

Guidance for Assessing Risk from Early-Life Exposure to Carcinogens

Summary

In March 2005, the U.S. Environmental Protection Agency (EPA) published [Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens](#)¹ (EPA, 2005). As discussed in the guidance, some chemicals have a documented mutagenic mode of action, which may cause damage to cellular DNA (Deoxyribonucleic Acid), resulting in greater effects during early-life exposure versus similar exposures later in life. This enhanced susceptibility has been attributed to several factors, including higher rates of cell division during childhood (with reduced time available for DNA repair), as well as incomplete development of the immune system (EPA, 2005). To address the increased childhood sensitivity (compared to adults) from carcinogens with a documented mutagenic mode of action, EPA's 2005 guidance recommends the application of Age-Dependent Adjustment Factors (ADAFs).

Washington state's Method B and Method C default cleanup level equations are found in the MTCA Cleanup Rule, Chapter [173-340](#) WAC.² Applying ADAFs affects the calculation of Method B cleanup levels because Method B must remain protective of both child and adult exposures.

MTCA Method C cleanup equations are based on adult exposure and do not incorporate early-life exposure (ELE) adjustments using ADAFs. However, if a non-industrial site qualifies for setting a Method C cleanup level (for groundwater, surface water, or air) based on the criteria in WAC [173-340-706](#)(1)(a),³ then the Method C cleanup level will need to be adjusted lower using ADAFs to account for ELE. This is further discussed in the sections below that describe MTCA cleanup level calculations for the various media.

In this guidance, the Washington State Department of Ecology (Ecology) identifies which chemicals have a documented mutagenic mode of action, and how to calculate cleanup levels in soil, groundwater, surface water, and air to address ELE using ADAFs. We also provide a list of the acronyms we've used following Section VI.

¹ <https://www.epa.gov/risk/supplemental-guidance-assessing-susceptibility-early-life-exposure-carcinogens>

² <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340> (Model Toxics Control Act (MTC) Cleanup Rule)

³ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-706> (Use of Method C.)

I. Chemicals with a Mutagenic Mode of Action

Based on the weight-of-evidence, EPA has determined that the chemicals listed below are carcinogenic by a mutagenic mode of action. These chemicals are included in Ecology's Cleanup Levels and Risk Calculation (CLARC) database. EPA has identified all of them as mutagenic in their [Regional Screening Levels for Chemical Contaminants at Superfund Sites](#).⁴

We note, however, that the EPA has identified additional other mutagenic chemicals that we haven't included in CLARC. The references cited below and found at end of this guidance provide our basis for determining that a chemical is a mutagen.

- **Acrylamide (CAS 79-06-1)**. EPA, 2010; IRIS, 2021
- **Benzidine (CAS 92-87-5)**. EPA, 2005; IRIS, 2021
- **Benzo(a)pyrene (CAS 50-32-8)**. EPA, 2017; IRIS, 2021 (see [CLARC Guidance for benzo\(a\)pyrene \(July 2021\)](#)).⁵ The following additional carcinogenic polycyclic aromatic hydrocarbons (cPAHs) are also identified as mutagenic: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd]pyrene. Ecology applies a toxicity equivalence factor (TEF) approach when determining compliance with cleanup levels established for mixtures of cPAHs (see [Implementation Memo 10](#)).⁶
- **Chromium (VI) (CAS 18540-29-9)**. EPA reported that a number of potentially mutagenic DNA lesions are formed during the reduction of Chromium VI (IRIS, 2021). California EPA (CalEPA) stated that numerous studies have shown a weight of evidence supports that Chromium VI is carcinogenic by a mutagenic mode of action (CalEPA, 2011). CalEPA also concluded that a mutagenic mode of action for Chromium VI has been fully described and justified (CalEPA, 2011).
- **Coke Oven Emissions (CAS 8007-45-2)**. Studies have shown that the solvent-extractable organic emissions from coke oven doors, and from the topside of coke ovens, are mutagenic in both single-celled organisms and in mammalian cells (IRIS, 2021). In addition, several polycyclic components identified in coke oven emissions have been shown to be mutagenic (IRIS, 2021). EPA's Final Rule on National Emission Standards for Coke Oven Batteries concludes that coke oven emissions are likely to cause cancer through a mutagenic mode of action (70 Federal Register 19992).⁷

