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Summary of Proposed MCP Method 1 Standards Revisions March 2019

PURPOSE

This summary is being provided to aid in the review of the proposed MCP Standards revisions. This document discusses the reasons and bases for the revisions. Attachment A summarizes the toxicity value changes and Attachments B and C show the equations used to calculate risk-based concentrations that account for early life exposures to mutagens.

PROPOSED EXPOSURE FACTOR CHANGES

Body Weights

MassDEP proposes updating body weight values used for Method 1 Standards to reflect newer data. The proposed body weights for the Method 1 Standards use data from the National Health and Nutrition Examination Survey (NHANES) conducted by the U.S. Center for Disease Control (USCDC), U.S. Department of Health and Human Services (USDHHS). MassDEP used the year-by-year body weight data presented in the 2008 USDHHS report titled *Anthropometric reference data for children and adults: United States, 2003-2006*.

An adjustment of the reported NHANES data is applied to obtain values consistent with MassDEP Methods. The NHANES data in USDHHS 2008 is presented as the body weight at a specific year of age (for example, *at* one year of age). In MCP risk assessments, however, MassDEP uses the average body weights for one year periods (for example, from one to two years of age). To obtain a value for each one-year period, MassDEP averaged the 50th percentile (median) values given for the beginning and ending of the year; thus, the proposed MassDEP body weight for the one to two-year age range is the average of the NHANES median weights for a one year old and a two year old. Consistent with MassDEP practice to date, female body weights are used.

Reference for Body Weight Values:

[USDHHS] US Department of Health and Human Services. 2008. Anthropometric reference data for children and adults: United States, 2003-2006. National Health Statistics Reports, Number 10, October 22, 2008.

[USEPA] US Environmental Protection Agency. 2011. Exposure Factors Handbook: 2011 Edition. Washington (DC): Office of Research and Development, National Center for Environmental Assessment, USEPA. EPA/600/R-09/052F.

Skin Surface Areas

MassDEP proposes revising the age-specific surface area values to reflect the updates in the 2011 Exposure Factors Handbook (EFH) published by United States Environmental Protection Agency (USEPA 2011). Unlike the 1997 EFH (USEPA 1997), which gives year-by-year skin surface values currently used by MassDEP, the 2011 EFH does not present year-by-year values. Instead it provides values for the age groups EPA evaluates in Superfund risk assessments. (As described in the preceding section, a similar problem was encountered in the 2011 EFH body weight data.)

In order to obtain year-by-year values, MassDEP adjusted the 1997 year-by-year values to reflect the differences in the age group data between 1997 and 2011. The adjustments were made according to the following procedure:

1. Calculate the 1997 average total skin surface area for each of the age ranges corresponding to the age bins used in the 2011 EFH;

2. Calculate the average percent difference between the 2011 EFH and 1997 EFH total surface areas for each age bin;

3. Approximate 2011 year-by-year total surface areas by multiplying each year-by-year EFH 1997 value by the average percent difference for the relevant bin; and

4. To obtain body part-specific surface areas, multiply the total surface areas (calculated in item 3 above) by the "percent of total surface area" for each body part. Since there is no single

Why MassDEP body weight values are not taken directly from U.S. EPA's Exposure Factors Handbook:

EPA's Exposure Factors Handbook (EFH) was updated in 2011. The source of the body weight values recommended in the 2011 EFH is the National Health and Nutrition Examination Survey 1999-2006 data (NHANES).

ORS could not obtain body weight values directly from the EPA's EFH because:

(a) The EFH presents average body weights only for the age groups (age ranges) EPA uses in risk assessments. The EFH does not report year-by-year (i.e., age-specific) body weights, which are needed by MassDEP to calculate values for the various age ranges considered in MCP risk assessments; and,

(b) The values reported in the EPA's EFH are based on the average (mean) weight for each year of age. Population percentile values are not reported. In contrast, as a matter of practice MassDEP uses the 50th percentile (median) body weights for each year of age.

reference that provides the “percent of total surface area” for each body part by year for females, the following sources of information were used to derive these values:

- For ages 0 to 2, the combined male and female “percent of total” values provided in the 2011 EFH (Table 7-11, page 42) were used.
- For ages 18 and over, the “percent of total” values for females provided in the 2011 EFH (Table 7-15, page 45) were used.
- For the ages between 2 and 18, the year-by-year body part-specific surface areas were approximated by applying the “percent of total” reported for females in Boniol et al. (referenced in the 2011 EFH). Boniol et al. reported even number ages only. For odd numbered years, “percent of total” values given for the next higher year were used.

To obtain “percent of total” estimates for forearms and lower legs, which are needed for MCP risk assessments, further approximations are required because the 2011 EFH reported values only for whole arms and legs.

- For ages 0 to 2 and adults over 18, the forearm surface areas were estimated as 47% of the whole arm surface area [1] and lower leg surface areas were estimated as 40% of the whole leg[2].
- For lower legs for the age groups in between, the Boniol value for legs was used because thighs were reported separately in that study. Forearm surface area for these age groups is based on the value for lower arms from Boniol.

Reference for Surface Area Values:

Boniol A, Verriest JP, Pedeux R, Dore JF. 2008. Proportion of skin surface area of children and young adults from 2 to 18 years old. Journal of Investigative Dermatology, 128(2): 461-464.

[USEPA] U.S. Environmental Protection Agency. 1985. Development of statistical distributions or ranges of standard factors used in exposure assessments. Washington (D.C.): Office of Health and Environmental Assessment. USEPA EPA/600/8-85-010.

[USEPA] U.S. Environmental Protection Agency. 1997. Exposure Factors Handbook (1997 Final Report*).* Washington (DC): Office of Research and Development, National Center for Environmental Assessment, USEPA. EPA/600/P-95/002F.

[USEPA] U.S. Environmental Protection Agency. 2011. Exposure Factors Handbook: 2011 Edition. Washington (DC): Office of Research and Development, National Center for Environmental Assessment, USEPA. EPA/600/R-09/052F.

[1] A forearm/arm ratio of is 47% used to estimate forearm surface area from data on whole arm surface area. This ratio is based on the arm and forearm data in USEPA 2011 EFH Table 7-12, Surface Areas for Adult Males.

[2] A lower leg/leg ratio of 40% is used to estimate lower leg surface area from whole leg surface area. This ratio is based on the values for 0-2 year old children provided in the 1985 USEPA report on standard exposure factors (USEPA 1985), which is cited in the 2011 EFH as the source of surface area values for 0-2 year old children. In Table 3-8 of that document, ratio of lower leg to leg for adult males and females averaged is 40%.

Dermal Soil Adherence Factors

Dermal soil adherence factors were automatically re-calculated in the Method 1 spreadsheets using the updated skin surface area values.

Shower Times

Shower times needed for calculating inhalation exposures from showering and bathing were revised to correspond to the values provided in the 2011 EFH. The EFH tables from which values for time in the shower and time in the room after the shower were taken for different age groups are shown in the following table:

Revised Shower Times

Age Group	Time Spent in the Shower (or Bath for Ages 0-2)	Time Spent in the Room after the Shower (or after the Bath for Ages 0-2)
0 - 2	EFH Table 16-28, 95th percentile values given for "Duration of Bath"	EFH Table 16-28, values given under "Duration in Bathroom Immediately Following a Bath"
2 - 21	EFH Table 16-28 , 95th percentile values given for "Duration of Shower"	EFH Table 16-28, values given for "Duration in Shower Room Immediately Following a Shower"
21 - 30	EFH Table 16-31, 95th percentile value given for "All"	EFH Table 16-28, values given for "Duration in Shower Room Immediately Following a Shower" for the 16-21 years of age group, because Table 16-31 does not provide these values for adults.

Note: The updated shower times are lower, and the result is an increase in the GW-1 Standard for some chemicals.

INCLUSION OF INFANTS IN RESIDENTIAL DRINKING WATER AND VAPOR INTRUSION PATHWAYS

In previous calculations of Method 1 Standards, exposure estimates for all pathways considered ages from one year and up, and excluded infants from zero to one year of age from the calculations. Because infants are exposed to contaminants in residential drinking water and indoor air, that age group is included in the calculations for the proposed Method 1 GW-1 and GW-2 Standards. The inclusion of infants when quantifying these exposures is consistent with current USEPA Superfund risk assessment practices.

PROPOSED EARLY LIFE EXPOSURE ADJUSTMENTS FOR MUTAGENS

Background Information

There is evidence in humans and animals that exposures occurring during early-life, the period from birth to adolescence, can increase susceptibility to cancer relative to comparable exposures that occur only during adulthood (Ginsberg 2003; Barton et al. 2005). Most toxicity values estimating cancer potency for a chemical are developed from animal bioassays, and less frequently, epidemiological studies. These studies usually evaluate effects from exposures that begin in adulthood or after puberty.

Thus, most cancer potency estimates used in risk assessment do not account for the potential for increased susceptibility of children from birth to adolescence.

USEPA provides guidance for assessing cancer risks from early-life exposures (USEPA 2005a). This guidance is based on a quantitative analysis of chemicals with studies where both early-life and adult exposure were reported in the same animal study (Barton et al. 2005) and includes approaches for quantitatively accounting for increased cancer risk from early-life exposures.

Approaches to Accounting for Increased Susceptibility to Early Life Exposures

USEPA recommends using one of two methods.

- Chemical specific method - A chemical-specific approach is used for data rich chemicals that have been extensively evaluated for effects from early-life exposures.

