Memorandum [Annotated by DEQ]

Date: July 2024

To: J. R. Giska, Apollonia Goeckner, and Susan MacMillan, Oregon Department of Environmental Quality; David Farrer and Holly Dixon, Oregon Health Authority

From: Eastern Research Group, Inc. (ERG)

Subject: Summaries of Published Inhalation Toxicity Values

Annotation

The Oregon Department of Environmental Quality (DEQ) has annotated this version of ERG's memorandum addressed to DEQ. The purpose of the annotation is to clarify which of the toxicity reference values (TRVs) researched by ERG DEQ is proposing for use in the DEQ's air quality programs. In many cases, multiple TRV options were described by ERG. These annotations also explain why DEQ selected certain TRVs over others for proposed use in the program.

DEQ's criteria for selection are described here (https://www.oregon.gov/deq/aq/Documents/ATSAC-TRVUpdate.pdf). In addition to those previously stated criteria, DEQ also preferred TRV candidates that:

1. Had transparent and publicly available derivation information
2. Were not derived from occupational exposure limits
3. Were not derived based on an LC50 or LD50

DEQ's annotations are in this larger, green font. All text not in this font is text from the original memo from ERG to DEQ.

1. Background

The Oregon Department of Environmental Quality (DEQ) Cleaner Air Oregon program within DEQ's Air Quality Division regulates emissions of Toxic Air Contaminants (TACs) from facilities operating in Oregon based on estimation of related public health risks. As part of the Cleaner Air Oregon program, DEQ and Oregon Health Authority (OHA) periodically review and update the inhalation Toxicity Reference Values (TRVs) used to assess the potential health impacts of facility emissions. DEQ's TRVs are based primarily on reference values published by one or more of four "Authoritative Sources" identified in Oregon Administrative Rule (OAR) 340–247-0030(1). Specifically, DEQ and OHA review TRVs published by U.S. EPA (including both the IRIS and PPRTV programs), California EPA's Office of Environmental Health Hazard Assessment (OEHHA), and U.S. Agency for Toxic Substances and Disease Registry (ATSDR). In

addition, DEQ may derive its own TRV in consultation with an Air Toxics Science Advisory Committee (ATSAC).

When TRVs are not available from the above Authoritative Sources, DEQ may refer to TRVs from other state or international agencies. Cleaner Air Oregon is currently in the process of updating its TRVs. To assist DEQ and OHA toxicologists, DEQ contracted with Eastern Research Group (ERG) to compile potentially relevant reference values from other agencies for certain TACs. Specifically, ERG was asked to compile and summarize TRVs from all 50 U.S. states, Australia, Canada, the European Union, and the World Health Organization (WHO) for the following TACS:

- 1-methylnaphthalene
- 2-methylnaphthalene
- Copper naphthenate
- 4,5-Dichloro-2-octyl-3(2H)-isothiazolone (DCOI)
- Poly- and perfluoroalkyl substances (PFAS)*

**DEQ/OHA provided ERG with a list of six PFAS: PFBS, PFBA, PFHxS, PFHxA, PFOA, and PFOS. In addition, DEQ/OHA asked ERG to supply a list of additional PFAS with reference values from other governmental agencies. The derivation of this list is documented below.*

This memorandum summarizes results of ERG's compilation of inhalation-based TRVs from state and international agencies.

2. Contents

3. Approach

ERG's approach for compiling inhalation TRVs from other government agencies consisted of several phases, each designed to ensure the thoroughness and accuracy of the compiled information. Details on each phase of the approach are described below.

Initial Compilation of Data Sources

ERG's public health scientists first assembled a comprehensive list of air toxics data sources. This list consists of state agency air toxics programs (primarily environmental agencies) from all 50 U.S. states as well as relevant agencies from Australia, Canada, the European Union, and the World Health Organization. Links to each agency's relevant air toxics lists were stored in an Excel workbook, so that staff could systematically gather published inhalation toxicity values. A complete list of these government agency websites is found in Appendix A.

Systematic Data Collection

For each assigned TAC, ERG public health scientists accessed every data source referenced above, searched for the TAC, and extracted relevant inhalation toxicity values. Since ERG was not provided a complete list of PFAS to search for, analysts also searched each list for other PFAS that were not included in DEQ/OHA's initial list (e.g., "GenX") and by searching for potentially relevant text, such as "fluoro". All findings were organized in an Excel workbook, which included the identified reference value with direct links to the source of the information as a reference.

Independent Evaluation and Broad Search

A senior ERG reviewer independently reviewed the work completed by ERG's public health scientists. This reviewer evaluated the compiled resources and performed a separate check for accuracy against other databases that might also contain state and other agency reference values (e.g., EPA's CompTox Chemicals Dashboard). ERG resolved any discrepancies identified from these secondary sources by double-checking the respective primary sources.

Obtaining Source Materials

Once a complete list of TRVs was compiled, ERG identified and downloaded technical support documents that contained the derivation of the toxicity values. In certain cases, these documents were not identifiable on public websites or there was uncertainty as to whether the identified information was old or current. In these instances, ERG emailed state agency contacts requesting clarifications and the source of the derived TRV.

Data Synthesis and Report Preparation

After obtaining the technical documentation for each reference value, ERG extracted relevant information that DEQ typically collects for the TRV derivation process. This information included the critical studies, exposure duration, health endpoint, uncertainty factors, and the overall formula used for the derivation. This information is summarized below in this memorandum.

4. Findings

Following a review of all sources identified in Appendix A, ERG identified health-based inhalation TRVs for the TACs of interest from nine different states and the European Chemicals Agency (ECHA). In addition, after the start of this project, DEQ/OHA requested ERG include a summary of the following toxicity reviews:

- a December 1999 toxicity review for DCOI from EPA's Office of Pesticide Protection (OPP),
- a March 2024 Provisional Peer-Reviewed Toxicity Value (PPRTV) document for 1-methylnaphthalene from EPA's Office of Research and Development (ORD), and
- a May 2024 Draft Toxicological Profile for 1-methylnaphthalene and 2-methylnaphthalene from ATSDR.

Table 1 summarizes which TACs ERG was able to identify an inhalation-based TRV for and the source of that TRV. A brief description of the types of health-based TRVs follows.

TABLE 1. SUMMARY OF TACS WITH IDENTIFIED TRVS FROM STATE AND OTHER REGULATORY AGENCIES.

State/Agency	MD[a]	MA[b]	MI[c]	MN[d]	NH[e]	NJ[f]	NY[g]	TX[h]	WI[i]	EU[j]	OPP[k]	ATSDR[l]	ORD[m]
1-methylnaphthalene	Yes	--	Yes	--	Yes	--	Yes	Yes	--	--	--	Yes	Yes
2-methylnaphthalene	Yes	Yes	Yes	--	Yes	--	Yes	Yes	--	--	--	Yes	--
Copper Naphthenate	Yes	--	--	--	--	--	--	Yes	--	Yes	--	--	--
DCOI	--	--	--	--	--	--	--	Yes	--	--	Yes	--	--
PFBA	--	--	--	Yes	--	--	--	Yes	--	--	--	--	--
PFBS	--	--	--	Yes	--	--	--	Yes	--	--	--	--	--
PFHxA	--	--	--	Yes	--	--	--	--	--	--	--	--	--
PFHxS	--	--	--	Yes	--	--	--	Yes	--	--	--	--	--
PFOA	--	--	Yes	Yes	Yes	Yes	Yes	Yes	Yes	--	--	--	--
PFOS	--	--	Yes	Yes	--	Yes	--	Yes	--	--	--	--	--
PFOSA	--	--	--	--	--	--	--	Yes	--	--	--	--	--
PFNA	--	--	--	--	--	--	--	Yes	--	--	--	--	--
PFDA	--	--	--	--	--	--	--	Yes	--	--	--	--	--
PFDoDA	--	--	--	--	--	--	--	Yes	--	--	--	--	--
6:2 FTS	--	--	Yes	--	--	--	--	--	--	Yes	--	--	--
HFPO-DA (Gen-X)	--	--	--	--	--	Yes	--	--	--	Yes	--	--	--
PFBE	Yes	--	Yes	--	--	--	--	--	--	Yes	--	--	--
PFIB	Yes	--	Yes	--	--	--	--	--	Yes	--	--	--	--
Perfluorobutylethylmethyldichlorosilane	--	--	Yes	--	--	--	--	--	--	--	--	--	--

[a] *Maryland Department of the Environment (MDE) Screening Level* – MDE screening levels are ambient benchmarks for toxic air pollutants intended to protect public health. "Public health is protected when the emissions of a facility are less than the maximum allowable emissions or when off-site impact of the premises-wide emissions of each TAP is less than the screening levels for the TAP, as determined by modeling." Source: https://mde.maryland.gov/programs/permits/AirManagementPermits/documents/tap%20reg%20guidance%20doc%2003-21-2016.pdf

[b] *Massachusetts Department of Environmental Protection (MassDEP) Threshold Effects Exposure Limit (TEL) / Allowable Ambient Limit (AAL)* – MassDEP TELs are based on non-cancer health effects and represents a "concentration intended to protect the general population, including sensitive populations such as children, from adverse health effects over a lifetime of continuous exposure" taking into account that people may be exposed from other sources. "For chemicals that do not pose cancer risks, the AAL is based on the TEL". Source: https://www.mass.gov/info-details/massdep-ambient-air-toxics-guidelines

[c] *Michigan Department of Environment, Great Lakes, and Energy (EGLE) Initial Threshold Screening Level (ITSL) / Initial Risk Screening Level (IRSL) / Secondary Risk Screening Level (SRSL)* – EGLE ITSL's are health-based screening levels for non-carcinogenic effects of a TAC. The IRSL and SRSL are screening levels for carcinogenic effects. The IRSL "is defined as an increased cancer risk of one in one million (10^{-6})," and the SRSL "is defined as an increased cancer risk of one in one hundred thousand (10^{-5})." If a new source permit applicant cannot meet the IRSL then they can meet the SRSL but must include all sources of the TAC. https://www.michigan.gov/egle/about/organization/air-quality/air-toxics

[d] *Minnesota Pollution Control Agency (MPCA) / Minnesota Department of Health (MDH) Health Based Values (HBVs) and Risk Assessment Advice (RAA)* – "MDH currently develops [HBVs] and [RAAs] when there is a need for guidance to evaluate health risks to chemicals in air, often by request of the [MPCA] or other state agencies. HBVs are developed after undergoing a comprehensive chemical review of available toxicity studies. RAA may contain greater uncertainty than HBVs as a result of a less rigorous chemical review or because toxicity information is more limited. MDH also develops RAA on a case-by-case basis for specific conditions or specific sites. It is not appropriate to apply a site-specific RAA to other sites without consulting MDH."
https://www.health.state.mn.us/communities/environment/risk/guidance/air/table.html

[e] *New Hampshire Department of Environmental Services (NHDES) Ambient Air Limits (AAL)* – NHDES AALs are short-term (24-hour) or long-term (annual) health-based values derived from "threshold limit values, reference concentration limits, and such other generally accepted scientific data as may be available."