⁴ <https://www.epa.gov/risk/regional-screening-levels-rsls>

⁵ https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/MTCA_PAHCleanupLevels.pdf

⁶ <https://apps.ecology.wa.gov/publications/SummaryPages/1509049.html>

⁷ National Emission Standards for Coke Oven Batteries, 70 Fed. Reg. 19992 (April 15, 2005)

- **1,2-Dibromo-3-chloropropane (CAS 96-12-8).** EPA, 2006a
- **Ethylene oxide (CAS 75-21-8).** EPA, 2016; IRIS, 2021
- **Methylene Chloride (CAS 75-09-2).** EPA, 2011; IRIS, 2021
- **4,4'-methylene bis(2-chloroaniline) (CAS 101-14-4).** EPA, 2006b
- **N-Nitrosodiethylamine (diethylnitrosamine) (CAS 55-18-5).** EPA, 2005; IRIS, 2021
- **N-Nitrosodimethylamine (dimethylnitrosamine) (CAS 62-75-9).** EPA, 2005; IRIS, 2021
- **N-nitroso-N-ethylurea (ethylnitrosourea) (CAS 759-73-9).** EPA, 2005
- **N-Nitroso-N-methylurea (methylnitrosourea) (CAS 684-93-5).** EPA, 2005
- **Trichloroethylene (TCE; CAS 79-01-6).** Based on the weight of evidence, EPA has concluded that TCE is carcinogenic by a mutagenic mode of action (operative for TCE-induced kidney tumors) (IRIS, 2021; see CLARC guidance, [Trichloroethylene \(TCE\): Deriving Cleanup Levels under the Model Toxics Control Act \(MTCA\)](#)⁸ (January 2020).
- **1,2,3-Trichloropropane (CAS 96-18-4).** IRIS, 2021
- **Vinyl Chloride (CAS 75-01-4).** EPA, 2005; IRIS, 2021

⁸ https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/Trichloroethylene_Guidance.pdf

II. Adjustments for Early-Life Exposure to Mutagenic Hazardous Substances

EPA has determined that the chemicals listed above have a mutagenic mode of action and, with the exception of vinyl chloride,⁹ recommends using Age-Dependent Adjustment Factors (ADAFs) to address the increased sensitivity of children (compared to adults) to their carcinogenic effects. This affects the calculation of Method B cleanup levels using the MTCA equations, resulting in lower cleanup levels compared to standard calculations. The adjustment methods are based on information in EPA's March 2005 document, *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens*, publication no. EPA/630/R-03/003F (EPA, 2005).

As recommended by EPA, the ability of a mutagen to cause cancer in children less than 2 years of age is assumed to be 10 times greater than in adults. In practice, the cancer potency factor is multiplied by an ADAF of 10 for cleanup level calculations that include exposure to children up to 2 years of age. Similarly, the ability of a mutagen to cause cancer in children from their second through sixteenth birthday is assumed to be 3 times greater than in adults, and the cancer potency factor is multiplied by an ADAF of 3 when children in that age range are exposed.

To calculate an **Early-Life Exposure (ELE) adjustment**, the ADAF is combined with certain exposure parameters that can change with age in the MTCA cleanup level equations (e.g., intake rate for soil, water, or air; body weight; exposure duration). This ELE is substituted into the MTCA equations for those exposure parameters to derive a cleanup level. The calculations start with the MTCA Equations for carcinogens for potable surface water and groundwater ([720-2](#)),¹⁰ surface water ([730-2](#))¹¹, soil ([740-2](#)),¹² and air ([750-2](#)).¹³ Depending on the environmental medium (soil, groundwater, surface water, or air), age-specific adjustments are made to the equations, based on the parameters in **Table 1** below.