- Default method - Age dependent adjustment factors (ADAFs) are used for chemicals when the data are insufficient for a chemical-specific approach. Per USEPA guidance, ADAFs are used only for compounds identified by USEPA as mutagenic.

Chemical-Specific Approach
When data are available to estimate the cancer potency from exposures during the early-life period, USEPA recommends that they should be used to develop chemical-specific age related cancer slope factors (USEPA 2005). Vinyl chloride is a chemical with sufficient data for chemical specific estimates (USEPA IRIS VC 2000).

Default Approach - Application of ADAFs (EPA 2005a)
USEPA's ADAFs are based on the quantitative analysis of available data by Barton et al. (2005). The database of chemicals and studies supporting the analysis of early-life susceptibility to carcinogens is largest for chemicals acting by a mutagenic mode of action. Thus, at this time USEPA applies default ADAFs only to chemicals that are mutagenic (USEPA 2006). In the proposed Method 1 Standards revisions, MassDEP has applied ADAFs to chemicals on the Method 1 list that have been identified by USEPA as acting by a mutagenic mode of action, consistent with EPA policy.

Application of ADAFs to younger age groups results in higher risk estimates for those groups.

- An ADAF of 10 is applied to the cancer slope factor (CSF) and inhalation unit risk (IUR) for exposures before 2 years of age, i.e., the interval from the day of birth until the child's second birthday. ($ADAF_{(0-2)} = 10$)

- An ADAF of 3 is applied to the cancer slope factor (CSF) and inhalation unit risk (IUR) for exposures beginning at 2 years of age until 16, i.e., the interval from the child's second birthday until the child's sixteenth birthday. ($ADAF_{(2-16)} = 3$)

- An ADAF of 1 is applied for children after turning 16 years of age. ($ADAF_{(16-30)} = 1$)

The chemicals (mutagens) that are adjusted for increased early-life susceptibility and the methods of adjustment are summarized in the table that follows:

Summary of Early Life Cancer Risk Assessment Approaches for Method 1 Standards

Chemical	Adjustment Approach
PAHs	
Benzo(a)pyrene	Default approach using ADAFs
Benzo(a)anthracene	Default approach using ADAFs
Benzo(b)fluoranthene	Default approach using ADAFs
Benzo(k)fluoranthene	Default approach using ADAFs
Chrysene	Default approach using ADAFs
Dibenzo(ah)anthracene	Default approach using ADAFs
Indeno(1,2,3-cd)pyrene	Default approach using ADAFs
Chromium VI	Default approach using ADAFs
Dichloromethane	Default approach using ADAFs
Trichloroethylene	Risk of kidney cancer is assessed with the default approach using ADAFs. Risk of liver cancer and non-Hodgkin's Lymphoma is assessed using the conventional approach for estimating cancer risk. The two risk estimates are summed to estimate total cancer risk.
Vinyl Chloride	Cancer slope factors for vinyl chloride are age-specific, so ADAFs are not used to evaluate cancer risk from early-life exposures. However, exposures up to the age of two are averaged over only that brief window of time; they are not averaged over a lifetime. As a consequence, exposures up to the age of two contribute more of the total lifetime risk than later exposures do.

Note: Few Method 1 standards are actually affected by these changes, because a number of the standards for which the risk-based concentrations have changed are set at background or MMCL concentrations.

Appendix B provides the equations that account for early-life susceptibility when estimating risk-based concentrations.

References/More Information for Early Life Exposure to Mutagens:

Barton HA, Cogliano VJ, Flowers L, Valcovic L, Setzer RW, Woodruff TJ. 2005. Assessing susceptibility from early-life exposure to carcinogens. Environmental Health Perspectives. 113(9):1125-1133.

Ginsberg GL. 2003. Assessing cancer risks from short-term exposures in children. Risk Analysis 23(1):19-34.

[USEPA] U.S. Environmental Protection Agency. 2006. Implementation of the cancer guidelines and accompanying supplemental guidance. Science Policy Council Cancer guidelines implementation workgroup communication II: performing risk assessments that included carcinogens described in the Supplemental Guidance as having a mutagenic mode of action. Washington (DC): Science Policy Council , USEPA. Memorandum from William Farland to Science Policy Council, June 14, 2006

[USEPA] US Environmental Protection Agency. 2005a. Supplemental guidance for assessing susceptibility from early-life exposure to carcinogens. Washington (DC): Risk Assessment Forum, USEPA. EPA/630/R-03/003F.

[USEPA] US Environmental Protection Agency. 2005b. Guidelines for cancer risk assessment. Washington (DC): Risk Assessment Forum, USEPA. EPA/630/P-03/001B.

PROPOSED METHOD 1 STANDARDS FOR PFAS

Introduction

The acronym "PFAS" stands for "per- and polyfluoroalkyl substances." These compounds are largely persistent and some are bioaccumulative. They are also highly mobile in groundwater. Method 1 Standards are proposed for the following six perfluorinated compounds:

- Perfluorooctanoic acid (PFOA)
- Perfluorooctanesulfonic acid (PFOS)
- Perfluorohexanesulfonic acid (PFHxS)
- Perfluorononanoic acid (PFNA)
- Perfluoroheptanoic acid (PFHpA)
- Perfluorodecanoic acid (PFDA)

The bases of the Method 1 standards for PFAS are summarized briefly in the bullet points below and described in more detail in the sections that follow:

- The GW-1 standards are set at the ORS Drinking Water Guideline (ORSG) that would result from the use of the reference dose (RfD) derived by ORS for these PFAS as described below. The ORSG is being reviewed concurrently with these regulation revisions and will take into consideration comments received during the public comment period. This is consistent with MassDEP's policy of setting the standard at the ORSG if a drinking water standard has not been promulgated but an ORSG has been developed.
- No GW-2 standards for PFAS have been set.
- GW-3 standards are based on surface water concentrations considered protective of aquatic organisms, adjusted for dispersion and dilution.
- The direct contact risk-based value for each soil category is calculated using the ORS-derived RfD for these compounds.
- The soil standards for any soil category in a GW-1 area are based on leaching potential and preventing exceedances of the GW-1 standard in the underlying groundwater. The leaching-based soil concentration is lower than the soil reporting limit, so the soil standard in a GW-1 area is set at the reporting limit.

Basis of PFAS Reference Doses Used in the Derivation of the MCP Standards

Background: On June 8, 2018 MassDEP issued an Office of Research and Standards Guideline (ORSG) for drinking water for five PFAS compounds (ORS, 2018a). The ORSG was based on the U. S. Environmental Protection Agency (USEPA) Reference Dose (RfD) of 2.0 X 10^{-5} milligrams per kilogram body weight per day (mg/kg-day) and drinking water Health Advisory of 70 nanograms (ng/L) per liter (parts per trillion or ppt) for perfluorooctanoic acid (PFOA) (USEPA 2016 a, b) and perfluorooctane sulfonate (PFOS) (USEPA 2016 c, d), extended to include three additional structurally similar compounds, perfluorononanoic acid (PFNA), perfluorohexane sulfonate (PFHxS) and perfluoroheptanoic acid (PFHpA) (ORS, 2018b).

On June 21, 2018 the federal Agency for Toxic Substances and Disease Registry (ATSDR) published a draft Toxicological Profile for Perfluoroalkyls, which included individual Minimum Risk Level (MRL) values for PFOS, PFOA, PFNA and PFHxS (ATSDR 2018). MRL and RfD values are equivalent and represent estimates of a daily exposure or intake of a chemical expected to be without appreciable risk of adverse non-cancer effects. The draft ATSDR PFOS MRL (2.0×10^{-6} mg/kg-day) is 10-fold lower, and the ATSDR PFOA MRL (2.7×10^{-6}) is approximately 7-fold lower, than USEPA's RfD of 2.0×10^{-5} for these compounds. The ATSDR values are similar to those derived by the New Jersey's Drinking Water Quality Institute (NJ 2015, 2017, 2018) (https://www.state.nj.us/dep/watersupply/g_boards_dwqi.html). The ATSDR also published MRLs for PFNA (3×10^{-6} mg/kg-day) and PFHxS (2×10^{-5} mg/kg-day). USEPA has not established any RfD values for these two compounds. Due to data deficiencies, ATSDR did not derive a MRL for PFHpA or other PFAS compounds.

The differences between the USEPA RfD and ATSDR MRL values prompted MassDEP to re-evaluate its approach to these compounds. As part of MassDEP efforts to address PFAS compounds, the MassDEP Office of Research and Standards (ORS) has reviewed numerous published toxicological assessments and key primary literature publications including the USEPA Health Effects Support and Drinking Water Health Advisory documents for PFOA and PFOS (USEPA 2016 a, b, c, d); the ATSDR draft Toxicological Profile for Perfluoroalkyls (ATSDR, 2018); the National Toxicology Program (NTP) Monograph, Immunotoxicity Associated with Exposure to PFOA or PFOS (NTP, 2016); the NJ Drinking Water Quality Institute MCL recommendation supporting documents for PFNA (NJ, 2015), PFOS (NJ, 2018) and PFOA (NJ, 2017), as well as numerous other sources.

Updated approach: Based on these reviews, MassDEP ORS has concluded that the RfD values for PFOS and PFOA should be adjusted downward from 2×10^{-5} to a value of 5×10^{-6} mg/kg-day. This revised value results from the inclusion of an additional data base uncertainty factor in the RfD derivations to account for evidence associating exposures to longer-chain PFAS (e.g. PFOS and PFOA) with several potentially adverse responses, including but not limited to effects on development and the immune system, in laboratory animals at dose levels below those used in the USEPA RfD calculations. Use of an additional uncertainty factor of 10 was considered, but not selected in light of the likely conservativeness of the Relative Source Contribution factor used with the RfD to derive a drinking water guidance value (see below).