https://www.gencourt.state.nh.us/rsa/html/X/125-I/125-I-mrg.htm

[f] *New Jersey Department of Environmental Protection (NJDEP) Initial Threshold Screening Level / Reference Concentration (RfC)*– NJDEP derived inhalation RfCs for PFOA, PFOS and a screening RfC for GenX based on oral-to-inhalation extrapolation from RfDs. These RfCs are analogous to NJDEP's Initial Threshold Screening Levels. https://dep.nj.gov/wp-content/uploads/dsr/njdep-pfoa-pfos-rfc-memo.pdf, https://dep.nj.gov/wp-content/uploads/dsr/hfpo-da-genx-tsd.pdf

[g] *New York State Department of Environmental Conservation (DEC) Short-Term Guideline Concentrations (SGC) and Annual Guideline Concentrations (AGC)* –AGCs are developed to protect the public health from the effects associated with long-term continuous, exposure to a contaminant. SGCs represent acute exposures on a one-hour basis. https://extapps.dec.ny.gov/docs/air_pdf/dar1.pdf

[h] *Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs), Inhalation Reference Values (ReVs), and RfCs* – TCEQ develops ESLs for air permitting. "ESLs are chemical-specific air concentrations set to protect human health and welfare. Short-term ESLs are based on data concerning acute health effects, the potential for odors to be a nuisance, and effects on vegetation, while long-term ESLs are based on data concerning chronic health and vegetation effects." The ESLs are screening levels. ReVs are used for air monitoring. "The ReV is a health-protective air concentration,

developed for chemicals with thresholds." "The ReV is used for air monitoring whereas the health-based ESL, which is 70% lower than the ReV, is used in air permitting."

"If predicted or measured airborne levels of a constituent do not exceed the screening level, adverse health or welfare effects would not be expected to result. If ambient levels of constituents in air exceed the screening level, it does not necessarily indicate a problem, but a more in-depth review is conducted." TCEQ has not set ReVs for the TACs described in this memo. TCEQ has also developed inhalation RfCs for select PFAS. https://www.tceq.texas.gov/downloads/toxicology/esl/special-notations.pdf, https://www.tceq.texas.gov/downloads/toxicology/monitoring/amcv/esls_amcvs.pdf, https://www.tceq.texas.gov/toxicology/dsd/dsds_about, https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf

[i] *Wisconsin* Department of Natural Resources (WDNR) Ambient Air Standard – WDNR sets ambient air standards for hazardous air pollutants based on short-term or annual health-based thresholds "protect people from air emissions that are known or suspected to cause cancer or other serious health problems." https://widnr.widen.net/view/pdf/n90lmcdhw9/AM405.pdf?t.download=true, https://docs.legis.wisconsin.gov/code/admin_code/nr/400/445.pdf#page=5

[j] *European Union's (EUs) European Chemicals Agency (ECHA) Derived No-Effect Level (DNEL)* – As a part of the EU's Registration, Evaluation, Authorisation, and Restriction of Chemical (REACH) regulation, chemical registrants need to provide chemical safety assessments for substances that are imported in a certain quantity. If a chemical has a threshold effect than a DNEL needs to be calculated representing "the level of exposure above which humans should not be exposed", and these can be based on worker or general population and short or long-term duration. https://academic.oup.com/annweh/article/59/4/416/2195991

[k] EPA Office of Pesticide Programs (OPP) Health Effects Division developed a memorandum for DCOI that identified RfDs and toxicological endpoints for inhalation for occupational exposure risk assessments. https://archive.epa.gov/pesticides/chemicalsearch/chemical/foia/web/pdf/128101/128101-034.pdf

[l] Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRL) – "An estimate of daily human exposure to a hazardous substances that is likely to be without an appreciable risk of adverse non-cancer health effects over a specified route and duration of exposure". Inhalation MRLs can be derived for acute, intermediate, and chronic exposures. https://www.atsdr.cdc.gov/mrls/index.html

[m] EPA Office of Research and Development (ORD) PPRTVs – "A toxicity derivation." value primarily derived for use in EPA's Superfund Program. PPRTVs are derived from a review of the relevant scientific literature using EPA methods, sources of data and guidance for value https://www.epa.gov/pprtv

The following sections of the memo contain tables that list the TRV options researched and collected by ERG. Rows shaded green in these tables signify the TRVs that DEQ selected for proposed use in DEQ's air quality programs.

4.1. 1-methylnaphthalene (CAS 90-12-0)

ERG identified both carcinogenic and non-carcinogenic inhalation TRVs for 1-methylnaphthalene from five different state agencies, ATSDR, and EPA. The identified values range from 0.003 µg/m^3 to 250 µg/m^3. Table 2 summarizes the identified TRVs for 1-methylnaphthalene.

Developmental or reproductive effects were not identified in any of the reviewed state TRV documentation nor in ATSDR's Toxicological Profile.

1-methylnaphthalene is not present on the Department of Transportation (DOT) list of inhalation hazards.

TABLE 2. INHALATION TRVS FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

State/Agency	TRV Type	TRV Value	Classification	DEQ Notes
Maryland DE	8-hour* Screening Level	2.91 µg/m^3	Non-cancer, chronic	Derived from Occupational
Michigan EGL	Annual ITSL	250 µg/m^3	Non-cancer, chronic	Older than selected non-cancer, chronic value
	Annual IRSL	0.14 µg/m^3	Cancer	Unmodified
	Annual SRSL	1.4 µg/m^3	Cancer	Older than selected acute value
New Hampshire DES	24-hr AAL	15 µg/m^3	Non-cancer, acute	Derived from Occupational
	Annual AAL	9.7 µg/m3	Non-cancer, chronic	Derived from Occupational
New York DEC	Annual AGC	7.1 µg/m3	Non-cancer, chronic	Derived from Occupational
Texas TCEQ	Short-term ESL	200 µg/m^3	Non-cancer, acute	Derived from Occupational
	Long-term ESL	20 µg/m^3	Non-cancer, chronic	Derived from Occupational
ATSDR	MRL	0.5 µg/m^3	Non-cancer, intermediate	Modified to eliminate days/week adjustment for acute TRV
EPA ORD PPRTV	Sub-chronic p-RfC	.03 µg/m^3	Non-cancer, sub-chronic	Doesn't match any categories for CAO TRVs
	Chronic p-RfC	.003 µg/m^3	Non-cancer, chronic	Unmodified

*Calculated from an occupational exposure limit that assumes an 8-hour workday and a 40-hour workweek

4.1.1. Maryland DE

TABLE 3. MARYLAND DE 8-HOUR SCREENING LEVEL FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
8-hour Screening Level	2.91 µg/m^3	Non-carcinogenic, 8-hour screening level. Calculated from a TLV-TWA, "for a conventional 8-hour workday and a 40-hour workweek"
Date	--	Calculated from an ACGIH TLV-TWA but year/date not provided.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	Calculated from an ACGIH TLV.
Critical study	--	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation?	--	No information on derivation.
Additional notes	ERG reached out to Maryland DE to obtain the Agency's current TRV values and their derivations. MDE responded by noting that the TRV was set by the ACGIH TLV. Other information was not provided. According to regulation: "If a toxic air pollutant (TAP) has a threshold limit value-time weighted average (TLV-TWA), divide the TLV-TWA by 100 to calculate an 8-hour time-weighted average screening level".	

Links to TRV Sources	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx https://www.law.cornell.edu/regulations/maryland/COMAR-26-11-16-03 (see email from MDE).

4.1.2. Michigan EGL

TABLE 4. MICHIGAN EGLE ITSL FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
ITSL	250 µg/m^3	Non-carcinogenic, annual screening level
Date	January 12, 2017	Originally derived on April 28, 2008, but updated the averaging time from the regulatory default of 24 hours to annual on January 12, 2017.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Derived from a chronic oral mouse study.	--
Critical study	Murata Y, Denda A, Maruyama H, and Konishi Y. 1993. Chronic Toxicity and Carcinogenicity Studies of 1-Methyl-naphthalene in B6C3F1 Mice. Fund Appl Toxidol 21:44-51. https://www.sciencedirect.com/science/article/abs/pii/S0272059083710705	Chronic oral mouse study. Same as used for IRSL/SRSL and by ATSDR to develop chronic *oral* MRL.
Species	Mouse	--
Target Organ	Respiratory system	And other (organ weights and hematology)
Description of TRV endpoints/ basis for points of departure (POD)	Pulmonary alveolar proteinosis, and changes in organ weights and hematology	Effects occurred at lowest dose of 71 mg/kg/day.
Other Endpoints	Peripheral blood changes including increased hemoglobin, mean corpuscular hemoglobin, albumin/globulin ratio, as well as significant organ weight changes for the brain, heart and thymus.	Male mice had a slight statistically increased incidence of alveolar/bronchiolar adenomas and adenocarcinomas. This cancer effect is used as the basis for the IRSL and SRSL.

Uncertainty Factors	Total UF = 1000	UF (sensitive individuals) = 10 UF (animal to human) = 10 UF (LOAEL to NOAEL) = 10
POD Method	LOAEL	RfD = 71 mg/kg/day / 1000 = 71 µg/kg/day, which is identical to ATSDR's chronic oral MRL based on the same study.
Human Equivalent Concentration in TRV?	No	--
Duration of exposure	81 weeks	ITSL originally assumed as 24 hour averaging time, but updated to annual based on 81 weeks.
Time Adjustment in TRV?	No	(see notes below)
Developmental or Reproductive Effects?	--	No mention of reproductive or developmental effects in TRV source document.
Oral to inhalation extrapolation?	Yes	Chronic ITSL calculated based on approach in R232(1)(b), which assumes a person breathing 20 m^3 a day and weighing 70 kg. ITSL = 71 µg/kg/day x (70kg/(20m^3/day)) = 248 µg/m^3 rounded to 250 µg/m^3. Originally this was applied to the statutory default of a 24hr averaging time, but this was then updated to apply to an annual averaging without changing the calculation.
Additional notes	In 2017 EGLE changed this TRV from applying to a 24-hour averaging time to an annual averaging time without changing the value of the TRV itself, so there was not a formal time adjustment in the calculation: "The averaging time (AT) assigned at that time was 24 hours, as per the default methodology (Rule 232(2)(b)). The current file review concludes that the AT may appropriately be set at annual, as the screening level is based on an 81 week feeding study in mice (Murata et al. 1993). Therefore, the AT is being changed from 24 hours to annual at this time."	
Links to TRV Sources	https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/AQD/toxics/screening-levels-alphabetical.pdf https://www.egle.state.mi.us/aps/downloads/ATSL/90-12-0/90-12-0_annual_ITSL.pdf https://casetext.com/regulation/michigan-administrative-code/department-environmental-quality/air-quality-division/part-2-air-use-approval/section-r-3361232-methodology-for-determining-initial-threshold-screening-level	