⁹ For **vinyl chloride**, EPA derived two types of slope factors. One is based on continuous exposure during adulthood, and the other is based on continuous lifetime exposure from birth. The higher slope factor of 1.5 kg-day/mg, which accounts for continuous lifetime exposure from birth, is used for calculating cleanup levels in CLARC. Considerations for applying the lower slope factor are contained in our 2005 CLARC guidance, CLARC Guidance on Vinyl Chloride at https://www.ezview.wa.gov/Portals/1987/Documents/Documents/VinylChloride_2005.pdf. Further adjustments using ADAFs are not needed for vinyl chloride because chemical-specific data on early life susceptibility are available and were used by EPA in deriving the slope factor.

¹⁰ <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-720> (Groundwater cleanup standards.)

¹¹ <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-730> (Surface water cleanup standards.)

¹² <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-740> (Unrestricted land use soil cleanup standards.)

¹³ <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-750> (Cleanup standards to protect air quality.)

Table 1: Age-specific adjustments for early-life exposure for carcinogens: Soil, Groundwater, Surface Water, and Air pathways

Parameter	Parameter Definition	Exposure Parameters for Early-Life Exposure			
		Age Groupings			
		0 to 2 years	2 to 6 years	6 to 16 years	16 to 30 years
ADAF (1)	Age-dependent adjustment factor, unitless	10	3	3	1
ED	Exposure duration, years	2	4	10	14
BW	Body weight, kg	16	16	70	70
DWIR	Drinking water ingestion rate, liters/day	1	1	2	2
SIR (2)	Soil Ingestion rate, mg/day	200	200	50	50
FCR (3)	Fish consumption rate, grams/day	54	54	54	54
BR	Breathing rate, m ³ /day	10	10	20	20

- (1) For trichloroethylene (TCE), ADAFs only apply to early-life adjustments for kidney cancer.
- (2) The Method B cancer soil cleanup level is based on child exposure (Equation 740-2). Therefore, exposure to age groups beyond 6-years-old was not incorporated into the ELE cleanup equation for soil.
- (3) The MTCA regulation does not include a default child-specific FCR. As such, the FCR for the child was conservatively assumed to be equal to that of the adult.

Detailed calculations for ELEs and cleanup levels for the various environmental media are described in the sections below.¹⁴

Note: The application of ADAFs for trichloroethylene (TCE) requires a unique set of equations because EPA developed its cancer values by adding together the increased risks of three separate types of cancer (kidney cancer, liver cancer, and non-Hodgkin’s lymphoma [NHL]). EPA determined that TCE causes kidney cancer (but not liver cancer or NHL) through a mutagenic mode of action. As such, early-life adjustments for TCE only apply to the kidney cancer endpoint (see 2020 CLARC guidance, [TCE: Deriving cleanup levels under MTCA](#).¹⁵)

¹⁴ Cleanup level calculations that incorporate adjustments to account for early life exposure are complex and it’s recommended to have assistance from a toxicologist/risk assessor.

¹⁵ https://www.ezview.wa.gov/Portals/_1987/Documents/Documents/Trichloroethylene_Guidance.pdf

III. Method B Soil Calculations

Step 1 of 2.

Without the ELE adjustment, MTCA Method B Equation 740-2 is normally used to calculate soil cleanup levels for carcinogens (WAC [173-340-740](#)):¹⁶

$$\text{Soil Cleanup Level} \left(\frac{\text{mg}}{\text{kg}} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{SIR} \times \text{AB1} \times \text{ED} \times \text{EF}}$$

Table 2: Default parameters for Equation 740-2 in the MTCA Cleanup Rule, WAC 173-340-740.

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1 x 10 ⁻⁶	unitless
Average Body Weight	ABW	16	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1,000,000	milligrams/kilogram
Oral Cancer Potency Factor	CPFo	Chemical-specific	kilogram-day/milligram
Soil Ingestion Rate	SIR	200	milligrams/day
GI Absorption Fraction	AB1	1	unitless
Exposure Duration	ED	6	years
Exposure Frequency	EF	1	unitless

Step 2 of 2.