As indicated above, this lower RfD is supported on the basis of animal bioassay data on a number of endpoints and epidemiology studies that have reported associations between human PFAS exposure and adverse immune and developmental effects. Potential PFAS effects on the immune system were highlighted by the NTP in a 2016 systematic review of PFOA and PFOS (NTP, 2016), which was issued after USEPA completed their RfD documents. In their review, the NTP concluded that both compounds should be presumed to be immune hazards to people based on a high level of evidence from animal studies and a moderate level of evidence from studies in humans.

Regarding approaches to addressing potential risks attributable to exposures to multiple PFAS, ORS continues to concur with the USEPA's additivity grouping approach as applied to PFOS and PFOA in deriving the Agency's drinking water Health Advisories (HAs) for these compounds (USEPA, 2016 c, d). ORS previously concluded that this additivity grouping approach should be extended to additional PFAS compounds that are structurally closely related, unless differences in potencies and mechanisms of action become apparent in appropriately robust data sets (ORS, 2018a). ORS has also concluded that the limited data relied upon by ATSDR in its MRL derivations for PFHxS and PFNA are insufficient to conclude that a significant difference in potency exists between these compounds and the more extensively studied PFOS and PFOA. Thus, MassDEP ORS is applying the revised RfD for **PFOS** and **PFOA** (5×10^{-6} mg/kg-day) to **PFNA**, **PFHxS**, and **PFHpA** following the approach previously described (ORS, 2018a).

Additionally, based on structural similarity and data indicating it has a long serum half-life, ORS is extending this approach to include **PFDA**.

Application of the ORS RfD values in the derivation of an Office of Research and Standards Guideline (ORSG) for drinking water, consistent with the approach used by USEPA in deriving the PFOA and PFOS HAs and that described in ORS, 2018b, results in an updated ORSG for each of these six PFAS of 20 ppt, rounded to one significant figure. ORS has concluded that additive toxicity across these compounds is likely to occur.

Key References for Development of the ORSG:

[ATSDR] Agency for Toxic Substances and Disease Registry. 2018. Toxicological Profile for Perfluoroalkyls - Draft for Public Comment. Atlanta, GA: Division of Toxicology and Human Health Sciences Environmental Toxicology Branch, ATSDR. https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf (accessed 10/1/2018)

[NTP] National Toxicology Program. 2016. NTP Monograph - Immunotoxicity Associated with Exposure to Perfluorooctanoic Acid or Perfluorooctane Sulfonate. Office of Health Assessment and Translation Division of the National Toxicology Program National Institute of Environmental Health Sciences National Institutes of Health, U.S. Department of Health and Human Services. https://ntp.niehs.nih.gov/ntp/ohat/pfoa_pfos/pfoa_pfosmonograph_508.pdf (accessed 10/1/2018)

[NJ] New Jersey Drinking Water Quality Institute. 2018. Maximum Contaminant Level Recommendation for Perfluorooctane Sulfonate in Drinking Water Basis and Background. Trenton, NJ: New Jersey Drinking Water Quality Institute June 8, 2018. https://www.state.nj.us/dep/watersupply/g_boards_dwqi.html (accessed 10/1/2018)

[NJ] New Jersey Drinking Water Quality Institute. 2017. Maximum Contaminant Level Recommendation for Perfluorooctanoic Acid in Drinking Water Basis and Background. Trenton, NJ: New Jersey Drinking Water Quality Institute March 15, 2017. . https://www.state.nj.us/dep/watersupply/g_boards_dwqi.html (accessed 10/1/2018)

[NJ] New Jersey Drinking Water Quality Institute (2015). Maximum Contaminant Level Recommendations for Perfluorononanoic Acid in Drinking Water Basis and Background. Trenton, NJ: New Jersey Drinking Water Quality Institute July 1, 2015.. https://www.state.nj.us/dep/watersupply/g_boards_dwqi.html (accessed 10/1/2018)

[ORS] MassDEP Office of Research and Standards. (2018a). Massachusetts Department of Environmental Protection Office of Research and Standards Final Recommendations for Interim Toxicity and Drinking Water Guidance Values for Perfluorinated Alkyl Substances Included in the Unregulated Chemical Monitoring Rule 3". Massachusetts Department of Environmental Protection, Office of Research and Standards. June 8, 2018. https://www.mass.gov/files/documents/2018/06/11/pfas-ors-ucmr3-recs_0.pdf

[ORS] MassDEP Office of Research and Standards. (2018b). ORSG for PER- and POLYFLUOROALKYL SUBSTANCES (PFAS), including the US EPA UCMR3 analytes: Perfluorooctane Sulfonic Acid (PFOS) Perfluorooctanoic Acid (PFOA) Perfluorohexane Sulfonic Acid (PFHxS) Perfluorononanoic Acid (PFNA) Perfluorohepatanoic Acid (PFHpA). Massachusetts Department of Environmental Protection Office of Research and Standards. June 8, 2018 https://www.mass.gov/files/documents/2018/06/11/orsg-pfas-20180608.pdf

[USEPA] U.S. Environmental Protection Agency. 2016a. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). Washington (DC): Office of Water Health and Ecological Criteria Division, USEPA. EPA 822-R-16-

005. https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final_508.pdf (accessed 10/1/2018)

[USEPA] U.S. Environmental Protection Agency. 2016b. Health Effects Support Document for Perfluorooctanoic Acid (PFOA). Washington (DC): Office of Water Health and Ecological Criteria Division, USEPA. 822-R-16-003. https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_hesd_final_508.pdf (accessed 10/1/2018)

[USEPA] U.S. Environmental Protection Agency. 2016c. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). Washington (DC): Office of Water Health and Ecological Criteria Division, USEPA. EPA 822-R-16-004. https://www.epa.gov/sites/production/files/2016-05/documents/pfos_health_advisory_final_508.pd (accessed 10/1/2018)

[USEPA] U.S. Environmental Protection Agency. 2016d. Health Effects Support Document for Perfluorooctane Sulfonate (PFOS). Washington (DC): Office of Water Health and Ecological Criteria Division, USEPA. EPA 822-R-16-002. https://www.epa.gov/sites/production/files/2016-05/documents/pfos_hesd_final_508.pdf (accessed 10/1/2018)

GW-1 Standards for PFAS

As stated above, MassDEP has developed an ORSG for PFAS compounds of 20 ppt (0.02 ppb). This value is applied to the total concentration of six PFAS compounds: PFDA, PFHoA, PFHxS, PFOA, PFOS, and PFNA. Consistent with the established procedure the GW-1 standard for these PFAS is set at 20 ppt.

GW-3 Values for PFAS

GW-3 standards are based on a surface water concentration (target value) that is protective for aquatic life. The surface water target values are then adjusted to account for the attenuation and dilution assumed to occur as the groundwater migrates from the site to a surface water body.

The surface water target values used to establish GW-3 standards for PFOA and PFOS are set at the surface water guidelines set by Minnesota using USEPA's Tier 2 Methodology for surface water criteria (Minnesota Pollution Control Agency 2007).

- The surface water target value for PFOA is 1705 ug/L
- The surface water target value for PFOS is 19 ug/L

The literature is insufficient to establish chemical-specific surface water concentrations for the remaining four PFAS (PFDA, PFHpA, PFHxS and PFNA). The proposed target concentrations for these compounds are based on chemical similarities in functional group as follows:

- The surface water target values for PFDA, PFHpA and PFNA are set at the PFOA target concentration.
- The surface water target value for PFHxS is set at the PFOS target concentration.

Key References for GW-3 Standards for PFAS Compounds:

[MPCA] Minnesota Pollution Control Agency. 2007. Surface Water Criteria for Perfluorooctane Sulfonic Acid. Prepared for MPCA by STS Consultants, Ltd..

[MPCA] Minnesota Pollution Control Agency. 2007. Surface Water Criteria for Perfluorooctanoic Acid. Prepared for MPCA by STS Consultants, Ltd..

Soil Standards for PFAS

Direct contact soil concentrations for the six M-1 PFAS standards are calculated using the RfD used to establish the ORSG, which is 5×10^{-6}. The non-GW-1 soil standards apply to individual PFAS; there is not a total PFAS standard for soil outside GW-1 areas.

For soil in GW-1 areas, the leaching-based soil concentration is lower than the PFAS reporting limit for soil, so the soil standards for GW-1 areas are set at the reporting limit of 0.2 ug/kg (ppb). This reporting limit was established by MassDEP based on a survey of several laboratories currently conducting PFAS analysis. The total PFAS S-1 standard applies to the total concentration of the six PFAS included in the Method 1 Standards.

GW-3 STANDARDS (OHM other than PFAS)

Background Information

Surface water target values used in setting GW-3 Standards for Cadmium (Cd) and Selenium (Se) have changed based on updated National Recommended Water Quality Criteria (NRWQCs) published by USEPA. The procedure for setting GW-3 Standards remains unchanged and is as follows:

- GW-3 Standards are derived from surface water target values that are set by MassDEP for the protection of aquatic organisms. If USEPA has published an NRWQC to protect aquatic organisms from the chemical in question, that value is used as the surface water target value. If not, the surface water target is set at the lowest observed effect concentration published in the literature.
- The surface water target value is then adjusted to account for dilution and attenuation in the groundwater to arrive at the groundwater target value.
- Finally, to arrive at the GW-3 standard, the groundwater target concentration may be adjusted downward if it exceeds the ceiling value or upward if it is below background or the quantitation limit.