TABLE 5. MICHIGAN EGLE IRSL/SRSL FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
IRSL	0.14 µg/m^3 annual	IRSL based on increased cancer risk of one in one million (10^{-6}).
SRSL	1.4 µg/m^3 annual	SRSL based on increased cancer risk of one in one hundred thousand (10^{-5}).
Date	April 28, 2008	Originally derived on April 28, 2008. The ITSL was updated on January 12, 2017, but the IRSL/SRSL were not changed.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Derived from a chronic oral mouse study.	--
Critical study	Murata Y, Denda A, Maruyama H, and Konishi Y. 1993. Chronic Toxicity and Carcinogenicity Studies of 1-Methyl-naphthalene in B6C3F1 Mice. Fund Appl Toxidol 21:44-51. https://www.sciencedirect.com/science/article/abs/pii/S0272059083710705	Chronic oral mouse study. Same as used for ITSL and by ATSDR to develop chronic oral MRL.
Species	Mouse	--
Target Organ / Effect	Cancer	--
Description of TRV endpoints/basis for points of departure (POD)	Increased incidence of alveolar/bronchiolar adenomas and adenocarcinomas in male mice	A "slight, statistically significant" increase in incidence in Male mice.
Other Endpoints	Peripheral blood changes including increased hemoglobin, mean corpuscular hemoglobin, albumin/globulin ratio, as well as significant organ weight changes for the brain, heart and thymus.	These non-cancer effects are used as the basis for the ITSL.
Uncertainty Factors	--	--
POD Method	--	--
Human Equivalent Concentration in TRV?	Yes	See additional notes below.
Duration of exposure	81 weeks	--
Time Adjustment in TRV?	--	--

Oral to inhalation extrapolation	Yes	See additional notes below.
Additional notes	"The BMDS multistage - cancer model can be used to calculate the male mouse oral potency of $3.63x10^{-3}$ $(mg/kg)^{-1}$, which can be converted to the human oral potency of $2.33x10^{2}$ $(mg/kg)^{-1}$ by using body weight adjustment to the 3/4 power. The inhalation cancer potency can then be determined by converting the oral potency to the human inhalation potency of $6.7x10^{-6}$ $(\mu g/m3)^{-1}$ based on a 70 kg person breathing $20m^3$ a day. This inhalation potency will result in the IRSL being 0.14 $\mu g/m^3$ and the SRSL being 1.4 $\mu g/m^3$ with annual averaging."	
Links to TRV Sources	https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/AQD/toxics/screening-levels-alphabetical.pdf https://www.egle.state.mi.us/aps/downloads/ATSL/90-12-0/90-12-0_annual_ITSL.pdf https://casetext.com/regulation/michigan-administrative-code/department-environmental-quality/air-quality-division/part-2-air-use-approval/section-r-3361231-cancer-risk-assessment-screening-methodology	

4.1.3. New Hampshire DES

TABLE 6. NEW HAMPSHIRE DES AAL FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
24-Hour AAL	15 $\mu g/m^3$	24-hour ambient air limit
Annual AAL	9.7 $\mu g/m^3$	Annual ambient air limit
Date	November 11, 2009	Based on date regulation was amended to add 1-Methylnaphthalene: https://www.des.nh.gov/sites/g/files/ehbemt341/files/inline-documents/2022-03/AnnualToxListUpdate-2000to2022.pdf
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit modified with toxicity data from an oral toxicity study	Regulatory approach calls for setting the AAL based on modifying the ACGIH value based on other available toxicity data. See additional notes below.

Critical study	1) ACGIH OEL, 2) Dangerous Properties of Industrial Materials, N. Irving Sax. page 2268 (1996), cited in the Hazardous Substances Data Bank (HSDB), and 3) DHHS/ATSDR; Toxicological Profile for Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene p. 37, 39, 44 (1995). Cited in HSDB	ACGIH is used as basis of AAL, and the other two studies are used to determine acute and chronic toxicity values to set a 'Toxicity Factor' and 'Time Adjustment Factor' to modify the ACGIH value according to the regulatory formula. (See additional notes below)
Species	Rat, Mice	Rat study was used to determine acute toxicity and Mice study was used for chronic toxicity.
Target Organ	--	See comment in 'Description of TRV endpoints'
Description of TRV endpoints/ basis for points of departure (POD)	--	The underlying source for the old ACGIH OEL value used is not available. Death (LD50) was the endpoint in the acute rat study. Hematological changes were observed in the chronic mice study.
Other Endpoints	--	--
Uncertainty Factors	NH DES refers to a 'Safety Factor (SF)' of 71. A time adjustment factor is also applied of 4.2 for the annual AAL and 2.8 for the 24-hour AAL. (See below).	New Hampshire assigned 1-methylnaphthalene a 'Toxicity Factor (TF)' designation of Class II based on acute and chronic toxicity studies. A Class II TF corresponds to a 'Safety Factor (SF)' of 71.
POD Method	OEL	OEL = 2900 µg/m^3
Human Equivalent Concentration in TRV?	--	Not explicit in calculation from OEL.
Duration of exposure	--	Varies by study.

Time Adjustment in TRV?	Yes For the Annual AAL, NHDES adjusted the OEL by a factor of 4.2 = 24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week) For the 24-hour AAL, NHDES assigned 1-methylnaphthalene a 'Time Adjustment Factor (TAF)' based on regulatory criteria 'D,' which corresponds to a TAF of 2.8.	See formulas in 'additional notes' below.
Developmental or Reproductive Effects?	No	No mention of developmental or reproductive effects/studies.
Oral to inhalation extrapolation	No	Not explicit in calculation of TRV from OEL.
Additional notes	Calculation of AALs are shown below: <u>Annual AAL</u> = OEL / (4.2 * SF) = 2900 µg/m^3 / (4.2 * 71) = 2900 µg/m^3 / 298.2 = 9.73 µg/m^3 Where: 4.2 = (24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week). <u>24-hour AAL</u> = OEL / (SF * TAF) = 2900 µg/m^3 / (71 * 2.8) = 2900 µg/m^3 / (198.8) = 14.6 µg/m^3 Note the ACGIH OEL of 2,900 µg/m^3 appears outdated as the current ACGIH Threshold Limit Value (TLV) is 0.3 mg/m^3 (300 µg/m^3).	
Links to TRV Sources	https://www.des.nh.gov/air/industrial-sources/air-toxics-compliance https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/env-a-1400.pdf See email from New Hampshire DES for documentation of derivation.	

4.1.4. New York DEC

TABLE 7. NEW YORK DEC AGC FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
AGC	7.1 µg/m^3	Annual Guideline Concentration
Date	February 12, 2021	Date of Issue for: "Guidelines for the Evaluation and Control of Ambient Air Contaminants Under 6NYCRR Part 212"
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational exposure limit	Based on 2018 ACGIH's TLV-TWAs
Critical study	American Conference of Governmental Industrial Hygienists (ACGIH) 2018. Documentation of Threshold Limit Values and Biological Exposure Indices, 7th Edition – 2015 Supplement. Cincinnati, Ohio.	The 2018 ACGIH TLV used by NYDEC appears to be the same as the current TLV (300 µg/m3).
Species	Rat, Mice	Based on current ACGIH documentation.
Target Organ	Respiratory tract, Lung, Liver	Based on current ACGIH documentation.
Description of TRV endpoints/ basis for points of departure (POD)	Upper respiratory tract irritation, lung damage, liver effects	Based on current ACGIH documentation.
Other Endpoints	--	Other studies reference skin and eye irritation in ACIGH documentation.

Uncertainty Factors	UF of 42 (inferred).	The UF is defined in regulation by the 'toxicity level', which can be High, Moderate, or Low. The UF is 420 for Medium or High toxicity substances and 42 for Low toxicity substances. (See additional notes). No toxicity level is explicitly defined by NYDOH for 1-methylnaphthlane; however, based on the current ACGIH value of 300 µg/m^3, and uncertainty factor of 42 is likely used to derive the AGC of 7.1 µg/m^3.
POD Method	--	Unclear POD method for ACGIH derivation.
Human Equivalent Concentration in TRV?	Not explicit in NYDE calculation.	Unclear on human equivalent concentration used in ACGIH derivation.
Duration of exposure	--	Unclear on duration of exposure from ACGIH derivation.
Time Adjustment in TRV?	Yes	The uncertainty factors are based on adjusting the 8-hr work day exposure to a 24-hr exposure and a 5-day work week to 7-day exposure.
Developmental or Reproductive Effects?	No	No developmental or reproductive effects listed in current ACGIH documentation.
Oral to inhalation extrapolation	No	--
Additional notes	"AGCs are calculated by starting with the TLV for an air contaminant and adjusting it by an uncertainty factor. The uncertainty factor for a chemical classified as HIGH or MODERATE toxicity is 420. The uncertainty factor for a chemical classified as LOW toxicity is 42. The uncertainty factors are based on adjusting the 8-hr work day exposure to a 24-hr exposure and a 5-day work week to 7-day exposure, and by applying an additional factor of 10 for LOW toxicity or 100 for MODERATE and HIGH toxicity contaminants to compensate for applying an occupational standard to the general population."	
Links to TRV Sources	https://dec.ny.gov/environmental-protection/air-quality/controlling-pollution-from-facilities/air-toxics-program https://dec.ny.gov/docs/air_pdf/dar1.pdf	

4.1.5. Texas TCEQ

TABLE 8. TEXAS TCEQ SHORT AND LONG-TERM ESLS FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
Short-Term ESL	200 µg/m^3	Short-Term defined as one hour
Long-Term ESL	20 µg/m^3	Long-Term defined as 70 years
Date	November 17, 2014	
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit (OEL)	TRV derived from "Russia OEL" of 20 mg/m^3.
Critical study	Russian OEL	Original source of Russia OEL was not available.
Species	--	--
Target Organ	--	--
Description of TRV endpoints/ basis for points of departure (POD)	--	--
Other Endpoints	--	--
Uncertainty Factors	--	--
POD Method	--	--
Human Equivalent Concentration in TRV?	--	--
Duration of exposure	--	--
Time Adjustment in TRV?	--	--
Developmental or Reproductive Effects?	No	No mention of developmental or reproductive studies.
Oral to inhalation extrapolation	--	
Additional notes	Values are "Interim." which "indicates that the ESL is current and will be reviewed by the Toxicology Division at a later date. Also, interim ESLs may be updated pending the release of updated toxicity information or odor data." Same source and values as 2-methylnaphthalene. The TRV documentation has the following note: "ATSDR groups naphthalene and 1- and 2-methylnaphthalene together in it's Tox Profile, no inhalation data is available for 1-methylnaphthalene, but LD50 is much higher than for naphthalene, surrogating would raise ESLs significantly, ACGIH based it's values on an RD50, which does not follow with the TCEQ guidelines, to be conservative, use Russia's OEL to calculate ESLs."	
Links to TRV Sources	TAMIS database -> Start Report -> Tox Document Report -> Next -> Create Report for CAS number 90-12-0: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.1.6. ATSDR