The soil cleanup level equation is based on exposures that occur during the first 6 years of life (birth through the 6th birthday [ED = 6 years]). However, since the ADAF is reduced from 10 to 3 at the second birthday, two separate calculations are needed; one from birth to age 2, and another from age 2 to age 6. The exposure duration is also changed to be consistent with the ADAF age-ranges. The ELE adjustment is calculated as follows:

$$\begin{aligned} \text{ELE (soil)} &= ((\text{ADAF}_{<2\text{yr}} \times \text{ED}_{<2\text{yr}} \times \text{SIR}_{<2\text{yr}}) / \text{BW}_{<2\text{yr}}) + ((\text{ADAF}_{2-6\text{yr}} \times \text{ED}_{2-6\text{yr}} \times \text{SIR}_{2-6\text{yr}}) / \text{BW}_{2-6\text{yr}}) = \\ &= ((10 \times 2 \text{ yr} \times 200 \text{ mg/day}) / 16 \text{ kg}) + ((3 \times 4 \text{ yr} \times 200 \text{ mg/day}) / 16 \text{ kg}) = \\ &= \mathbf{400 \text{ (milligram-year)/(kilogram-day)}} \end{aligned}$$

This is substituted into the soil cleanup level equation, replacing the equivalent parameters:

¹⁶ <https://apps.leg.wa.gov/wac/default.aspx?cite=173-340-740> (Unrestricted land use soil cleanup standards.)

$$\begin{aligned} \text{Soil Cleanup Level } \left(\frac{\text{mg}}{\text{kg}} \right) &= \frac{\text{RISK} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{AB1} \times \text{EF} \times \text{ELE}} \\ &= \frac{0.000001 \times 75 \text{ yr} \times 1,000,000 \text{ mg/kg}}{\text{CPFo} \frac{\text{kg-day}}{\text{mg}} \times 1 \times 1 \times 400 \frac{\text{mg-yr}}{\text{kg-day}}} \end{aligned}$$

Note that Method C soil cleanup levels may only be established where the person conducting the cleanup action can demonstrate that the area under consideration is an industrial property (WAC [173-340-706\(1\)\(c\)](#)).¹⁷ As such, the Method C calculated soil cleanup level (see [MTCA Equation 745-2](#))¹⁸ is based on adult exposure and does not include an adjustment for ELE.

IV. Method B Groundwater Calculations

Step 1 of 2. Without the ELE adjustment, the MTCA Method B Equation 720-2 is normally used to calculate Groundwater Cleanup levels for carcinogens (WAC [173-340-720](#)):¹⁹

$$\text{Groundwater Cleanup Level } \left(\frac{\mu\text{g}}{\text{L}} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF}}{\text{CPFo} \times \text{DWIR} \times \text{ED} \times \text{INH} \times \text{DWF}}$$

Table 3: Default parameters for Equation 720-2 in the MTCA Cleanup Rule, WAC 173-340-720.

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1 x 10 ⁻⁶	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1,000	micrograms/milligram
Oral Cancer Potency Factor	CPFo	Chemical-specific	kilogram-day/milligram
Drinking Water Ingestion Rate	DWIR	2	liters/day
Exposure Duration	ED	30	years
Inhalation Correction Factor	INH	Chemical-specific*	unitless
Drinking Water Fraction	DWF	1	unitless

* Use 2 for volatile organic compounds, and 1 for all other substances (see INH values in CLARC)

¹⁷ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-706> (Use of Method C.)

¹⁸ <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-745> (Soil cleanup standards for industrial properties.)

¹⁹ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720> (Groundwater cleanup standards.)

Step 2 of 2.

