{Cancer risk} = (\text{chronic dose}_{\text{non-cancer}}) \times \frac{(\text{\# years of exposure})}{78 \text{ years}} \times \text{cancer slope factor}$$

As mentioned previously, EPA has classified certain chemicals as having a mutagenic MOA; therefore, the cancer risk estimates for MOA chemicals include age-dependent adjustment factors (ADAF) (EPA 2005).

$$\text{Cancer risk}_{\text{MOA chemicals}} = (\text{chronic dose}_{\text{non-cancer}}) \times \frac{(\text{\# years of exposure})}{78 \text{ years}} \times (\text{ADAF}) \times (\text{CSF})$$

EPA suggests using these ADAFs for chemicals with a mutagenic mode of action that do not have age-specific CSFs:

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

Appendix C: Derivation of Intake Rates for Standard Age Groups and Special Groups

Standard Age Group (Table 1, pg 5)

2 to < 6 years

The intake rates for children 2 to < 6 years were derived by taking a time-weighted average (TWA) of children 2 to < 3 years and children 3 to < 6 years as reported in the 2019 update of the 2011 EFH, Chapter 3, Table 3-1 (EPA 2019).

- Mean TWA = [(338*1+336*3)/4] = 337 mL/day
- 95th Percentile TWA = [(901*1+836*3)/4 = 852 mL/day

Adult (21 to 78 years)

- Mean TWA = [(1,183*9) + (1,277*10) + (1,356*10) + (1,419*10) + (1,394*10) + (1,214*8)]/57 = 1,313 mL/day
- 95th Percentile TWA = [(3,407*9) + (3,278*10) + (3,374*10) + (3,388*10) + (3,187*10) + (2,641*8)]/57 = 3,229 mL/day

Special Age Groups (Table 2, pg 6)

ATSDR derived intake rates for the following special age groups using intake rates from the standard age groups to generate a slope that describes the intake rate across the entire age range:

- 3 to < 5 years
- 5 to < 6 years
- 11 to < 14 years
- 14 to < 16 years
- 16 to < 18 years

To derive the mean and 95th percentile intake rates for these special age groups, ATSDR first assigned a midpoint age value to each of ATSDR's standard exposure groups for persons aged 1 to 18. The midpoint age value for the 1 to < 2 years exposure group was 1.5 years, the midpoint age value for the 2 to < 6 years exposure groups was 4 years, and so on. Next, ATSDR used Excel to develop linear regression relationships between the midpoint age values for the standard exposure groups and their mean and 95 percentile intake rates. Both relationships were highly linear and had R-squared coefficients greater than 0.99. Finally, ATSDR used the linear regression equations to estimate the mean and 95th percentile intake rates for the special exposure groups, based on the midpoint age value of each group.