TABLE 9. ATSDR MRL FOR 1-METHYLNAPHTHALENE (CAS 90-12-0)

Variable	Value	Comment
MRL	$9x10^{-5}$ ppm (0.5 µg/m^3)	Provisional intermediate exposure MRL
Date	May 2024	Updated draft Tox Profile released over the course of this project.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation toxicity study	--
Critical study	Kim YS, Lee MJ, Seo DS, Kim TH, Kim MH, Lim CH. Thirteen-week inhalation toxicity study of 1-methylnaphthalene in F344 rats. Toxicol Res. 2019 Nov 26;36(1):13-20. doi: 10.1007/s43188-019-00009-1.	Same study as PPRTV RfCs https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6990237/
Species	Rat	--
Target Organ / Effect	Respiratory tract	--
Description of TRV endpoints/basis for points of departure (POD)	Nasal mucous cell hyperplasia	--
Other Endpoints	Significant increase in activated partial thromboplastin time (APTT) and prothrombin time (PT); significant serum increases of albumin (4%) and sodium (1%); transitional epithelial cell hyperplasia (males only)	--
Uncertainty Factors	UF = 3 x 10 = 30	UF (animal to human) = 3 UF (sensitive individuals) = 10
POD Method	$BMCL_{HEC}$	$BMCL_{10}$ = 0.06 ppm $BMCL_{HEC}$ = 0.0027 ppm

Human Equivalent Concentration in TRV?	"The critical effects of 1-methylnaphthalene were nasal lesions, therefore, the BMCL10ADJ was converted to a HEC by multiplying the BMCL10 by the rat-specific regional gas dose ratio that corresponds with the extrathoracic region (RGDRET). This RGDRET is calculated using the following equation as defined by EPA (1994):" $RGDR_{ET} = (V_{Ea} / SA_a) / (V_{Eh} / SA_h)$ = (0.254/15) / (13.8/200) = 0.25 $BMCL_{HEC} = BMCL_{10ADJ}$ x RGDR = 0.011ppm x 0.25 = 0.0027ppm	$RGDR_{ET}$ = Rat-specific regional gas dose ratio that corresponds with the extrathoracic region V_{eA} = ventilation rate for male F344 rats = 0.254 L/minute (EPA 2012) V_{eH} = ventilation rate for humans = 13.8 L/minute (EPA 1994) SA_a = surface area of the extrathoracic region in rats = 15 cm^2 (EPA 1994) SA_h = surface area of the extrathoracic region in humans = 200 cm^2 (EPA 1994 See Time Adjustment in TRV for calculation of chronic BMCL from intermittent BMCL
Duration of exposure	6 hours/day for 5 days/week for 13 weeks	--
Time Adjustment in TRV?	$BMCL_{10adj}$ = BMCL * 6 hours / 24 hours * 5 days/ 7 days = 0.6ppm * 6/24 * 5/7 = 0.011ppm	--
Oral to inhalation extrapolation	No	--
Additional notes	MRL = $BMCL_{HEC}$ / UFs MRL = 0.0027 ppm / (3x10) = 0.00009 ppm ($9x10^{-5}$ ppm)	
Links to TRV Sources	https://www.atsdr.cdc.gov/toxprofiles/tp67.pdf	

4.1.7. EPA ORD PPRTV

TABLE 10. EPA PPRTV FOR 1-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
PPRTV sub-chronic p-RfC	3×10^{-5} mg/m^3 (0.03 µg/m^3)	Provisional sub-chronic reference concentration
PPRTV chronic p-RfC	3×10^{-6} mg/m^3 (0.003 µg/m^3)	Provisional chronic reference concentration
Date	March 2024	--

Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation toxicity study	--
Critical study	Kim, YS; Lee, MJ; Seo, DS; Kim, TH; Kim, MH; Lim, CH. (2020). Thirteen-week inhalation toxicity study of 1-methylnaphthalene in F344 rats. Toxicological Research 36: 13-20.	Same study as ATSDR MRLs https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6990237/
Species	Rat	--
Target Organ / Effect	Respiratory tract	--
Description of TRV endpoints/basis for points of departure (POD)	Nasal mucous cell hyperplasia	--
Other Endpoints	Transitional epithelial cell hyperplasia in nasopharyngeal tissues	--
Uncertainty Factors	**Sub-chronic:** 3 x 10 x 10 = 300 **Chronic:** 3 x 10 x 10 x 10= 3,000	**Sub-chronic and Chronic:** interspecies uncertainty factor [UFA] of 3, a database uncertainty factor [UFD] of 10, and an intraspecies uncertainty factor [UFH] of 10 **Chronic only:** subchronic to chronic uncertainty factor [UFS] of 10
POD Method	$BMCL_{10}$ (HEC_{ET})	$BMC_{10}(HEC_{ET})$ = 0.018 mg/m3 $BMCL_{10}(HEC_{ET})$ = 0.009 mg/m3 BMC_{10} = 10% benchmark concentration; $BMCL_{10}$ = The 10% benchmark concentration lower confidence limit HEC_{ET} = human equivalent concentration based on extrathoracic effects

Human Equivalent Concentration in TRV?	HEC_{ET} of 0.009 mg/m^3 "HEC_{ET} values are calculated by treating 1-methylnaphthalene as a Category 1 gas and using the following equation from U.S. EPA (1994): HEC = exposure level (mg/m^3) × (hours/day exposed ÷ 24 hours) × (days/week exposed ÷ 7 days) × RGDR" RGDR = regional gas dose ratio (animal:human);	LOAEL = 3.0 mg/m3 $RGDR_{ET}$ values of 0.184, 0.183, and 0.182 for males and 0.121, 0.120, and 0.117 for females in the low-, mid-, and high-dose groups, respectively, were calculated as per U.S. EPA (1994) using default values for human VE and human and animal respiratory tissue surface area and animal VE values calculated using study-specific TWA body-weight values of 0.268, 0.266, and 0.265 kg for low-, mid-, and highdose males, respectively, and 0.161, 0.160, and 0.154 kg for low, mid-, and high-dose females, respectively, determined for this review.
Duration of exposure	6 hours/day, 5 days/week for 13 weeks	--
Time Adjustment in TRV?	Imeddedin HEC_{ET} formula above.	Subchronic to chronic UF also applied.
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	No	
Additional notes	"No chronic inhalation studies were identified for 1-methylnaphthalene. In the absence of available chronic inhalation studies, the POD from the subchronic study by Kim et al. (2020) was selected as a suitable basis for the chronic p-RfC." **Subchronic p-RfC** = POD (HEC_{ET}) ÷ UFC = 0.009 mg/m^3 ÷ 300 = 3×10^{-5} mg/m^3 (0.03 $\mu g/m^3$) "Confidence in the subchronic p-RfC for 1-methylnaphthalene is low" **Chronic p-RfC** = POD (HEC_{ET}) ÷ UFC = 0.009 mg/m^3 ÷ 3,000 = 3×10^{-6} mg/m^3 (0.003 $\mu g/m^3$) "Confidence in the chronic p-RfC for 1-methylnaphthalene is low"	
Links to TRV Sources	https://hhpprtv.ornl.gov/issue_papers/Methylnaphthalene1.pdf	

4.2. 2-methylnaphthalene (CAS 91-57-6)

ERG identified non-carcinogenic health-based screening values for 2-methylnaphtalene. The identified values come from six different state agencies and ATSDR and range from 9.7 to 200 µg/m^3. Cancer screening values were not identified.

Developmental or reproductive effects were not identified in any of the reviewed state TRV documentation nor in ATSDR's Toxicological Profile.

2-methylnaphthalene is not present on the DOT list of inhalation hazards.

TABLE 11. INHALATION TRVS FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

State/Agency	TRV	TRV	Classification	DEQ Notes
Maryland DE	8-hour* Screening Level	2.91 µg/m^3	Non-cancer, chronic	Derived from occupational
Massachusetts DEP	24-hr TEL	14.25 µg/m^3	Non-cancer, acute	Derived from occupational
	Annual AAL	14.25 µg/m^3	Non-cancer, chronic	Derived from occupational
Michigan EGL	Annual ITSL	10 µg/m^3	Non-cancer, chronic	Derived from LC50
New Hampshire DES	24-hr AAL	15 µg/m^3	Non-cancer, acute	Derived from occupational
	Annual AAL	9.7 µg/m^3	Non-cancer, chronic	Derived from occupational
New York DEC	Annual AGC	7.1 µg/m^3	Non-cancer, chronic	Derived from occupational
Texas TCEQ	Short-term ESL	200 µg/m^3	Non-cancer, acute	Derived from occupational
	Long-term ESL	20 µg/m^3	Non-cancer, chronic	Derived from occupational
ATSDR	MRL	2 µg/m^3	Non-cancer, intermediate	Modified to remove days/week adjustment for acute TRV

*Calculated from an occupational exposure limit that assumes an 8-hour workday and a 40-hour workweek

4.2.1. Maryland DE

TABLE 12. MARYLAND DE 8-HOUR SCREENING LEVEL FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
8-hour Screening Level	2.91 µg/m^3	Non-carcinogenic, 8-hour screening level. Calculated from a TLV-TWA, "for a conventional 8-hour workday and a 40-hour workweek"

Date	--	Calculated from an ACGIH TLV but year/date not provided.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	Calculated from an ACGIH TLV.
Critical study	--	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation?	--	No information on derivation.
Additional notes	ERG reached out to Maryland DE to obtain the Agency's current TRV values and their derivations. MDE responded by noting that the TRV was set by the ACGIH TLV. Other information was not provided. According to regulation: "If a toxic air pollutant (TAP) has a threshold limit value-time weighted average (TLV-TWA), divide the TLV-TWA by 100 to calculate an 8-hour time-weighted average screening level".	
Links to TRV Sources	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx https://www.law.cornell.edu/regulations/maryland/COMAR-26-11-16-03 (see email from MDE).	

4.2.2. Massachusetts DEP

TABLE 13. MASSACHUSETTS DEP TEL/AAL FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
TEL and AAL	14.25 µg/m^3	Set to same value as naphthalene.