The groundwater cleanup level equation is based on exposures that occur during the first 30 years of life (birth through the 30th birthday [ED = 30 years]). The ADAF changes from 10 to 3 at the second birthday, and from 3 to 1 at age 16. Also, the body weight and drinking water ingestion rate change at age 6. The calculation of the ELE adjustment requires four separate calculations; one from birth to age 2, one from age 2 to age 6, one from age 6 to age 16, and one from age 16 through age 30. The ELE adjustment is calculated as follows:

$$\begin{aligned} \text{ELE (groundwater)} &= ((\text{ADAF}_{<2\text{yr}} \times \text{ED}_{<2\text{yr}} \times \text{DWIR}_{<2\text{yr}})/\text{BW}_{<2\text{yr}}) + ((\text{ADAF}_{2-6\text{yr}} \times \text{ED}_{2-6\text{yr}} \times \text{DWIR}_{2-6\text{yr}})/\text{BW}_{2-6\text{yr}}) + \\ & ((\text{ADAF}_{6-16\text{yr}} \times \text{ED}_{6-16\text{yr}} \times \text{DWIR}_{6-16\text{yr}})/\text{BW}_{6-16\text{yr}}) + ((\text{ADAF}_{16-30\text{yr}} \times \text{ED}_{16-30\text{yr}} \times \text{DWIR}_{16-30\text{yr}})/\text{BW}_{16-30\text{yr}}) = \\ & ((10 \times 2 \text{ yr} \times 1 \text{ L/day})/16 \text{ kg}) + ((3 \times 4 \text{ yr} \times 1 \text{ L/day})/16 \text{ kg}) + ((3 \times 10 \text{ yr} \times 2 \text{ L/day})/70 \text{ kg}) + ((1 \times 14 \text{ yr} \times 2 \\ & \text{ L/day})/70 \text{ kg})= \end{aligned}$$

3.26 (liter-year)/(kilogram-day)

This is substituted into the groundwater cleanup level equation, replacing the equivalent parameters:

$$\begin{aligned} \text{Groundwater Cleanup Level } \left(\frac{\mu\text{g}}{\text{L}}\right) &= \frac{\text{RISK} \times \text{AT} \times \text{UCF}}{\text{CPF}_o \times \text{INH} \times \text{DWF} \times \text{ELE}} \\ &= \frac{0.000001 \times 75 \text{ yr} \times 1,000 \mu\text{g}/\text{mg}}{\text{CPF}_o \frac{\text{kg-day}}{\text{mg}} \times \text{INH} \times 1 \times 3.26 \frac{\text{L-yr}}{\text{kg-day}}} \end{aligned}$$

For sites that may qualify for setting a Method C groundwater cleanup level based on the criteria in WAC [173-340-706\(1\)\(a\)](#),²⁰ the Method C groundwater cleanup level is calculated the same as above except that the target cancer risk is 1×10^{-5} .

²⁰ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-706> (Use of Method C.)

V. Method B Surface Water Calculations

Step 1 of 2. Without the ELE adjustment, the MTCA Method B Equation 730-2 is normally used to calculate Surface Water Cleanup levels for carcinogens (WAC 173-340-730)²¹:

$$\text{Surface Water Cleanup Level } \left(\frac{\mu\text{g}}{\text{L}} \right) = \frac{\text{RISK} \times \text{ABW} \times \text{AT} \times \text{UCF1} \times \text{UCF2}}{\text{CPFo} \times \text{BCF} \times \text{FCR} \times \text{FDF} \times \text{ED}}$$

Table 4: Default parameters for Equation 730-2 in the MTCA Cleanup Rule, WAC 173-340-730

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1 x 10 ⁻⁶	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor 1	UCF1	1,000	micrograms/milligram
Unit Conversion Factor 2	UCF2	1,000	grams/kilogram
Oral Cancer Potency Factor	CPFo	Chemical-specific	kilogram-day/milligram
Bioconcentration Factor	BCF	Chemical-specific	liters/kilogram
Fish Consumption Rate	FCR	54	grams/day
Fish Diet Fraction	FDF	0.5	unitless
Exposure Duration	ED	30	years

Step 2 of 2.