The numerical bases for proposed changes in the target surface water concentrations and the corresponding proposed revisions of GW-3 Standards are summarized in the table below for Cadmium and Selenium. Proposed GW-3 Standards for PFAS compounds are discussed in the preceding section.

Comparison of 2014 GW-3 Standards with Proposed 2019 GW-3 Standards for Cadmium and Selenium

OHM	Surface Water Target Value: Lowest Eco-Based Criterion ug/L	Basis of Target Value	Target Value Adjusted for Dilution & Attenuation ug/L	GW Bckgrnd Conc. ug/L	Water PQL ug/L	GW-3 Standard (Lowest of Background, PQL, Adjusted Target Value ug/l
Cd (2014)	0.094	Hardness-Adjusted Chronic NRWQC	2.35	4.2	0.8	4
Cd (2019 Proposed)	0.3 (USEPA 2016a)	Hardness-Adjusted Chronic NRWQC*	7.5	4.2	0.8	8
Se (2014)	5		125	NA	50	100
Se (2019 Proposed)	1.5 (USEPA 2016b)		37.5	NA	50	50

* Hardness-adjusted from the published freshwater criterion continuous concentration (CCC) of 0.72 ug/L (corresponding to a hardness of 100 mg/L as $CaCO_3$) to a value of 0.3 ug/L (corresponding to a hardness of 25 mg/L of $CaCO_3$)

References for GW-3 Standard Revisions

[USEPA] U.S. Environmental Protection Agency. 2016a. Aquatic Life Ambient Water Quality Criteria, Cadmium. Washington (D.C.): Office of Water Health and Ecological Criteria Division, USEPA. EPA 820-r-16-002.

[USEPA] U.S. Environmental Protection Agency. 2016b. Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater. Washington (D.C.): Office of Water, Office of Science and Technology. EPA 822-R-16-006.

Summary of Proposed MCP Method 1 Standards Revisions

ATTACHMENT A

TOXICITY VALUE UPDATES

March 2019

Chemical	2014 Value	2014 Source	2019 Value	2019 Source
Antimony	C, SC RfC = 1×10^{-2} mg/m^3	CHEM/AAL[A]	C, SC RfC = 2×10^{-4} mg/m^3	IRIS
Benzene	C, SC RfC = 1×10^{-2} mg/m^3	ORS[B]	C, SC RfC = 3×10^{-3} mg/m^3	ORS[B]
Benzo(a)anthracene	CSF = 7.3×10^{-1}per mg/kg-day	IRIS[C]	CSF = 1×10^{-1} per mg/kg-day	IRIS[C]
Benzo(a)anthracene	IUR = 2.1×10^{-4} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-5} per ug/m^3 *	IRIS[C]
Benzo(a)pyrene	C RfD = 3×10^{-2} mg/kg-day	MassDEP[E]	C, SC RfD = 3×10^{-4} mg/kg·day	IRIS
Benzo(a)pyrene	SC RfD = 3×10^{-1} mg/kg-day	MassDEP[E]	C, SC RfD = 3×10^{-4} mg/kg-day	IRIS
Benzo(a)pyrene	C RfC = 5×10^{-2} mg/m^3	MassDEP[E]	C, SC RfC = 2×10^{-6} mg/m^3	IRIS
Benzo(a)pyrene	SC RfC = 5×10^{-1} mg/m^3	MassDEP[E]	C, SC RfC = 2×10^{-6} mg/m^3	IRIS
Benzo(a)pyrene	CSF = 7.3 per mg/kg-day	IRIS	CSF = 1 per mg/kg-day	IRIS
Benzo(a)pyrene	IUR = 2.1×10^{-3} per ug/m^3 *	IRIS[D]	IUR = 6×10^{-4} per ug/m^3 *	IRIS
Benzo(b)fluoranthene	CSF = 7.3×10^{-1}per mg/kg-day	IRIS[C]	CSF = 1×10^{-1}per mg/kg-day	IRIS[C]
Benzo(b)fluoranthene	IUR = 2.1×10^{-4} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-5} per ug/m^3 *	IRIS[C]
Benzo(k)fluoranthene	CSF = 7.3×10^{-2} per mg/kg-day	IRIS[C]	CSF = $1x10^{-2}$ per mg/kg-day	IRIS[C]
Benzo(k)fluoranthene	IUR = 2.1×10^{-5} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-6} per ug/m^3 *	IRIS[C]
1,1-Biphenyl	No CSF	NA	CSF = 8×10^{-3} per mg/kg-day	IRIS
Cadmium	C, SC RfC = 2×10^{-5} mg/m^3	CHEM/AAL[A]	C,SC RfC = 1×10^{-5} mg/m^3	ORS
Chrysene	CSF = 7.3×10^{-2} per mg/kg-day	IRIS[C]	CSF = 1×10^{-2} per mg/kg-day	IRIS[C]
Chrysene	IUR = 2.1×10^{-5} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-6} per ug/m^3 *	IRIS[C]
Dibenzo(ah)anthracene	CSF = 7.3×10^{0} per mg/kg-day	IRIS[C]	CSF = 1×10^{0} per mg/kg-day	IRIS[C]
Dibenzo(ah)anthracene	IUR = 2.1×10^{-3} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-4} per ug/m^3 *	IRIS[C]
Cis-1,2-dichloroethylene	C RfC = 6.0×10^{-3} mg/m^3	IRIS[F]	C RfC = 7×10^{-3} mg/m^3	Conversion Correction
Cis-1,2-dichloroethylene	SC RfC = 6.0×10^{-2} mg/m^3	IRIS[F]	SC RfC = 7×10^{-2} mg/m^3	Conversion Correction

TOXICITY VALUE UPDATES

March 2019

Chemical	2014 Value	2014 Source	2019 Value	2019 Source
Trans-1,2-dichloroethylene	C RfC = 6.0×10^{-2} mg/m^3	PPRTV	C RfC = 7×10^{-2} mg/m^3	IRIS[F] (PPRTV RfC retracted)
Trans-1,2-dichloroethylene	SC RfC = 6.0×10^{-2} mg/m^3	PPRTV	SC RfC = 7×10^{-1} mg/m^3	IRIS[F] (PPRTV RfC retracted)
2,4-Dichlorophenol	C, SC dermal RAF = 0.4	NA	C, SC dermal RAF = 0.3	MassDEP[H]
1,2-Dichloropropane	No RfDs	NA	C,SC RfD = 4×10^{-2} mg/kg-day	PPRTV
1,2-Dichloropropane	CSF = 6.8×10^{-2} per mg/kg-day	HEAST	CSF = 3.7×10^{-2} per mg kg-day	PPRTV
1,4-Dioxane	C, SC RfC = 1.2×10^{-1} mg/m^3	HEAST	C, SC RfC = 3×10^{-2} mg/m^3	IRIS
1,4-Dioxane	IUR = 4.1×10^{-6} per ug/m^3 *	CHEM/AAL	IUR = 5×10^{-6} per ug/m^3 *	IRIS
Fluoranthene	SC RfD = 4×10^{-1} mg/kg-day	HEAST	SC RfD = 1 x 10-[1] mg/kg-day	PPRTV
Indeno(1,2,3-cd)pyrene	CSF = 7.3×10^{-1} per mg/kg-day	IRIS[C]	CSF = 1×10^{-1} per mg/kg-day	IRIS[C]
Indeno(1,2,3-cd)pyrene	IUR = 2.1×10^{-4} per ug/m^3 *	IRIS[C,D]	IUR = 6×10^{-5} per ug/m^3 *	IRIS[C]
PERFLUORO-DECANOIC ACID (PFDA)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value
PERFLUORO-HEPTANOIC ACID (PFHpA)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value
PERFLUORO-HEXANESULFONIC ACID (PFHxS)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value
PERFLUORO-OCTANOIC ACID (PFOA)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value
PERFLUORO-OCTANE SULFONATE (PFOS)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value
PERFLUORO-NONANOIC ACID (PFNA)	Not on M-1 Standards list	NA	20 ppt in drinking water (Total of 6) RfD = 5×10^{-6}	Proposed MassDEP Value

TOXICITY VALUE UPDATES

March 2019

Chemical	2014 Value	2014 Source	2019 Value	2019 Source
2,3,7,8-TCDD Equivalents	RfC Not Available	**NA**	C, SC Rf C = 2 x 10^{-10} mg/m^3	Conversion from RfD updated in 2014
Tetrachloroethylene	C RfD = 1x10^{-2} mg/kg-day	IRIS (2009 MCP)	C RfD = 6 x 10^{-3} mg/kg-day	IRIS
Tetrachloroethylene	SC RfD = 1x10^{-1} mg/kg-day	HEAST (2009 MCP)	SC RfD = 6 x 10^{-3} mg/kg-day	IRIS
Tetrachloroethylene	C, SC RfC = 4.6 x 10^{0} mg/m^3	CHEM/AAL (2009)	C, SC RfC = 4 x 10^{-2} mg/m^3	IRIS
Tetrachloroethylene	CSF = 5.1x10^{-2} per mg/kg-day	1992 EPA Fact Sheet	CSF = 2 x 10^{-2} per mg/kg-day	ORS[G]
Tetrachloroethylene	IUR = 5.52x10^{-5} per ug/m^3	CHEM/AAL	IUR = 3 x 10^{-6} per ug/m^3	ORS[G]
Vinyl chloride	CSF = 1.4 x 10^{0} per mg/kg-day (Continuous lifetime exposure from birth)	IRIS	CSF_{0-2} = 7.2 x 10^{-1} per mg/kg-day (Age-specific)	IRIS
			CSF_{2-30} = 7.2 x 10^{-1} per mg/kg-day (Age-specific)	IRIS
Vinyl chloride	IUR = 8.8 x 10^{-6} per ug/m^3 (Continuous lifetime exposure from birth)	IRIS	IUR_{0-2} = 4.4 x 10^{-6} per ug/m^3 (Exposure from birth to age 2)	IRIS (Toxicity Profile)
			IUR_{2-30} = 4.4 x 10^{-6} per ug/m^3 (Lifetime exposure from beginning at age 2)	IRIS (Toxicity Profile)