Date	February 1990	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit modified by other factors	Regulatory approach calls for identifying a "Most Appropriate Occupational Exposure Limit (MAOL)" and modifying the value based on other available toxicity data.
Critical study	ACGIH	The source of MAOL is an ACGIH citation from 1987 for Naphthalene.
Species	--	No information ACGIH 1987 derivation.
Target Organ	--	No information ACGIH 1987 derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information ACGIH 1987 derivation.
Other Endpoints	--	Severity factor = Moderate to severe irritant effects

Uncertainty Factors	Yes, multiple 'adjustment factors' Occupational Exposure > Environmental Exposure = 4.2 Derived by converting a 40-hr. workweek occupational exposure to a 168-hr. week continuous environmental exposure (168 hr./40 hr. = 4.2). Adult > Child 1.75 Derived by converting an exposure based on the adult average body weight (70 kg.) and ventilation volume (20 m^3 /24 hrs.) to an exposure based on the child average body weight (20 kg.) and ventilation volume (10 m^3 /24 hrs.) (10 m^3 /24 hrs.) (70 kg.) (20 m^3 /24 hrs.) (20 kg.) = 1.75 Occupational Population > High Risk Group (intraspecies variability) 10 Uncertainty factor to extrapolate from an occupational population to high risk groups in the general population. Tox factor 1-10 Uncertainty factor to compensate for inadequacies or limitations in the toxicity data used to set MAOL. 10 Is used here. A relative source contribution factor of 20% is also included to account for exposures to given contaminants from sources other than air. Multiply by 0.2 produces the TEL (Threshold Effects Exposure Limit.)	MAOL divided by adjustment factors = "Adjusted MAOL". Based on the amount, type, and quality of the data available (and SAR analysis), uncertainty factors called Nonthreshold Effects Uncertainty Factors (NTEUF) are applied to the adjusted MAOL to arrive at an acceptable nonthreshold effects exposure limit (NTEL). Further adjusted to produce a Threshold Effects Exposure Limit.
POD Method	OEL	MAOL = 10 mg/m^3 for Naphthalene
Human Equivalent Concentration in TRV?	--	No information available from ACGIH 1987 derivation.
Duration of exposure	--	No information available from ACGIH 1987 derivation.
Time Adjustment in TRV?	Yes	OEL occupational exposure adjusted to continuous exposure (see UF above).

Developmental or Reproductive Effects?	No	Considered but none identified.
Oral to inhalation extrapolation	No	Not explicit in calculation of TRV from OEL.
Additional notes	Calculation of AAL shown below: Adjusted MAOL = MAOL / (4.2 * 1.75 * 10) = 52.37 mg/m^3 / (4.2 * 71) = 71.25 µg/m3 (13.61 ppb) *Where: 4.2 = Continuous time adjustment* *And 1.75 = Adult to child adjustment* TEL = Adjusted MAOL * 0.2 = 71.25 µg/m3 * 0.2 = 14.25 µg/m3 (13.61 ppb) AAL = TEL since there are no carcinogenic concerns. MAOL = 52.37 mg/m^3 (10ppm) *Appears to be set based on ACGIH values for Naphthalene.*	
Links to TRV Sources	https://www.mass.gov/doc/the-chemical-health-effects-assessment-methodology-the-method-to-derive-allowable-ambient-0 https://www.mass.gov/doc/methodology-for-updating-guidelines-allowable-ambient-limits-threshold-effect-exposure/download https://www.mass.gov/info-details/massdep-ambient-air-toxics-guidelines	

4.2.3. Michigan EGLE

TABLE 14. MICHIGAN EGLE ITSL FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
ITSL	10 µg/m^3	Non-carcinogenic, annual screening level
Date	December 30, 2002	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Derived from a short-term (4-hour) inhalation rat study.	--

Critical study	Korsak et al., 1998. Toxic effects of acute inhalation exposure to 1-MN and 2-MN in experimental animals. Int J Occup Med Environ Health 11: 335-342.	https://pubmed.ncbi.nlm.nih.gov/10028200/
Species	Rat	--
Target Organ	Death (LC50)	--
Description of TRV endpoints/ basis for points of departure (POD)	Death	Regulatory LC50 formula used with highest concentration where no deaths were observed.
Other Endpoints	Rotarod performance, paw sensitivity to heat (a measure of analgesia) and changes in respiration rate	--
Uncertainty Factors	--	See note below
POD Method	LC50 (highest concentration where no deaths occurred)	No deaths occurred at the highest concentration, which was used in an LC50 formula.
Human Equivalent Concentration in TRV?	No	--
Duration of exposure	4 hours	--
Time Adjustment in TRV?	No	--
Developmental or Reproductive Effects?	No direct mention of developmental or reproductive effects in TRV document.	20% growth retardation noted at high doses by Murata et al., 1993
Oral to inhalation extrapolation	No	
Additional notes	ITSL calculated based on approach in R232(1)(f): ITSL = 527 mg/m^3 / (500 * 100) = 10 µg/m^3 with annual averaging. Highest concentration, which had no deaths was used in place of LC50. Note: it is not clear what uncertainty factors the 500 and 100 represent but this is the formula written into regulation when using LC50. 24-hour ITSL was also calculated based on Murata et al., 1993 (used for 1-methylnaphthalene), but was deemed inappropriate given it would exceed the 24-hour particulate matter NAAQS.	

Links to TRV Sources	https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/AQD/toxics/screening-levels-alphabetical.pdf https://www.egle.state.mi.us/aps/downloads/ATSL/91-57-6/91-57-6_annual_ITSL.pdf https://casetext.com/regulation/michigan-administrative-code/department-environmental-quality/air-quality-division/part-2-air-use-approval/section-r-3361232-methodology-for-determining-initial-threshold-screening-level

4.2.4. New Hampshire DES

TABLE 15. NEW HAMPSHIRE DES 24-HOUR AND ANNUAL AAL FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
24-Hour AAL	15 µg/m^3	24-hour ambient air limit
Annual AAL	9.7 µg/m^3	Annual ambient air limit
Date	1996	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit modified with toxicity data from an oral toxicity study	Regulatory approach calls for setting the AAL based on modifying the ACGIH value based on other available toxicity data. See additional notes below.
Critical study	1) ACGIH OEL, 2) Dangerous Properties of Industrial Materials, N. Irving Sax. page 2268 (1996), cited in the Hazardous Substances Data Bank (HSDB) 3) EPA IRIS	Regulatory approach calls for setting the AAL based on modifying the ACGIH value based on other available toxicity data. See additional notes below. "The compound has a reference dose (RfD) listed on the USEPA's Integrated Risk Information System (IRIS) with a critical effect of pulmonary alveolar proteinosis."
Species	Rat	Rat study was used to determine acute toxicity. IRIS was used for chronic toxicity.
Target Organ	--	See comment in 'Description of TRV endpoints'

Description of TRV endpoints/ basis for points of departure (POD)	--	The underlying source for the old ACGIH OEL value used is not available. Death (LD50) was the endpoint in the acute rat study. Pulmonary alveolar proteinosis was the critical effect identified in IRIS.
Other Endpoints	--	--
Uncertainty Factors	Annual Combined UF = 71 24-hour Combined UF = 198.8 (see formula below)	New Hampshire assigned 2-methylnaphthalene a Toxicity Factor = II and Time Adjustment Factor = D which correspond to SF = 71 and TAF = 2.8.
POD Method	OEL	OEL = 2900 µg/m^3
Human Equivalent Concentration in TRV?	--	Not explicit in calculation from OEL.
Duration of exposure	--	Varies by study.
Time Adjustment in TRV?	Yes For the Annual AAL, NHDES adjusted the OEL by a factor of 4.2 = 24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week) For the 24-hour AAL, NHDES assigned 1-methylnaphthalene a 'Time Adjustment Factor (TAF)' based on regulatory criteria 'D,' which corresponds to a TAF of 2.8.	See formulas in 'additional notes' below.
Developmental or Reproductive Effects?	No	No mention of developmental or reproductive effects/studies.
Oral to inhalation extrapolation	No	Not explicit in calculation of TRV from OEL.

Additional notes	Calculation of AALs is shown below: Annual AAL = OEL / (4.2 * SF) = 2900 µg/m^3 / (4.2 * 71) = 2900 µg/m^3 / 298.2 = 9.73 µg/m^3 Where: 4.2 = (24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week). 24-hour AAL = OEL / (SF * TAF) = 2900 µg/m^3 / (71 * 2.8) = 2900 µg/m^3 / (198.8) = 14.6 µg/m^3 Note the ACGIH OEL of 2,900 µg/m^3 appears outdated as the current ACGIH Threshold Limit Value (TLV) is 0.3 mg/m^3 (300 µg/m^3). Same calculation as 1-methylnaphthalene.
Links to TRV Sources	https://www.des.nh.gov/air/industrial-sources/air-toxics-compliance https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/env-a-1400.pdf See email from New Hampshire DES for documentation of derivation.

4.2.5. New York DEC

TABLE 16. NEW YORK DEC AGC FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
AGC	7.1 µg/m^3	Annual Guideline Concentration
Date	February 12, 2021	Date of Issue for: "Guidelines for the Evaluation and Control of Ambient Air Contaminants Under 6NYCRR Part 212"

Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational exposure limit	Based on 2018 ACGIH's TLV-TWAs
Critical study	American Conference of Governmental Industrial Hygienists (ACGIH) 2018. Documentation of Threshold Limit Values and Biological Exposure Indices, 7th Edition – 2015 Supplement. Cincinnati, Ohio.	The 2018 ACGIH TLV used by NYDEC appears to be the same as the current TLV (300 µg/m3).
Species	Rat, Mice	Based on current ACGIH documentation.
Target Organ	Respiratory tract, Lung, Liver	Based on current ACGIH documentation.
Description of TRV endpoints/ basis for points of departure (POD)	Upper respiratory tract irritation, lung damage, liver effects	Based on current ACGIH documentation.
Other Endpoints	--	Other studies reference skin and eye irritation in ACIGH documentation.
Uncertainty Factors	UF of 42 (inferred).	The UF is defined in regulation by the 'toxicity level', which can be High, Moderate, or Low. The UF is 420 for Medium or High toxicity substances and 42 for Low toxicity substances. (See additional notes). No toxicity level is explicitly defined by NYDOH for 1-methylnaphthlanee; however, based on the current ACGIH value of 300 µg/m^3, and uncertainty factor of 42 is likely used to derive the AGC of 7.1 µg/m^3.
POD Method	--	Unclear POD method for ACGIH derivation.
Human Equivalent Concentration in TRV?	Not explicit in NYDE calculation.	Unclear on human equivalent concentration used in ACGIH derivation.
Duration of exposure	--	Unclear on duration of exposure from ACGIH derivation.