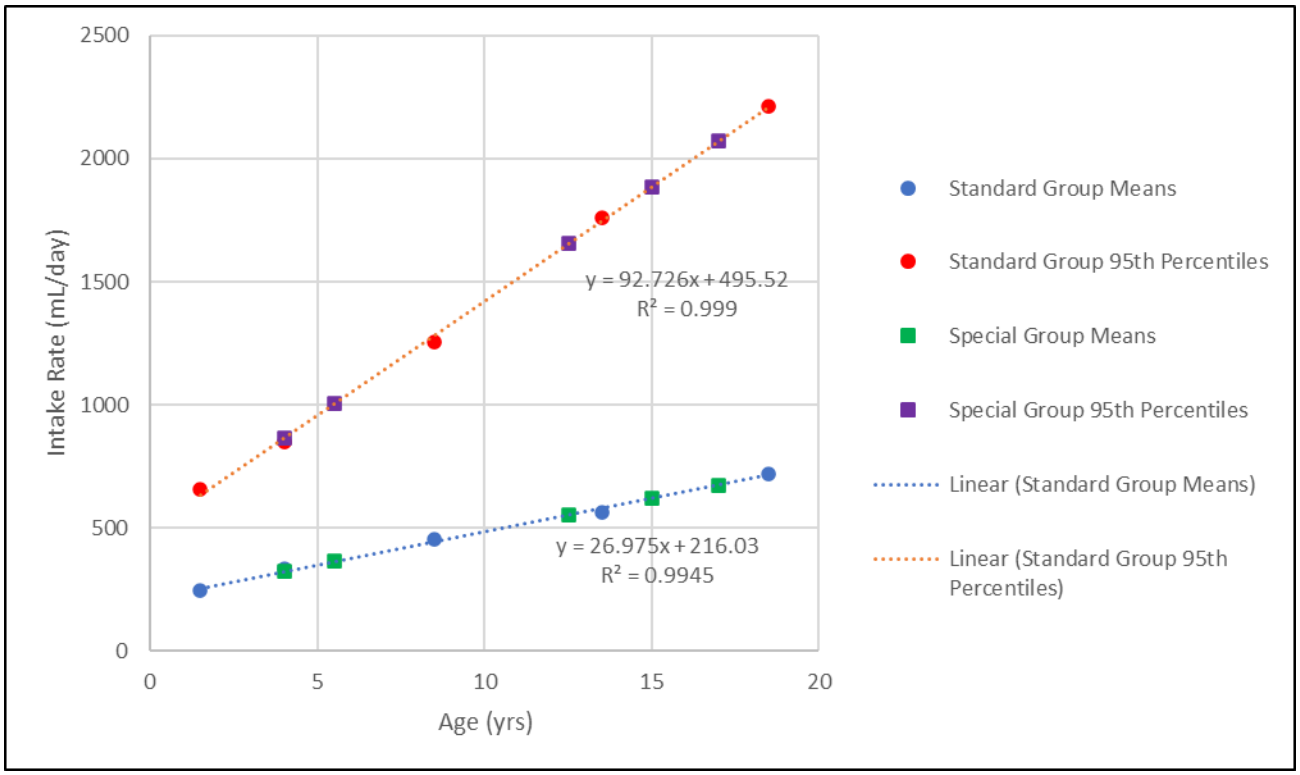

Figure 1 shows the regression plots for the mean and 95th percentile intake rates for ATSDR's standard age groups along with the regression equation used to estimate the drinking water intake rate for special age groups reported in Table 2.

Table C1, Children

Age Group	Mid-point	Mean, mL/day	95th Percentile, mL/day
3 to < 5 years	4	324	866
5 to < 6 years	5	364	1,006
11 to < 14 years	12.5	553	1,655
14 to < 16 years	15	621	1,866
16 to < 18 years	17	675	2,072

Sample calculation for 3 to < 5 years

CTE: (4*26.975)+216.03 = 324 mL/day
RME: (4*92.726)+495.52 = 866 mL/day

Table C2, Adults (21 to 78 year)

The mean and 95th percentile intake rates for adults are based on the following intake rates reported in EPA 2019 EFH, Chapter 3, Table 3-1.

Age Range	Mean, mL/day	95th Percentile, mL/day
21 to < 30 years	1,183	3,407
30 to < 40 years	1,277	3,278
40 to < 50 years	1,356	3,374
50 to < 60 years	1,419	3,388
60 to < 70 years	1,394	3,187
70 to < 80 years	1,214	2,641
Average	1,307	3,213

Table C3, Adult Workers (18 ≤ 64), full and part-time

The mean and 95th percentile intake rates for adult workers are based on the following intake rates reported in EPA 2019 EFH, Chapter 3, Table 3-1.

Age Range	Mean, mL/day	95th Percentile, mL/day
18 to < 21 years	722	2,214
21 to < 30 years	1,183	3,407
30 to < 40 years	1,277	3,278
40 to < 50 years	1,356	3,374
50 to < 60 years	1,419	3,388
60 to < 67 years	1,394	3,187
Time-weighted Average*	1,284	3,270

* Mean = (722*3) + (1183*10) + (1277*10) + (1356*10) + (1419*10) + (1394*7)/50 = 1,285 mL/day
95th percentile = (2214*3) + (3407*10) + (3278*10) + (3374*10) + (3388*10) + (3187*7)/50 = 3,270 mL/day