Abbreviations:

ug = micrograms (The letter "u" is used in place of the micron symbol (µ) to avoid inter-computer formatting errors.)
C = Chronic
SC = Subchronic
RfD - Reference dose
RfC = Reference concentration
CSF = Cancer slope factor
IUR = Inhalation unit risk

TOXICITY VALUE UPDATES

March 2019

Chemical	2014 Value	2014 Source	2019 Value	2019 Source

Notes:

A Former ORS procedure for deriving AALs and TELs

B MassDEP Methodology for Updating Air Guidelines: Allowable Ambient Limits (AALs) and Threshold Effects Exposure Limits (TELs) (MassDEP 2011) and Current AALs and TELs Table. http://www.mass.gov/eea/agencies/massdep/toxics/sources/air-guideline-values.html#CurrentAALsTELs

C The IRIS Oral Cancer Slope Factor and Inhalation Unit Risk for benzo(a)pyrene is the basis for the Oral Cancer Slope Factors and Inhalation Unit Risks applied to the seven PAH compounds which are designated as category A, B1, B2 or C carcinogens. The values are adjusted by Relative Potency Factors.

D IUR based on conversion of CSF

E Toxicity values for PAHs are consistent with the approach presented in "Updated Petroleum Hydrocarbon Fraction Toxicity Values for the VPH/EPH/APH Methodology" MassDEP 2003.

F Conversion of the oral reference dose

G Tetrachloroethylene (Perchloroethylene) Inhalation Unit Risk Value. Office of Research and Standards, Boston, MA. (MassDEP 2014) (Accessed 10/10/2017 http://www.mass.gov/eea/agencies/massdep/toxics/sources/tetrachloroethylene-pce.html)

H MassDEP 2012 RAF Review.

I Current AALs and TELs Table

Summary of Proposed MCP Method 1 Standards Revisions

Attachment B

Example Calculations for Ingestion Risk-Based Concentrations for Mutagens in Drinking Water

March 2019

The following drinking water ingestion calculations are presented for the purpose of illustration only. Examples of the three different equation forms used to assess early life exposures consistent with EPA guidelines are provided. Each of the example chemicals has a drinking water standard on which the Method 1 GW-1 standard is based. Thus, the concentrations calculated by these equations are not the basis of GW-1 standards for the chemicals in these examples.

1. Dichloromethane

The calculation of the dichloromethane (DCM) risk-based concentration for drinking water ingestion uses the default age-dependent adjustment factors (ADAFs) to incorporate additional risk associated with early life exposures to mutagens for which age-specific slope factors are not available. This equation form would also be used for PAHs.

$$[DCM\ conc] = \frac{ELCR}{CSF\ x\ \left((DWEF_{0-2}\ x\ \ ADAF_{0-2})\ +\ (DWEF_{2-6}\ x\ \ ADAF_{2-6})+\ (DWEF_{6-16}\ x\ \ ADAF_{6-16})+\ (DWEF_{16-30}\ x\ \ ADAF_{16-30})\right)}$$

Where:

[DCM conc] = dichloromethane concentration in drinking water in micrograms per liter (ug/L)
ELCR = excess lifetime cancer risk limit for Method 1 Standards of 1×10^{-6}
CSF = cancer slope factor for dichloromethane of 2×10^{-3} per mg/kg-day
ADAF = the default age dependent adjustment factor used to account for age-dependent cancer susceptibility

$ADAF_{0-2}$ = 10
$ADAF_{2-6}$ = 3
$ADAF_{6-16}$ = 3
$ADAF_{16-30}$ = 1

DWEF = drinking water exposure factor for each age group. Units: L x mg / ($kg_{body\ wt}$ - day x ug)

$$DWEF_{age\ x} = \frac{IR\ x\ RAF\ x\ EF\ x\ EP\ x\ CF1\ x\ CF2}{AP\ x\ BW}$$

Where:

- IR = daily drinking water intake rate
  - IR_{0-2} = 1 liter per day
  - IR_{2-6} = 1 liter per day
  - IR_{6-16} = 2 liters per day
  - IR_{16-30} = 2 liters per day
- RAF = Relative absorption factor = 1
- EF = exposure frequency = 365 days per year, all age groups
- EP = exposure period = number of years in each age group
  - EP_{0-2} = 2 years
  - EP_{2-6} = 4 years
  - EP_{6-16} = 10 years
  - EP_{16-30} = 14 years
- AP = averaging period = 70 years, all age groups
- BW = body weight
  - BW_{0-2} = 9.6 kg
  - BW_{2-6} = 17.6 kg
  - BW_{6-16} = 43.2 kg
  - BW_{16-30} = 64.8 kg
- CF1 (conversion factor) = 1/365 years per day
- CF2 (conversion factor) = 0.001 mg per ug (milligrams per microgram)

$$DWEF_{0-2} = \frac{\frac{1\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 2y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{9.6\ kg_{bw}\ x\ 70\ y} = 2.9754 \text{ x } 10^{-6}$$

$$DWEF_{2-6} = \frac{\frac{1\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 4y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{17.6\ kg_{bw}\ x\ 70\ y} = 3.2459\ x\ 10^{-6}$$

$$DWEF_{6-16} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 10y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{43.2\ kg_{bw}\ x\ 70\ y} = 6.6120\ x\ 10^{-6}$$

$$DWEF_{16-30} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 15\ y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{64.8\ kg_{bw}\ x\ 70\ y} = 6.6120\ x\ 10^{-6}$$

$$[\boldsymbol{DCM\ conc}] = \frac{\mathbf{1\ x\ 10^{-6}}}{\mathbf{2\ x\ 10^{-3}\ x\left((2.9754x\ 10^{-6}\ x\ 10) + (3.2459\ x\ 10^{-6}\ x\ 3) + (6.6120\ x\ 10^{-6}\ x\ 3) + (6.6120\ x\ 10^{-6}\ x\ 1)\right)}}$$

[DCM conc] = 7.6 x 10^0 ug/L

2. Vinyl Chloride

Age-specific cancer slope factors are available for vinyl chloride (VC). Cancer risks for each age group are calculated using the age-specific cancer slope factor instead of applying the default ADAFs. The slope factor for the 0-2 age group is based on a type of cancer observed in adult test animals that were only exposed to vinyl chloride early in life, roughly equivalent to the period from 0 to 2 years of age in humans, with no additional exposure. Thus, the exposure for that age group is averaged over a 2 year period. The slope factor for all other age groups is based on cancer observed after a lifetime of exposure. Age groups are noted in subscripts of the terms in the equations that follow. (In the case of vinyl chloride, the slope factor for the 0-2 year age group is the same as the slope factor for other age groups.)

$$[VC\ conc] = \frac{ELCR}{((CSF_{0-2}\ x\ DWEF_{0-2}) + (CSF_{2-6}\ x\ DWEF_{2-6}) + (CSF_{6-16}\ x\ DWEF_{6-16}) + (CSF_{16-30}\ x\ DWEF_{16-30}))}$$

Where:

[conc] = concentration in drinking water in micrograms per liter (ug/L)

ELCR = excess lifetime cancer risk limit for Method 1 Standards of 1×10^{-6}

CSF = age group-specific cancer slope factor

- $CSF_{(0-2)}$ = 7.2×10^{-1} per mg/kg-day
- $CSF_{(2-30)}$ = 7.2×10^{-1} per mg/kg-day

$DWEF_{age\ x}$ = drinking water exposure factor for each age group
Units: L x mg / ($kg_{body\ wt}$-day x ug)

$$DWEF_{age\ x} = \frac{IR\ x\ RAF\ x\ EF\ x\ EP\ x\ CF1\ x\ CF2}{AP\ x\ BW}$$

Where:

- IR = daily drinking water intake rate
  - IR_{0-2} = 1 liter per day
  - IR_{2-6} = 1 liter per day
  - IR_{6-16} = 2 liters per day
  - IR_{16-30} = 2 liters per day
- RAF_{ing} = 1
- EF = exposure frequency = 365 days per year, all age groups
- EP = exposure period = number of years in each age group
  - EP_{0-2} = 2 years
  - EP_{2-6} = 4 years
  - EP_{6-16} = 10 years
  - EP_{16-30} = 14 years
- AP = averaging period
  - AP = 2 years for the 0 to 2 year age group
  - AP = 70 for all other age groups
- BW = body weight
  - BW_{0-2} = 9.6 kg
  - BW_{2-6} = 17.6 kg