Time Adjustment in TRV?	Yes	The uncertainty factors are based on adjusting the 8-hr workday exposure to a 24-hr exposure and a 5-day work week to 7-day exposure.
Developmental or Reproductive Effects?	No	No developmental or reproductive effects listed in current ACGIH documentation.
Oral to inhalation extrapolation	No	--
Additional notes	"AGCs are calculated by starting with the TLV for an air contaminant and adjusting it by an uncertainty factor. The uncertainty factor for a chemical classified as HIGH or MODERATE toxicity is 420. The uncertainty factor for a chemical classified as LOW toxicity is 42. The uncertainty factors are based on adjusting the 8-hr work day exposure to a 24-hr exposure and a 5-day work week to 7-day exposure, and by applying an additional factor of 10 for LOW toxicity or 100 for MODERATE and HIGH toxicity contaminants to compensate for applying an occupational standard to the general population." Same source and values as 1-methylnaphthalene.	
Links to TRV Sources	https://dec.ny.gov/environmental-protection/air-quality/controlling-pollution-from-facilities/air-toxics-program https://dec.ny.gov/docs/air_pdf/dar1.pdf	

4.2.6. Texas TCEQ

TABLE 17. TEXAS TCEQ SHORT- AND LONG-TERM ESL FOR 2- METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
Short-Term ESL	200 µg/m^3	Short-Term defined as one hour
Long-Term ESL	20 µg/m^3	Long-Term defined as 70 years
Date	November 17, 2014	
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit (OEL)	TRV derived from "Russia OEL" of 20 mg/m^3.
Critical study	Russian OEL	Original source of Russia OEL was not available.
Species	--	--
Target Organ	--	--
Description of TRV endpoints/ basis for points of departure (POD)	--	--

Other Endpoints	--	--
Uncertainty Factors	--	--
POD Method	--	--
Human Equivalent Concentration in TRV?	--	--
Duration of exposure	--	--
Time Adjustment in TRV?	--	--
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	--	
Additional notes	Values are "Interim." which "indicates that the ESL is current and will be reviewed by the Toxicology Division at a later date. Also, interim ESLs may be updated pending the release of updated toxicity information or odor data." Same source and values as 2-methylnaphthalene. The TRV documentation has the following note: "ATSDR groups naphthalene and 1- and 2-methylnaphthalene together in it's Tox Profile, no inhalation data is available for 1-methylnaphthalene, but LD50 is much higher than for naphthalene, surrogating would raise ESLs significantly, ACGIH based it's values on an RD50, which does not follow with the TCEQ guidelines, to be conservative, use Russia's OEL to calculate ESLs."	
Links to TRV Sources	TAMIS database -> Start Report -> Tox Document Report -> Next -> Create Report for CAS number 90-12-0: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.2.7. ATSDR

TABLE 18. ATSDR MRL FOR 2-METHYLNAPHTHALENE (CAS 91-57-6)

Variable	Value	Comment
MRL	2 µg/m^3 (3x10^{-4} ppm)	Provisional Intermediate exposure MRL
Date	May 2024	Updated draft Tox Profile released over the course of this project.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation toxicity study	--

Critical study	Swiercz R, Wąsowicz W, Stetkiewicz J, Gromadzińska J, Majcherek W. 4-Week inhalation toxicity of 2-methylnaphthalene in experimental animals. Int J Occup Med Environ Health. 2011 Dec;24(4):399-408. doi: 10.2478/s13382-011-0036-9.	--
Species	Rat	--
Target Organ / Effect	Respiratory system	--
Description of TRV endpoints/basis for points of departure (POD)	Bronchial goblet cell metaplasia	--
Other Endpoints	Serum chemistry changes, reduced relative weight of liver, heart, kidne.	--
Uncertainty Factors	UF = 3 x 10 x 10 = 300	UF (animal to human) = 3 UF (sensitive humans) = 10 UF (use of LOAEL) = 10
POD Method	$LOAEL_{HEC}$	LOAEL = 0.34 ppm $LOAEL_{adj}$ = 0.061 ppm (time adjustment) $LOAEL_{HEC}$ = 0.081 ppm
Human Equivalent Concentration in TRV?	$RGDR_{TB} = \frac{(Dose_{TB})_a}{(Dose_{TB})_h} = \frac{(\frac{V_E}{SA_{tb}})_a}{(\frac{V_E}{SA_{tb}})_h} \frac{(e^{\frac{-SA_{et}}{V_E}})_a}{(e^{\frac{-SA_{et}}{V_E}})_h}$ $RGDR_{TB}$ = 1.33 $LOAEL_{HEC}$ = $LOAEL_{ADJ}$ x RGDR = 0.061 ppm x 1.33 = 0.081 ppm	**$RGDR_{TB}$** = Rat-specific regional gas dose ratio that corresponds with the tracheobronchial effect **ET** = Extrathoracic **TB** = Tracheobronchial **$[V_E]_a$** = minute volume for rats = 0.141 L/min **$SA_{TB\ a}$** = TB surface area for rats = 22.5 cm^2 **$e^{-(SAet/Ve)}{}_a$** = Fraction of chemical concentration penetrating the ET region and available for uptake in the TB region in rats = 0.899 **$[V_E]_a$** = minute volume for humans = 13.8 L/min **$SA_{TB\ h}$** = TB surface area for humans = 3200 cm^2 **$e^{-(SAet/Ve)}{}_h$** = Fraction of chemical concentration penetrating the ET region and available for uptake in the TB region in humans = 0.986
Duration of exposure	6 hours/day, 5 days/week for 4 weeks	

Time Adjustment in TRV?	LOAELadj = LOAEL * 6hr/24hr * 5day/7days = 0.061ppm	--
Developmental or Reproductive Effects?	No	Considered but none identified.
Oral to inhalation extrapolation	No	
Additional notes	MRL = $LOAEL_{HEC}$ / UFs = 0.081 ppm / (3x10x10) ≈ 0.0003 ppm (0.002 mg/m^3)	
Links to TRV Sources	https://www.atsdr.cdc.gov/toxprofiles/tp67.pdf	

4.3. Copper naphthenate (CAS 1338-02-9)

ERG identified non-carcinogenic health-based screening values for copper naphthenate. The identified values come from two different state agencies and ECHA. Values from Maryland DE and ECHA range from 26.558 µg/m^3 to 1,940 µg/m^3. TCEQ uses particulate matter national ambient air quality standards (NAAQS) as a surrogate for its TRVs for copper naphthenate. Cancer screening values were not identified.

Developmental and reproductive effects were not identified for copper naphthenate.

Copper naphthenate is not present on the DOT list of inhalation hazards.

TABLE 19. INHALATION TRVS FOR COPPER NAPHTHENATE (CAS 1338-02-9)

State/Agency	TRV	TRV	Classification	DEQ Notes
Maryland DE	8-hour* Screening Level	26.558 µg/m^3	Non-cancer, chronic	Derived from occupational
Texas TCEQ	Short-Term ESL	Must meet NAAQs**	Non-cancer, acute	No values listed but they apply their toxicity information for copper and compounds to this TAC
	Long-Term ESL	Must meet NAAQs**	Non-cancer, chronic	No values listed but they apply their toxicity information for copper and compounds to this TAC
ECHA	Occupational Long-Term DNEL	1,940 µg/m^3 (1.94 mg/m^3)	Non-cancer, chronic	Based on copper toxicity – not copper

				naphthenate specifically
	General Population Long-Term DNEL	380 µg/m^3 (0.38 mg/m^3)	Non-cancer, chronic	Based on copper toxicity – not copper

** Calculated from an occupational exposure limit that assumes an 8-hour workday and a 40-hour workweek

*See Texas subsection

DEQ does not propose to use any of the values listed in the table above, but DEQ does propose to apply the TRV for copper and copper compounds to this TAC (i.e. use copper and compounds as a surrogate for copper naphthenate) like TCEQ and ECHA did.

4.3.1. Maryland DE

TABLE 20. MARYLAND DE 8-HOUR SCREENING LEVEL FOR COPPER NAPHTHENATE (CAS 1338-02-9)

Variable	Value	Comment
8-hour Screening Level	26.558 µg/m^3	Non-carcinogenic, 8-hour screening level. Calculated from a TLV-TWA, "for a conventional 8-hour workday and a 40-hour workweek"
Date	--	Calculated from an ACGIH TLV but year/date not provided.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	Calculated from an ACGIH TLV.
Critical study	--	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.

Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation?	--	No information on derivation.
Additional notes	ERG reached out to Maryland DE to obtain the Agency's current TRV values and their derivations. MDE responded by noting that the TRV was set by the ACGIH TLV. Other information was not provided. According to regulation: "If a toxic air pollutant (TAP) has a threshold limit value-time weighted average (TLV-TWA), divide the TLV-TWA by 100 to calculate an 8-hour time-weighted average screening level".	
Links to TRV Sources	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx https://www.law.cornell.edu/regulations/maryland/COMAR-26-11-16-03 (see email from MDE).	

4.3.2. Texas TCEQ

On September 4, 2015, TCEQ assigned the National Ambient Air Quality Standards for particulate matter as a "surrogate" for copper naphthenate's short-term and long-term ESL. ERG emailed TCEQ to request additional information, but TCEQ was unable to provide additional information on this derivation.

A list of the TCEQ ESLs with this information can be found as a download here: https://www.tceq.texas.gov/toxicology/esl/ESLMain.html

4.3.3. ECHA

TABLE 21. ECHA OCCUPATIONAL AND GENERAL POPULATION DNELS FOR COPPER NAPHTHENATE (CAS 1338-02-9)

Variable	Value	Comment
Occupational Long-term DNEL	1,940 µg/m^3 (1.94 mg/m^3)	Derived No Effect Level
General Population Long-term DNEL	380 µg/m^3 (0.38 mg/m^3)	Derived No Effect Level
Date	December 12, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Subacute inhalation toxicity study of CuO_2	--

Critical study	Kirkpatrick D. 2010. A four-week inhalation toxicity study of cuprous oxide in Sprague-Dawley rats with a time course evaluation and a 13-week recovery evaluation. WIL Research Labs, LLC. WIL-708003.	--
Species	Rat	--
Target Organ	Lungs / Immune System	--
Description of TRV endpoints/ basis for points of departure (POD)	CuO_2: Macrophages in the lungs	--
Other Endpoints	CuO_2: increase in neutrophils, lactate dehydrogenase and protein in bronchoalveolar lavage fluid; lung inflammation	--
Assessment Factors	Yes but unclear which factors were applied for derivation of DNEL	--
POD Method	NOAEL	LOEL = 0.2 mg/m³ air NOAEL = ≥ 2.0 mg/m³ air
Human Equivalent Concentration in TRV?	--	Possibly through UF but unclear from documentation
Duration of exposure	6 hours per day for 28 days	--
Time Adjustment in TRV?	--	Possibly through UF but unclear from documentation
Developmental or Reproductive Effects?	No	
Oral to inhalation extrapolation	No	
Additional notes	Documentation and derivation are not clear.	
Links to TRV Sources	https://chem.echa.europa.eu/100.014.234/dossier-view/34645ba5-9f80-4c4d-ab7f-e91be436bfab/ee5b248e-e326-4c2e-8927-e4047c2a135a_b8679f61-6287-414e-8c3e-6b6b01ba21aa https://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf/e153243a-03f0-44c5-8808-88af66223258	

4.4. 4,5-Dichloro-2-octyl-3(2H)-isothiazolone (DCOI) (CAS 64359-81-5)

ERG identified non-carcinogenic health-based screening values for 4,5-Dichloro-2-octyl-3(2H)-isothiazolone (DCOI). The identified values come from Texas and the EPA Office of Pesticide Programs, and values range from 0.06 to 0.6 µg/m³ (ESLs) and 0.002 to 0.03 mg/kg/day (RfDs). Note that the OPP

RfDs are oral RfDs, which were not extrapolated to inhalation values but are summarized here per request by Oregon DOH. Cancer screening values were not identified.

Developmental toxicity endpoints were observed in the EPA OPP documentation.

DCOI is not present on the DOT list of inhalation hazards.