The surface water cleanup level equation is based on exposures that occur during the first 30 years of life (birth through the 30th birthday [ED = 30 years]). The ADAF changes from 10 to 3 at the second birthday, and from 3 to 1 at age 16. Also, the body weight changes at age 6. This requires four separate calculations; one from birth to age 2, one from age 2 to age 6, one from age 6 to age 16, and one from age 16 through age 30.

$$\begin{aligned} \text{ELE (surface water)} &= ((\text{ADAF}_{<2\text{yr}} \times \text{ED}_{<2\text{yr}} \times \text{FCR}_{<2\text{yr}})/\text{BW}_{<2\text{yr}}) + ((\text{ADAF}_{2-6\text{yr}} \times \text{ED}_{2-6\text{yr}} \times \text{FCR}_{2-6\text{yr}})/\text{BW}_{2-6\text{yr}}) + \\ & ((\text{ADAF}_{6-16\text{yr}} \times \text{ED}_{6-16\text{yr}} \times \text{FCR}_{6-16\text{yr}})/\text{BW}_{6-16\text{yr}}) + ((\text{ADAF}_{16-30\text{yr}} \times \text{ED}_{16-30\text{yr}} \times \text{FCR}_{16-30\text{yr}})/\text{BW}_{16-30\text{yr}}) = \\ & ((10 \times 2 \text{ yr} \times 54 \text{ g/day})/16 \text{ kg}) + ((3 \times 4 \text{ yr} \times 54 \text{ g/day})/16 \text{ kg}) + ((3 \times 10 \text{ yr} \times 54 \text{ g/day})/70 \text{ kg}) + ((1 \times 14 \text{ yr} \times \\ & 54 \text{ g/day})/70 \text{ kg}) = \\ & \mathbf{141.9 \text{ (gram-year)/(kilogram-day)}} \end{aligned}$$

This is substituted into the surface water cleanup level equation, replacing the equivalent parameters:

²¹ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-730> (Surface water cleanup standards.)

$$\begin{aligned} \text{Surface Water Cleanup Level } \left(\frac{\mu\text{g}}{\text{L}}\right) &= \frac{RISK \times AT \times UCF1 \times UCF2}{CPFo \times BCF \times FDF \times ELE} \\ &= \frac{0.000001 \times 75 \text{ yr} \times 1,000 \frac{\mu\text{g}}{\text{mg}} \times 1,000 \frac{\text{g}}{\text{kg}}}{CPFo \frac{\text{kg-day}}{\text{mg}} \times BCF \frac{\text{L}}{\text{kg}} \times 0.5 \times 141.9 \frac{\text{g-yr}}{\text{kg-day}}} \end{aligned}$$

For sites that may qualify for setting a Method C surface water cleanup level based on the criteria in WAC 173-340-706(1)(a), the Method C surface water cleanup level is calculated the same as above except that the target cancer risk is 1×10^{-5} and the fish diet fraction is 0.2.

VI. Method B Air Calculations

Step 1 of 2.

Without the ELE adjustment, the MTCA Method B Equation 750-2 is normally used to calculate Air Cleanup levels for carcinogens (WAC [173-340-750](#)):²²

$$\text{Air Cleanup Level } \left(\frac{\mu\text{g}}{\text{m}^3}\right) = \frac{RISK \times ABW \times AT \times UCF}{CPFi \times BR \times ABS \times ED \times EF}$$

Table 5: Default parameters for Equation 750-2 in the MTCA Cleanup Rule, WAC 173-340-750

Parameter	Abbreviation	Default Value	Units
Increased Cancer Risk	RISK	1×10^{-6}	unitless
Average Body Weight	ABW	70	kilograms
Averaging Time	AT	75	years
Unit Conversion Factor	UCF	1,000	micrograms/milligram
Inhalation Cancer Potency Factor	CPFi	Chemical-specific	kilogram-day/milligram
Breathing Rate	BR	20	cubic meters/day
Inhalation Absorption Fraction	ABS	1	unitless
Exposure Duration	ED	30	years
Exposure Frequency	EF	1	unitless

²² <https://app.leg.wa.gov/WAC/default.aspx?cite=173-340-750> (Cleanup standards to protect air quality.)