$BW_{6\text{-}16}$ = 43.2 kg
$BW_{16\text{-}30}$ = 64.8 kg

- CF1 (conversion factor) = 1/365 years per day
- CF2 (conversion factor) = 0.001 mg per ug (milligrams per microgram)

$$DWEF_{0-2} = \frac{\frac{1\,L}{d}\ x\ 1\,x\ \frac{365\,d}{y}\ x\ 2y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{9.6\,kg_{bw}\ x\ 2\,y} = 1.0414\,x\,10^{-4}$$

$$DWEF_{2-6} = \frac{\frac{1\,L}{d}\ x\ 1\,x\ \frac{365\,d}{y}\ x\ 4y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{17.6\,kg_{bw}\ x\ 70\,y} = 3.2459\,x\,10^{-6}$$

$$DWEF_{6-16} = \frac{\frac{2\,L}{d}\ x\ 1\,x\ \frac{365\,d}{y}\ x\ 10y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{43.2\,kg_{bw}\ x\ 70\,y} = 6.6120\,x\,10^{-6}$$

$$DWEF_{16-30} = \frac{\frac{2\,L}{d}\ x\ 1\,x\ \frac{365\,d}{y}\ x\ 15\,y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{64.8\,kg_{bw}\ x\ 70\,y} = 6.6120\,x\,10^{-6}$$

$$[\boldsymbol{VC\ conc}] = \frac{\mathbf{1\,x\,10^{-6}}}{\mathbf{7.2\,x\,10^{-1}\,x\ (1.0414\,x\,10^{-4}\ +\ 3.2459\,x\,10^{-6}\ +\ 6.6120\,x\,10^{-6}\ +\ 6.6120\,x\,10^{-6})}}$$

[VC conc] = 1.2 x 10^{-2} ug/L

3. Trichloroethylene

Assessment of cancer risk from trichloroethylene (TCE) considers three types of cancer that contribute to total risk: kidney cancer, liver cancer and non-Hodgkin's lymphoma (NHL). There is evidence that kidney cancer, but not liver cancer or NHL, arises through a mutagenic process. The additional risk of kidney tumors from early life exposure is accounted for by using default age-dependent adjustment factors (ADAFs). The liver cancer and NHL risk are calculated in the conventional manner. The risks are summed.

$$[conc] = ELCR / \Big(\big((CSF_{kidney})\ x\ \big((DWEF_{0-2}\ x\ ADAF_{0-2}) + (DWEF_{2-6}\ x\ ADAF_{2-6}) + (DWEF_{6-16}\ x\ ADAF_{6-16}) + (DWEF_{16-30}\ x\ ADAF_{16-30}) \big) \big) + \big((CSF_{liver\ \&\ NHL})\ x (DWEF_{0-7} + DWEF_{7-14} + DWEF_{14-30}) \big) \Big)$$

Where:

[conc] = the drinking water concentration in micrograms per liter (ug/L)

ELCR = excess lifetime cancer risk limit of 1 x 10^{-6} for Method 1 Standards

FOR KIDNEY CANCER RISK

CSF_{kidney} = Cancer slope factor for kidney cancer of 9.3 x 10^{-3} per mg/kg-day

$ADAF_{age\ x}$ = the default age dependent adjustment factor to account for age-dependent cancer sensitivity

- $ADAF_{0-2}$ = 10
- $ADAF_{2-6}$ = 3
- $ADAF_{6-16}$ = 3
- $ADAF_{16-30}$ = 1

$DWEF_{kidney,\ age\ x}$ = drinking water exposure factor for each age group

Units: L x mg / ($kg_{body\ wt}$ - day x ug)

$$DWEF_{kidney,\ age\ x} = \frac{IR\ x\ RAF\ x\ EF\ x\ EP\ x\ CF1\ x\ CF2}{AP\ x\ BW}$$

Where:

- IR = daily drinking water intake rate
  - IR_{0-2} = 1 liter per day
  - IR_{2-6} = 1 liter per day
  - IR_{6-16} = 2 liters per day
  - IR_{16-30} = 2 liters per day

- RAF_{ing} = relative absorption factor for ingestion = 1
- EF = exposure frequency = 365 days per year, all age groups
- EP = exposure period = number of years in each age group
  - EP_{0-2} = 2 years
  - EP_{2-6} = 4 years
  - EP_{6-16} = 10 years

EP$_{16\text{-}30}$ = 14 years

- AP = averaging period = 70 years, all age groups
- BW = body weight

    BW$_{0\text{-}2}$ = 9.6 kg
    BW$_{2\text{-}6}$ = 17.6 kg
    BW$_{6\text{-}16}$ = 43.2 kg
    BW$_{16\text{-}30}$ = 64.8 kg
- CF1 (conversion factor) = 1/365 years per day
- CF2 (conversion factor) = 0.001 mg per ug (milligrams per microgram)

$$DWEF_{0-2} = \frac{\frac{1\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 2y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{9.6\ kg_{bw}\ \ x\ 70\ y} = 2.9754\ x\ 10^{-6}$$

$$DWEF_{2-6} = \frac{\frac{1\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 4y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{17.6\ kg_{bw}\ \ x\ 70\ y} = 3.2459\ x\ 10^{-6}$$

$$DWEF_{6-16} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 10y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{43.2\ kg_{bw}\ \ x\ 70\ y} = 6.6120\ x\ 10^{-6}$$

$$DWEF_{16-30} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 15\ y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{64.8\ kg_{bw}\ \ x\ 70\ y} = 6.6120\ x\ 10^{-6}$$

FOR LIVER CANCER RISK AND NON-HODGKINS LYMPHOMA

CSF $_{\text{liver \& NHL}}$ = cancer slope factor for liver cancer and Non-Hodgkin's lymphoma of 3.7 x 10^{-2} per mg/kg-day

DWEF $_{\text{liver \& NHL, age x}}$ = drinking water exposure factor for each age group
Units: L x mg / (kg$_{\text{body wt}}$ - day x ug)

$$DWEF_{liver\ \&\ NHL,\ \ age\ x} = \frac{IR\ x\ RAF\ x\ EF\ x\ EP\ x\ CF1\ x\ CF2}{AP\ x\ BW}$$

Where:

- IR = daily drinking water intake rate

    IR$_{0\text{-}7}$ = 1 liter per day
    IR$_{7\text{-}14}$ = 2 liters per day
    IR$_{14\text{-}30}$ = 2 liters per day
- RAF$_{ing}$ = relative absorption factor for ingestion = 1
- EF = exposure frequency = 365 days per year, all age groups
- EP = exposure period = number of years spanned by each age group:

    EP$_{0\text{-}7}$ = 7 years
    EP$_{7\text{-}14}$ = 7 years

$EP_{14\text{-}30}$ = 16 years

- AP = averaging period = 70 years, all age groups
- BW = body weight

  $BW_{0\text{-}7}$ = 16.2 kg

  $BW_{7\text{-}14}$ = 42.0 kg

  $BW_{14\text{-}30}$ = 63.5 kg

- CF1 (conversion factor) = 1/365 years per day
- CF2 (conversion factor) = 0.001 mg per ug (milligrams per microgram)

$$DWEF_{0-7} = \frac{\frac{1\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 7y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{16.2\ kg_{bw}\ x\ 70\ y} = 6.1712\ x\ 10^{-6}$$

$$DWEF_{7-14} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 7y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{42.0\ kg_{bw}\ x\ 70\ y} = 4.7606\ x\ 10^{-6}$$

$$DWEF_{14-30} = \frac{\frac{2\,L}{d}\ x\ 1\ x\ \frac{365\,d}{y}\ x\ 16y\ x\ \frac{0.002739\,y}{d}\ x\ 10^{-3}\frac{mg}{ug}}{63.5\ kg_{bw}\ x\ 70\ y} = 7.1972\ x\ 10^{-6}$$

$$[\boldsymbol{TCE\ conc}] = \mathbf{1\ x\ 10^{-6}} / \Big(\big(\mathbf{9.3\ x\ 10^{-3}\ x}\,((\mathbf{2.9754\ x\ 10^{-6}\ x\ 10}) + (\mathbf{3.2459\ x\ 10^{-6}\ x\ 3}) + (\mathbf{6.6120\ x\ 10^{-6}\ x\ 3}) + (\mathbf{6.6120\ x\ 10^{-6}\ x\ 1})\,)\big) + \big(\mathbf{3.7\ x\ 10^{-2}\ x}\ (\mathbf{6.1712\ x\ 10^{-6}} + \mathbf{4.7606\ x\ 10^{-6}} + \mathbf{7.1972\ x\ 10^{-6}})\big)\Big)$$

[TCE conc] = 7.8 x 10^{-1} ug/L

Summary of Proposed MCP Method 1 Standards Revisions

Attachment C

Example Calculations for Direct Contact Risk-Based Concentrations for Mutagens in Soil

March 2019

1. Risk-Based Vinyl Chloride Concentration in Residential Soil

Age-specific cancer slope factors are available for vinyl chloride (VC). Cancer risks for each age group are calculated using the age-specific cancer slope factor instead of applying the default ADAFs. The slope factor for the 0-2 age group is based on a type of cancer observed in adult test animals that were only exposed to vinyl chloride early in life, roughly equivalent to the period from 0 to 2 years of age in humans, with no additional exposure. Thus, the exposure for that age group is averaged over a 2 year period. The slope factor for all other age groups is based on cancer observed after a lifetime of exposure. Age groups are noted in subscripts of the terms in the equations that follow. (In the case of vinyl chloride, the slope factor for the 0-2 year age group is the same as the slope factor for other age groups.)