TABLE 22. INHALATION TRVS FOR 4,5-DICHLORO-2-OCTYL-3(2H)-ISOTHIAZOLONE (DCOI) (CAS 64359-81-5)

State/Agency	TRV	TRV	Classification	DEQ Notes
Texas TCEQ	Short-term ESL	0.6 µg/m^3	Non-cancer, acute	No publicly available derivation information
	Long-term ESL	0.06 µg/m^3	Non-cancer, chronic	No publicly available derivation information
EPA OPP	Acute RfD	0.03 mg/kg/day	Non-cancer, acute	Oral value only
	Chronic RfD	0.002 mg/kg/day	Non-cancer, chronic	Oral value only

DEQ does not propose any inhalation TRV for this TAC. Values in table above are not defensible by DEQ.

4.4.1. Texas TCEQ

On November 3, 1997, TCEQ assigned the short-term ESL to DCOI of 0.6 µg/m^3 and a long-term ESL of 0.06 µg/m^3. ERG emailed TCEQ to request additional information but TCEQ was unable to provide additional information on this derivation.

A list of the TCEQ ESLs with this information can be found as a download here: https://www.tceq.texas.gov/toxicology/esl/ESLMain.html

4.4.2. EPA OPP

TABLE 23. EPA OPP ACUTE AND CHRONIC RFD FOR DCOI (CAS 64359-81-5)

Variable	Value	Comment
Acute (One-Day) RfD	0.03 mg/kg/day	Oral RfD
Chronic (Lifetime) RfD	0.002 mg/kg/day	Oral RfD
Date	December 8, 1999	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	**Acute**: developmental oral toxicity study **Chronic:** oral toxicity study	--

Critical study	**Acute:** MRID Number 43471604 **Chronic:** MRID Number 42214903	Only executive summaries provided for studies.
Species	Rat	-
Target Organ	**Acute:** Skeletal system (developmental) **Chronic:** Hematological changes	-
Description of TRV endpoints/ basis for points of departure (POD)	**Acute:** Increased incidence and severity of wavy ribs in offspring **Chronic:** decreased mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC)	-
Other Endpoints	**Acute**: Reduced food consumption and decreased body weight gain in dams **Chronic:** Hyperplasia of the mucosa and granulation of the tunica propria mucosa of the non-glandular stomach. Also, in the highest dose group, clinical signs of toxicity (anal staining, reduced spontaneous movements, salivation, hypothermia, abdominal distension)	--
Uncertainty Factors	**Acute: UF_{total}** = 10 x 10 = 100 **Chronic UF_{total}** = 10 x 10 x 10 = 1000	**Acute and chronic:** UF (animal to human) = 10 UF (sensitive individuals) = 10 **Chronic:** UF (lack of chronic studies) = 10
POD Method	**Acute:** LOAEL **Chronic:** NOAEL	**Acute** NOAEL = 30 mg/kg/day **Acute** LOAEL = 100 mg/kg/day **Chronic** NOAEL = 20 mg/kg/day
Human Equivalent Concentration in TRV?	No	Not explicit in RfD calculation.
Duration of exposure	**Acute:** 7 days (GD 6-15) **Chronic:** 28 days	**Chronic:** Similar lesion in the stomach were observed in a 90-day study but at a lower dose in the 28-day study.
Time Adjustment in TRV?	Not explicit in calculations.	Chronic has an UF related to use of sub-chronic study.
Developmental or Reproductive Effects?	Developmental	From acute dietary study: “Increased number of litters with wavy ribs”.

Oral to inhalation extrapolation	No
Additional notes	Acute RfD = LOAEL/UF_{total} = 30 mg/kg / 100 = 0.3 mg/kg Chronic RfD = LOAEL/UF_{total} = 20 mg/kg / 1000 = 0.002 mg/kg The report also provides some information on an inhalation study which has a NOAEL of 0.02 mg/m3 (0.0037 mg/kg/day), but doesn't expand on this or derive an RfC.
Links to TRV Sources	https://archive.epa.gov/pesticides/chemicalsearch/chemical/foia/web/pdf/128101/128101-034.pdf

4.5. Perfluorobutanoic acid (PFBA) (CAS 375-22-4)

ERG identified non-carcinogenic health-based screening values for PFBA. The identified values come from Minnesota and Texas and range from 3.5 to 10 µg/m^3. Cancer screening values were not identified.

Developmental or reproductive effects were cited for PFBA in both Minnesota and Texas TRV documentation. In addition, ATSDR's 2022 Toxicological Profile noted one study that observed delayed developmental milestones in rats (Das et al. 2008).

PFBA is not present on the DOT list of inhalation hazards.

TABLE 24. INHALATION TRVS FOR PERFLUOROBUTANOIC ACID (PFBA) (CAS 375-22-4)

State/Agency	TRV Type	TRV Value	Classification	DEQ Notes
Minnesota DH	Short-term RAA	10 µg/m^3	Non-cancer, acute	Unmodified
	Sub-chronic RAA	10 µg/m^3	Non-cancer, sub-chronic	Not needed because same value as acute
	Chronic RAA	10 µg/m^3	Non-cancer, chronic	Not needed because same value as acute
Texas TCEQ	RfC	3.5 µg/m^3	Non-cancer, chronic	Unmodified – derived from newer oral tox study (2022) than Minnesota DH chronic value

4.5.1. Minnesota DH

TABLE 25. MINNESOTA DH RAA FOR PFBA (CAS 375-22-4)

Variable	Value	Comment
Short-term Non-Cancer RAA	10 µg/m^3	Short-term (>24 hours; < 30 days); though short-term has a different derivation than sub-chronic and chronic.
Sub-chronic Non-Cancer RAA	10 µg/m^3	Sub-chronic (>30 days and <10% of lifetime) sub-chronic and chronic have same derivation.
Chronic Non-Cancer RAA	10 µg/m^3	Chronic (>10% of lifetime) all have the same value of 10 µg/m^3, sub-chronic and chronic have same derivation.
Date	September 2021	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	All three are based on RfDs from oral rat studies.
Critical study	**Short-term:** NOTOX 2007a. Project 470677 Final Report. Repeated dose 28-day oral toxicity study with MTDID-8391 by daily gavage in the rat, followed by a 21-day recovery period. June 21, 2007. **Sub-chronic and chronic:** NOTOX 2007b. Project 484492 Final Draft Report. Repeated dose 90-day oral toxicity study with MTDID 8391 by daily gavage in the rat followed by a 3-week recovery period. October 2007.	--
Species	Rat	--
Target Organ / Effect	Liver, and Thyroid	--
Description of TRV endpoints/basis for points of departure (POD)	**Short-term:** Decreased cholesterol **Subchronic and chronic:** Liver weight changes, morphological changes in liver and thyroid gland, decreased TT4, decreased red blood cells, decreased hematocrit and hemoglobin	--

Other Endpoints	**Short-term** "co-critical effects": Increased relative thyroid weight, decreased serum total thyroxine (TT4), decreased dialysis free thyroxine (dFT4) **Subchronic and chronic** "co-critical effects": Increased relative thyroid weight, decreased serum TT4 and dFT4, decreased cholesterol, delayed eye opening	--
Uncertainty Factors	**Short-term:** Total UF = 3 x 3 = 100 **Subchronic and chronic:** Total UF = 3 x 10 x 10 = 300	**Short-term:** Interspecies TD UF = 3 Intraspecies UF = 10 Database UF = 3 **Subchronic and chronic:** Interspecies TD UF = 3 Intraspecies Variability UF = 10 Database UF = 10
POD Method	**Short-term:** $BMDL_{1SD}$ **Subchronic and Chronic:** NOAEL	**Short-term:** $BMDL_{1SD}$ = 3.01 mg/kg/day **Subchronic and Chronic** NOAEL = 6.9 mg/kg/day
Human Equivalent Concentration in TRV?	HED = POD / DAF Where DAF = Dose Adjustment Factor **Short-term:** POD_{HED} = (3.01 mg/kg/day) / 8 = 0.38 mg/kg/day **Sub-chronic/chronic:** POD_{HED} = (6.9 mg/kg/day) / 8 = 0.86 mg/kg/day	DAF = t½Human / t½MaleRat = 72 hours / 9.22 hours = 8
Duration of exposure	**Short-term:** 28 day **Sub-chronic/Chronic:** 90 day	--
Time Adjustment in TRV?	No	"Dose Adjustment Factor" used based on relative half-life in humans and rats.

Developmental or Reproductive Effects?	Developmental	MDH 2018; Developmental delays were observed in offspring of mice exposed during pregnancy. This effect was observed at 2-fold higher than the human equivalent dose, upon which the short-term RfD is based.
Oral to inhalation extrapolation	Yes (see below)	
Additional notes	RAA = RfD (mg/kg-d) x Route-to-route scaling factor (kg/m3-d) x (1000 µg/mg) RfD = HED / Total UF **Short-Term RAA:** RfD = 0.0038 (mg/kg/day) RAA = 0.0038 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 13.3 µg/m^3 rounded to 10 µg/m^3 **Subchronic and Chronic RAA:** RfD = 0.0029 (mg/kg/day) RAA = 0.0029 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 10.2 µg/m^3 rounded to 10 µg/m^3	
Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfba.pdf Short-term: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NHEERL&dirEntryId=237924 Subchronic and chronic: NOTOX 2007b. Project 484492 Final Draft Report. Repeated dose 90-day oral toxicity study with MTDID 8391 by daily gavage in the rat followed by a 3-week recovery period. October 2007.	

4.5.2. Texas TCEQ

TABLE 26. TEXAS TCEQ RFC FOR PFBA (CAS 375-73-5)

Variable	Value	Comment
RfC	3.5 µg/m^3	--
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	RfC derived from oral RfD

Critical study	Butenhoff JL, Bjork JA, Chang S, Ehresman DJ, Parker GA, Das K, Lau C, Lieder PH, van Otterdijk FM, Wallace KB. 2012. Toxicological evaluation of ammonium perfluorobutyrate in rats: twenty-eight-day and ninety-day oral gavage studies. Reprod Toxicol 33:513-530.	TCEQ references USEPA 2022 tox assessment, which cites Buttenhoff 2012
Species	Rats	--
Target Organ	Liver, Thyroid	--
Description of TRV endpoints/ basis for points of departure (POD)	Increased relative liver weight (i.e., liver hypertrophy) and decreased thyroxine (T4) in adult male rats	--
Other Endpoints	Human health hazards of potential concern (liver, thyroid, developmental toxicity), hepatocellular hypertrophy and increased relative liver weight (i.e., liver hypertrophy) and decreased thyroxine (T4) in adult male rats	--
Uncertainty Factors	3x10x10x3 = 1000	3 for interspecies TK and TD differences 10 for intrahuman variability, 10 for subchronic to chronic, and 3 for significant database insufficiencies
POD Method	NOAEL	NOAEL = 6 mg/kg-day PFBA ammonium salt
Human Equivalent Concentration in TRV?	POD_{HED} of 1.15 mg/kg-day and 1.27 mg/kg-day for liver hypertrophy and decreased T4, respectively.	After converting the PODs from units of mg/kg-day PFBA ammonium salt to units of mg/kg-day PFBA (by multiplying by the ratio of the molecular weights of the free acid and the ammonium salt), the ratio of serum clearance values between rats and humans was used to account for toxicokinetic differences between species
Duration of exposure	28 day and 90 days	--
Time Adjustment in TRV?	Not explicit in calculation	UF of subchronic to chronic applied.
Developmental or Reproductive Effects?	Developmental	Citing EPA IRIS assessment

Oral to inhalation extrapolation	PFBA RfD = 1.15 and 1.27 mg/kg/day / (3 x 10 x 10 x 3) = 1.0E-03 mg/kg/day Using PFBA RfD = 1.0E-03 mg/kg/day: PFBA RfC = 1.0E-03 mg/kg/day x 70 kg / 20 m^3/day = 3.5E-03 mg/m^3 = 3.5 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3
Additional notes	--
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf

4.6. Perfluorobutane Sulfonic Acid (PFBS) (CAS 375-73-5)

ERG identified non-carcinogenic health-based screening values for PFBS. The identified values come from Minnesota and Texas and range from 0.3 to 4.9 µg/m^3. Cancer screening values were not identified.