Step 2 of 2.

The air cleanup level equation is based on exposures that occur during the first 30 years of life (birth through the 30th birthday [ED=30 years]). The ADAF changes from 10 to 3 at the second birthday, and from 3 to 1 at age 16. Also, the body weight and breathing rate change at age 6. The calculation of the ELE adjustment requires four separate calculations; one from birth to age 2, one from age 2 to age 6, one from age 6 to age 16, and one from age 16 through age 30. The ELE adjustment is calculated as follows:

$$\begin{aligned} \text{ELE (air)} &= ((\text{ADAF}_{<2\text{yr}} \times \text{ED}_{<2\text{yr}} \times \text{BR}_{<2\text{yr}})/\text{BW}_{<2\text{yr}}) + ((\text{ADAF}_{2-6\text{yr}} \times \text{ED}_{2-6\text{yr}} \times \text{BR}_{2-6\text{yr}})/\text{BW}_{2-6\text{yr}}) + \\ &((\text{ADAF}_{6-16\text{yr}} \times \text{ED}_{6-16\text{yr}} \times \text{BR}_{6-16\text{yr}})/\text{BW}_{6-16\text{yr}}) + ((\text{ADAF}_{16-30\text{yr}} \times \text{ED}_{16-30\text{yr}} \times \text{BR}_{16-30\text{yr}})/\text{BW}_{16-30\text{yr}}) = \\ &((10 \times 2 \text{ yr} \times 10 \text{ m}^3/\text{day})/16 \text{ kg}) + ((3 \times 4 \text{ yr} \times 10 \text{ m}^3/\text{day})/16 \text{ kg}) + ((3 \times 10 \text{ yr} \times 20 \text{ m}^3/\text{day})/70 \text{ kg}) + ((1 \times 14 \\ &\text{ yr} \times 20 \text{ m}^3/\text{day})/70 \text{ kg})= \end{aligned}$$

32.6 (cubic meters-year)/(kilogram-day)

$$\text{Air Cleanup Level} \left(\frac{\mu\text{g}}{\text{m}^3} \right) = \frac{\text{RISK} \times \text{AT} \times \text{UCF}}{\text{CPF}_i \times \text{ABS} \times \text{EF} \times \text{ELE}}$$

$$\text{Air Cleanup Level} \left(\frac{\mu\text{g}}{\text{m}^3} \right) = \frac{0.000001 \times 75 \text{ yr} \times 1,000 \mu\text{g}/\text{mg}}{\text{CPF}_i \frac{\text{kg-day}}{\text{mg}} \times 1 \times 1 \times 32.6 \frac{\text{m}^3\text{-yr}}{\text{kg-day}}}$$

For non-industrial sites that may qualify for setting a Method C air cleanup level based on the criteria in WAC 173-340-706(1)(a), the Method C cleanup level is calculated the same as above except that the target cancer risk is 1×10^{-5} . For industrial sites, the Method C air cleanup level is based on adult exposure (MTCA Equation 750-2 adjusted for Method C by setting the target cancer risk to 1×10^{-5}).

Acronyms

Acronym or abbreviation ²³	Definition
ADAF	Age-Dependent Adjustment Factor
CalEPA	California EPA
CLARC	Cleanup Levels and Risk Calculation
cPAH	Carcinogenic Polycyclic Aromatic Hydrocarbon
DNA	Deoxyribonucleic Acid
Ecology	Washington State Department of Ecology
ELE	Early-Life Exposure
EPA	United States Environmental Protection Agency
GI	Gastrointestinal
IRIS	Integrated Risk Information System
MTCA	Model Toxics Control Act
NHL	non-Hodgkin's lymphoma
TCE	Trichloroethylene
TEF	Toxicity Equivalence Factor

²³ Acronyms used in the equations provided in the guidance are defined in Tables 1 through 5, and are not provided in acronym list.

References

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