The risk-based soil vinyl chloride concentration is calculated as follows:

$$[VC\ conc] = \frac{ELCR}{\left((CSF_{1-2}\ x\ SEF_{1-2}) + (CSF_{2-31}\ x\ SEF_{2-6}) + (CSF_{2-31}\ x\ SEF_{6-16}) + (CSF_{2-31}\ x\ SEF_{16-30})\right)}$$

Where:

[VC conc] = soil vinyl chloride concentration in in milligrams per kilogram (mg/kg)

ELCR = excess lifetime cancer risk limit for Method 1 Standards of 1×10^{-6}

CSF = age group-specific cancer slope factor. EPA has published CSFs for two age ranges:

$CSF_{(0-2)}$ = 7.2×10^{-1} per mg/kg-day

Note: EPA developed this CSF for children under 2 years of age (0-2). MassDEP evaluates soil exposures beginning at 1 year of age, so this CSF is used to evaluate soil exposures for the one year period from age 1 to age 2.

$CSF_{(2-31)}$ = 7.2×10^{-1} per mg/kg-day

Note: EPA developed this CSF for lifetime exposures. MassDEP evaluates soil exposures up to age 31. This CSF is used to evaluate risks for the 29-year period from age 2 to age 31.

SEF_{age} = soil exposure factor for each age group = kg soil per ($kg_{body\ weight}$ - day)

$$SEF_{age} = \frac{\left(\left(soil\ IR_{age}\ x\ RAF_{ing}\right) + \left(SAF_{age}\ x\ SSA_{age}\ x\ RAF_{derm}\right)\right)\ x\ EF1\ x\ EF2\ x\ EP\ x\ C1\ x\ C2}{BW\ x\ AP}$$

Where:

- IR = soil incidental ingestion rate
  - $IR_{1\text{-}2}$ = 100 mg/day
  - $IR_{2\text{-}6}$ = 100 mg/day
  - $IR_{6\text{-}16}$ = 50 mg/day
  - $IR_{16\text{-}31}$ = 50 mg/day
- RAF_{ing} = 1
- SAF = skin adherence factor
  - $SAF_{1\text{-}2}$ = 0.37 mg/cm^2
  - $SAF_{2\text{-}6}$ = 0.37 mg/cm^2
  - $SAF_{6\text{-}16}$ = 0.14 mg/cm^2
  - $SAF_{16\text{-}31}$ = 0.14 mg/cm^2
- SSA = skin surface area
  - $SSA_{1\text{-}2}$ = 1705 cm^2/day
  - $SSA_{2\text{-}6}$ = 2107 cm^2/day
  - $SSA_{6\text{-}16}$ = 3897 cm^2/day
  - $SSA_{16\text{-}31}$ = 5463 cm^2/day
- RAF_{derm} = 0.03
- EF1 = exposure frequency = 5 days per week
- EF2 = exposure frequency = 30 weeks per year
- EP = exposure period = number of years in each age group
  - $EP_{1\text{-}2}$ = 1 year
  - $EP_{2\text{-}6}$ = 4 years
  - $EP_{6\text{-}16}$ = 10 years
  - $EP_{16\text{-}31}$ = 15 years
- AP = averaging period
  - AP = 1 year for the 1-2 year old age group
  - AP = 70 years for all other age groups
- BW = body weight
  - $BW_{1\text{-}2}$ = 12.0 kg
  - $BW_{2\text{-}6}$ = 17.6 kg
  - $BW_{6\text{-}16}$ = 43.2 kg
  - $BW_{16\text{-}31}$ = 64.8 kg
- CF1 (conversion factor) = 0.00274 year/day
- CF2 (conversion factor) = 10^{-6} kg/mg

$$SEF_{1-2} = \frac{\left(\left(\frac{100\ mg}{d}\ x\ 1\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{1785cm2}{d}\ x\ 0.03\right)\right) x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 1y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{12\ kg_{bw}\ x\ 1\ y} = 4.0437\ x\ 10^{-6}$$

$$SEF_{2-6} = \frac{\left(\left(\frac{100\ mg}{d}\ x\ 1\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{2107cm2}{d}\ x\ 0.03\right)\right) x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 4y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{17.6\ kg_{bw}\ x\ 70\ y} = 1.6225\ x\ 10^{-7}$$

$$SEF_{6-16} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 1\right) + \left(\frac{0.14\ mg}{cm2}\ x\ \frac{3897cm2}{d}\ x\ 0.03\right)\right) x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 10y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{43.2\ kg_{bw}\ x\ 70\ y} = 8.8885\ x\ 10^{-8}$$

$$SEF_{16-31} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 1\right) + \left(\frac{0.14\ mg}{cm2}\ x\ \frac{5463cm2}{d}\ x\ 0.03\right)\right) x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 15\ y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{64.8\ kg_{bw}\ x\ 70\ y} = 9.7694\ x\ 10^{-8}$$

$$[\boldsymbol{VC\ conc}] = \frac{\mathbf{1\ x\ 10^{-6}}}{\mathbf{7.2\ x\ 10^{-1}\ x\ (4.0437\ x\ 10^{-6} + 1.6225\ x\ 10^{-7} + 8.8885\ x\ 10^{-8} + 9.7694\ x\ 10^{-8})}}$$

[VC conc] = 3.1 x 10^{-1} mg/kg

2. Risk-Based Trichloroethylene Concentration in Residential Soil

Assessment of cancer risk from trichloroethylene (TCE) considers three types of cancer that contribute to total risk: kidney cancer, liver cancer and non-Hodgkin's lymphoma (NHL). There is evidence that kidney cancer, but not liver cancer or NHL, arises through a mutagenic process. The additional risk of kidney tumors from early life exposure is accounted for by using the default adjustment approach. The liver cancer and NHL risk are calculated in the conventional manner. The risks are summed.

The risk-based TCE soil concentration is calculated as follows:

$$[TCE\ conc] = ELCR/\Big(\Big(CSFkidney\ x\ \big((SEF_{1-2}\ x\ ADAF_{1-2}) + (SEF_{2-6}\ x\ ADAF_{2-6}) + (SEF_{6-16}\ x\ ADAF_{6-16}) + (SEF_{16-31}\ x\ ADAF_{16-31})\big)\Big) + \big(CSF_{liver}\ x\ (SEF_{1-2} + SEF_{2-6} + SEF_{6-16} + SEF_{16-31})\big)\Big)$$

Where:

[TCE conc] = TCE soil concentration in milligrams per kilogram (mg/kg)

ELCR = excess lifetime cancer risk limit for Method 1 Standards of 1 x 10^{-6}

$SEF_{age\ x}$ = soil exposure factor for each age group = kg_{soil} per $kg_{body\ weight}$-day

$$SEF_{age} = \frac{\big((soil\ IR_{age}\ x\ RAF_{ing}) + (SAF_{age}\ x\ SSA_{age}\ x\ RAF_{derm})\big)\ x\ EF1\ x\ EF2\ x\ EP\ x\ C1\ x\ C2}{BW\ \ x\ AP}$$

FOR KIDNEY CANCER RISK:

CSF_{kidney} = 9.3 x 10^{-3} per mg/kg-day

ADAF = Age-Dependent Adjustment Factors

- $ADAF_{1-2}$ = 10
- $ADAF_{2-6}$ = 3
- $ADAF_{6-16}$ = 3
- $ADAF_{16-31}$ = 1

- IR = soil incidental ingestion rate
  - IR_{1-2} = 100 mg/day
  - IR_{2-6} = 100 mg/day
  - IR_{6-16} = 50 mg/day
  - IR_{16-31} = 50 mg/day
- RAF_{ing} = 1
- SAF = skin adherence factor
  - SAF_{1-2} = 0.37 mg/cm^2
  - SAF_{2-6} = 0.37 mg/cm^2
  - SAF_{6-16} = 0.14 mg/cm^2
  - SAF_{16-31} = 0.14 mg/cm^2
- SSA = skin surface area
  - SSA_{1-2} = 1705 cm^2/day
  - SSA_{2-6} = 2107 cm^2/day
  - SSA_{6-16} = 3897 cm^2/day
  - SS_{16-31} = 5463 cm^2/day

- RAF_{derm} = 0.03
- EF1 = exposure frequency = 5 days per week
- EF2 = exposure frequency = 30 weeks per year
- EP = exposure period = number of years in each age group
  - $EP_{1\text{-}2}$ = 1 year
  - $EP_{2\text{-}6}$ = 4 years
  - $EP_{6\text{-}16}$ = 10 years
  - $EP_{16\text{-}31}$ = 15 years
- AP = averaging period = 70 years for all age groups
- BW = body weight
  - $BW_{1\text{-}2}$ = 12.0 kg
  - $BW_{2\text{-}6}$ = 17.6 kg
  - $BW_{6\text{-}16}$ = 43.2 kg
  - $BW_{16\text{-}31}$ = 64.8 kg
- CF1 (conversion factor) = 0.00274 year/day
- CF2 (conversion factor) = 10^{-6} kg/mg

$$SEF_{1-2} = \frac{\left(\left(\frac{100\,mg}{d}\ x\ 1\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{1785cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 1y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{12\ kg_{bw}\ x\ 70\ y} = 5.7767\ x\ 10^{-8}$$

$$SEF_{2-6} = \frac{\left(\left(\frac{100\,mg}{d}\ x\ 1\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{2107cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 4y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{17.6\ kg_{bw}\ x\ 70\ y} = 1.6225\ x\ 10^{-7}$$

$$SEF_{6-16} = \frac{\left(\left(\frac{50\,mg}{d}\ x\ 1\right) + \left(\frac{0.14\,mg}{cm2}\ x\ \frac{3897cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 10y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{43.2\ kg_{bw}\ x\ 70\ y} = 8.8885\ x\ 10^{-8}$$

$$SEF_{16-31} = \frac{\left(\left(\frac{50\,mg}{d}\ x\ 1\right) + \left(\frac{0.14\,mg}{cm2}\ x\ \frac{5463cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 15\,y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{64.8\ kg_{bw}\ x\ 70\ y}$$

$$= 9.7694\ x\ 10^{-8}$$

FOR LIVER CANCER AND NON HODGKIN"S LYMPHOMA:

- $CSF_{liver\& NHL}$ = 3.7×10^{-2} per mg/kg-day
- IR = soil incidental ingestion rate
  - IR_{1-8} = 100 mg/day
  - IR_{8-15} = 50 mg/day
  - IR_{15-31} = 50 mg/day
- RAF_{ing} = 1
- SAF = skin adherence factor
  - SAF_{1-8} = 0.37 mg/cm^2
  - SAF_{8-15} = 0.14 mg/cm^2
  - SAF_{15-31} = 0.14 mg/cm^2
- SSA = skin surface area
  - SSA_{1-8} = 2246 cm^2/day
  - SSA_{8-15} = 4073 cm^2/day
  - SSA_{15-31} = 5425 cm^2/day
- RAF_{derm} = 0.03
- EF1 = exposure frequency = 5 days per week
- EF2 = exposure frequency = 30 weeks per year
- EP = exposure period = number of years in each age group
  - EP_{1-8} = 7 years
  - EP_{8-15} = 7 years
  - EP_{15-31} = 16 years
- AP = averaging period = 70 for all age groups
- BW = body weight
  - BW_{1-8} = 19.0 kg
  - BW_{8-15} = 46.1 kg
  - BW_{15-31} = 64.4 kg
- CF1 (conversion factor) =0.00274 year/day
- CF2 (conversion factor) = 10^{-6} kg/mg

$$SEF_{1-8} = \frac{\left(\left(\frac{100\ mg}{d}\ x\ 1\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{2246\ cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 7y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{19.0\ kg_{bw}\ x\ 70\ y} = 2.6630\ x\ 10^{-7}$$

$$SEF_{8-15} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 1\right) + \left(\frac{0.14mg}{cm2}\ x\ \frac{4073cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 7y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{46.1\ kg_{bw}\ x\ 70\ y} = 5.8955\ x\ 10^{-8}$$

$$SEF_{15-31} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 1\right) + \left(\frac{0.14\ mg}{cm2}\ x\ \frac{5425cm2}{d}\ x\ 0.03\right)\right)\ x\ \frac{5d}{wk}\ x\ \frac{30wk}{y}\ x\ 16y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{64.4\ kg_{bw}\ x\ 70\ y}$$

$$= 1.0462\ x\ 10^{-7}$$

THE RISK-BASED TCE SOIL CONCENTRATION FOR ALL CANCER TYPES

$$[\boldsymbol{TCE\ conc}] = \mathbf{1x10^{-6}}/\left(\left(\mathbf{9.3\ x\ 10^{-3}\ \ x\ \ }\left((\mathbf{5.7677\ x\ 10^{-8}\ x\ 10}) + (\mathbf{1.6225\ x\ 10^{-7}\ x\ 3}) + (\mathbf{8.8885\ x\ 10^{-8}\ \ x\ \ 3}) + (\mathbf{9.7694\ x\ 10^{-8}\ x\ 1})\right)\right) + \left(\mathbf{3.7\ x\ 10^{-2}\ x\ }(\mathbf{2.6630\ x\ 10^{-7} + 5.8955\ x\ 10^{-8} + 1.0462\ x\ 10^{-7}})\right)\right)$$

[TCE conc] = 3.4 x 10^{1} mg/kg

3. Risk-Based Benzo(a)Pyrene Concentration in Residential Soil

The equations that follow illustrate the default approach for incorporating additional risk associated with early life exposures to mutagens for which age-specific slope factors are not available. Age-dependent adjustment factors (ADAFs) are used to account for higher susceptibility early in life. The group of mutagens for which the default approach is used includes dichloromethane, benzo(a)pyrene (BaP) and the other carcinogenic PAHs.

The risk-based BaP soil concentration calculations follow:

$$[BaP\ conc] = ELCR \ / \left(CSF\ x\ \left(SEF_{1-2}\ x\ ADAF_{1-2} + SEF_{2-6}\ x\ ADAF_{2-6} + SEF_{6-16}\ x\ ADAF_{6-16} + SEF_{16-31}\ x\ ADAF_{16-31}\right)\right)$$

Where:

[BaP conc] = BaP soil concentration in milligrams per kilogram (mg/kg)
ELCR = excess lifetime cancer risk limit for Method 1 Standards of 1×10^{-6}
CSF = cancer slope factor = 1×10^{0}
ADAF = Age-Dependent Adjustment Factors
- $ADAF_{1-2}$ = 10
- $ADAF_{2-6}$ = 3
- $ADAF_{6-16}$ = 3
- $ADAF_{16-31}$ = 1

$SEF_{age\ x}$ = soil exposure factor for each age group with units of kg_{soil} per ($kg_{body\ weight}$ - day)

$$SEF_{age} = \frac{\left(soil\ IR_{age}\ x\ RAF_{ing} + SAF_{age}\ x\ SSA_{age}\ x\ RAF_{derm}\right) x\ EF1\ x\ EF2\ x\ EP\ x\ C1\ x\ C2}{BW\ \ x\ AP}$$

Where:

- IR = soil incidental ingestion rate
  - IR_{1-2} = 100 mg/day
  - IR_{2-6} = 100 mg/day
  - IR_{6-16} = 50 mg/day
  - IR_{16-31} = 50 mg/day
- RAF_{ing} = 0.3
- SAF = skin adherence factor =
  - SAF_{1-2} = 0.37 mg/cm^2
  - SAF_{2-6} = 0.37 mg/cm^2
  - SAF_{6-16} = 0.14 mg/cm^2
  - SAF_{16-31} = 0.14 mg/cm^2
- SSA = skin surface area
  - SSA_{1-2} = 1705 cm^2/day
  - SSA_{2-6} = 2107 cm^2/day
  - SSA_{6-16} = 3897 cm^2/day
  - SSA_{16-31} = 5463 cm^2/day
- RAF_{derm} = 0.02
- EF1 = exposure frequency = 5 days per week
- EF2 = exposure frequency = 30 weeks per year

- EP = exposure period = number of years in each age group
  - $EP_{1\text{-}2}$ = 1 year
  - $EP_{2\text{-}6}$ = 4 years
  - $EP_{6\text{-}16}$ = 10 years
  - $EP_{16\text{-}31}$ = 15 years
- AP = averaging period
  - AP = 70 for all age groups
- BW = body weight
  - $BW_{1\text{-}2}$ = 12.0 kg
  - $BW_{2\text{-}6}$ = 17.6 kg
  - $BW_{6\text{-}16}$ = 43.2 kg
  - $BW_{16\text{-}31}$ = 64.8 kg
- CF1 (conversion factor) =0.00274 year/day
- CF2 (conversion factor) = 10^{-6} kg/mg

$$SEF_{1-2} = \frac{\left(\left(\frac{100\ mg}{d}\ x\ 0.3\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{1785cm2}{d}\ x\ 0.02\right)\right) x\ \frac{5d}{wk} x \frac{30wk}{y}\ x\ 1y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{12\ kg_{bw}\ x\ 70\ y} = 2.0833\ x\ 10^{-8}$$

$$SEF_{2-6} = \frac{\left(\left(\frac{100\ mg}{d}\ x\ 0.3\right) + \left(\frac{0.37mg}{cm2}\ x\ \frac{2107cm2}{d}\ x\ 0.02\right)\right) x\ \frac{5d}{wk} x \frac{30wk}{y}\ x\ 4y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{17.6\ kg_{bw}\ x\ 70\ y} = 5.9950\ x\ 10^{-8}$$

$$SEF_{6-16} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 0.3\right) + \left(\frac{0.14\ mg}{cm2}\ x\ \frac{3897cm2}{d}\ x\ 0.02\right)\right) x\ \frac{5d}{wk} x \frac{30wk}{y}\ x\ 10y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{43.2\ kg_{bw}\ x\ 70\ y} = 3.4703\ x\ 10^{-8}$$

$$SEF_{16-31} = \frac{\left(\left(\frac{50\ mg}{d}\ x\ 0.03\right) + \left(\frac{0.14\ mg}{cm2}\ x\ \frac{5463cm2}{d}\ x\ 0.02\right)\right) x\ \frac{5d}{wk} x \frac{30wk}{y}\ x\ 15\ y\ x\ \frac{0.0027y}{d}\ x\ 10^{-6}\frac{kg}{mg}}{64.8\ kg_{bw}\ x\ 70\ y} = 4.0576\ x\ 10^{-8}$$

$$[\boldsymbol{BaP\ conc}] = \mathbf{1x10^{-6}} \\ / \left(\mathbf{1\ x\ 10^{0}}\ \boldsymbol{x}\ \left(\left(\mathbf{2.0833\ x\ 10^{-8}\ x\ 10}\right) + \left(\mathbf{5.9950\ x\ 10^{-8}\ x\ 3}\right) + \left(\mathbf{3.4703\ x\ 10^{-8}\ x\ 3}\right) \\ + \left(\mathbf{4.0576\ x\ 10^{-8}\ x\ 1}\right)\right)\right)$$

[BaP conc] = 1.9 x 10^{0} mg/kg