Developmental or reproductive effects were not observed for PFBS in TRV documentation. However, ATSDR's 2022 Toxicological Profile noted developmental effects across multiple studies including decreases in pup body weight, delays in eye opening, vaginal opening, and first estrous (York 2002, 2003a); and reproductive and endocrine effects in offspring (Feng et al. 2017).

PFBS is not present on the DOT list of inhalation hazards.

TABLE 27. INHALATION TRVS FOR PERFLUOROBUTANE SULFONIC ACID (PFBS) (CAS 375-73-5)

State/Agency	TRV	TRV	Classification	DEQ Notes
Minnesota DH	Short-term RAA	0.3 µg/m^3	Non-cancer, acute	Unmodified
	Sub-chronic RAA	0.3 µg/m^3	Non-cancer, sub-chronic	Not needed because same as acute
	Chronic RAA	0.3 µg/m^3	Non-cancer, chronic	Not needed because same as acute
Texas TCEQ	RfC	4.9 µg/m^3	Non-cancer, chronic	Not selected – see notes below

DEQ proposes Minnesota's value over TCEQ despite an older publication date because it: 1- is based on a more recent critical study than the TCEQ value, 2- has more transparent derivation calculations, 3- is based on a study that is closer to matching DEQ's 24-hour averaging time, 4- has lower uncertainty factors (100 vs. 300), 5- is based on the preferred benchmark dose modeling for POD rather than a NOAEL.

4.6.1. Minnesota DH

TABLE 28. MINNESOTA DH RAA FOR PFBS (CAS 375-73-5)

Variable	Value	Comment
Short-term Non-Cancer RAA	0.3 µg/m3	Short-term (>24 hours; < 30 days).
Sub-chronic Non-Cancer RAA	0.3 µg/m3	Sub-chronic (>30 days and <10% of lifetime); The calculated MDH subchronic RfD (0.00054 mg/kg-d) results in RAA (2 µg/m3) that is higher than the short-term RAA (0.3 µg/m3) which is based on thyroid effects. The RAA must be protective of shorter duration exposures that occur within the subchronic period and therefore, the subchronic RAA is set equal to the short-term RAA of 0.3 µg/m3 (MDH 2001, 2008).
Chronic Non-Cancer RAA	0.3 µg/m3	Chronic (>10% of lifetime); The calculated MDH chronic RfD (0.00018 mg/kg-d) results in RAA (0.6 µg/m3) that is higher than the short-term RAA (0.3 µg/m3) which is based on thyroid effects. The chronic RAA must be protective of shorter duration exposures that occur within the chronic period and therefore, the chronic RAA is set equal to the short-term RAA of 0.3 µg/m3 (MDH 2001, 2008).
Date	August 2022	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	--
Critical study	National Toxicology Program (NTP). 2019. "Toxicity studies of perfluoroalkyl sulfonates administered by gavage to Sprague Dawley (Hsd:Sprague Dawley SD) rats (TOX-96)." from https://cebs.niehs.nih.gov/cebs/publication/TOX-96	--

Species	Rat	--
Target Organ / Effect	Thyroid	--
Description of TRV endpoints/basis for points of departure (POD)	Decreased total T4	--
Other Endpoints	--	--
Uncertainty Factors	Total UF = 3 x 3 x 10= 100	Interspecies TD UF = 3 Intraspecies Variability UF = 10 Database UF = 3
POD Method	$BMDL_{1SD}$ = 6.97 mg/kg/day	--
Human Equivalent Concentration in TRV?	HED = POD * DAF Where DAF = Dose Adjustment Factor POD_{HED} = (6.97 mg/kg/day) x 0.0012 = 0.0084 mg/kg/day	Chemical- and Study-Specific Toxicokinetic Adjustment DAF = t½ Female Rat/ t½ Human = 1.3 hours / 1050 hours = 0012
Duration of exposure	28-day	--
Time Adjustment in TRV?	No	"Dose Adjustment Factor" used based on relative half-life in humans and rats.
Developmental or Reproductive Effects?	Developmental and Reproductive	MDH 2022; Two oral developmental studies (one in rats and one in mice) and a 2-generation study in rats have been conducted. The developmental effects reported in the mouse study included decreased pup body weight, decreased serum thyroid hormones, delayed eye opening, delayed vaginal opening and first estrus as well as smaller ovarian and uterine size in adult offspring MDH 2022; Researchers examined the association between PFAS chemicals and endometriosis related infertility among Chinese reproductive-age women in a case-control study. Women with endometriosis-related infertility had significantly higher median levels of PFBS compared with those without the disease
Oral to inhalation extrapolation	Yes (see below)	

Additional notes	RAA = RfD (mg/kg-d) x Route-to-route scaling factor (kg/m3-d) x (1000 µg/mg) RfD = HED / Total UF **Short-Term RAA:** RfD = 0. 000084 (mg/kg/day) RAA = 0. 000084 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 0.29 µg/m^3 rounded to 0.3 µg/m^3
Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfbs.pdf

4.6.2. Texas TCEQ

TABLE 29. TEXAS TCEQ RFC FOR PFBS (CAS 375-73-5)

Variable	Value	Comment
RfC	4.9 µg/m^3	--
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	RfC derived from oral RfD
Critical study	Leider PH, SC Chang, RG York, JL Butenhoff. 2009. Toxicological evaluation of potassium perfluorobutanesulfonate in a 90-day oral gavage study with Spraque-Dawley rats. Toxicology 255:45-52. York RG 2003. Oral (Gavage) Repeated Dose 90-Day Toxicity Study of Potassium Perfluorobutane Sulfonate (PFBS) in Rats. Argus Research Protocol Number 418-026.	TCEQ references Minnesota Department of Health, which cites Leider et al. 2009 and York 2003
Species	Rats	--
Target Organ	Blood, Kidney	--
Description of TRV endpoints/ basis for points of departure (POD)	Decreased hemoglobin and hematocrit, and histological changes in the kidney	--
Other Endpoints	--	--

Uncertainty Factors	1x10x3x10 = 300	1 for interspecies TD differences 10 for intrahuman variability, 3 for subchronic to chronic, and 10 for significant database insufficiencies (i.e., only one study available)
POD Method	NOAEL	NOAEL = 60 mg/kg-day
Human Equivalent Concentration in TRV?	HED = 0.42 mg/kg-day	Obtained by Minnesota Department of Health using a TK interspecies factor of 142 (for extrapolation form males rate to humans; detailed calculation not provided)
Duration of exposure	90 days	--
Time Adjustment in TRV?	Not explicit in calculation	UF of subchronic to chronic applied.
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	PFBS RfD = 60 mg/kg/day / (142 x 1 x 10 x 3 x 10) = 1.4E-03 mg/kg/day Using PFBS RfD = 1.4E-03 mg/kg/day: PFBS RfC = 1.4E-03 mg/kg/day x 70 kg / 20 m3/day = 4.9E-03 mg/m^3 = 4.9 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3	
Additional notes	--	
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf	

4.7. Perfluorohexanoic acid (PFHxA) (CAS 307-24-4)

ERG identified non-carcinogenic health-based screening values for PFHxA. The identified values come from Minnesota and range from 0.5 to 1 µg/m^3. Cancer screening values were not identified.

Developmental and reproductive effects were cited for PFHxA in multiple TRV source documents. In addition, ATSDR's 2022 Toxicological Profile found multiple studies with developmental or reproductive effects including an inverse association for testosterone levels in adolescent boys (Zhou et al. 2016); and decreases in fetal weight in rats (Loveless et al. 2009).

PFHxA is not present on the DOT list of inhalation hazards.

TABLE 30. TRVS FOR PERFLUOROHEXANOIC ACID (PFHXA) (CAS 307-24-4)

State/Agency	TRV	TRV	Classification	DEQ Notes
Minnesota DH	Short-term RAA	1 µg/m^3	Non-cancer, acute	Unmodified
	Sub-chronic RAA	0.5 µg/m^3	Non-cancer, sub-chronic	No analogous TRV category
	Chronic RAA	0.5 µg/m^3	Non-cancer, chronic	Unmodified

No other options to choose from.

4.7.1. Minnesota DH

TABLE 31. MINNESOTA DH SHORT-TERM AND LONG-TERM RAA VALUE FOR PFHXA (CAS 307-24-4)

Variable	Value	Comment
Non-Cancer Short-term RAA	1 µg/m^3	Short-term (>24 hours; < 30 days)
Non-Cancer Subchronic and Chronic RAA	0.5 µg/m^3	Sub-chronic (> 30days and <10% of lifetime) and chronic (>10% of lifetime) haver the same RAA value of 0.5 µg/m^3 and same derivation.
Date	February 2022	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat studies	All three are based on RfDs from oral rat studies.
Critical study	**Short-term:** National Toxicology Program (NTP). 2019. 28-Day Evaluation of the Toxicity (C20613) of Perfluorohexanoic acid (PFHXA) (307-24-4) in Harlan Sprague-Dawley Rats Exposed via Gavage. Study tables retrieved from https://cebs.niehs.nih.gov/cebs/publication/TOX-97 **Subchronic/chronic:** Loveless, S. E., Slezak, B., Serex, T., Lewis, J., Mukerji, P., O'Connor, J. C., . . . Buck, R. C. 2009. Toxicological evaluation of sodium perfluorohexanoate. Toxicology, 264(1-2), 32-44. doi:10.1016/j.tox.2009.07.011	--
Species	Rat	--
Target Organ / Effect	**Short-term:** Thyroid **Subchronic/chronic:** Liver	--
Description of TRV endpoints/basis for points of departure (POD)	**Short-term:** Decreased total T4 **Subchronic/chronic**: Nasal epithelium degeneration	--

Other Endpoints	**Short-term** "Co-critical effects": Decreased pup body weight **Subchronic/chronic** "Co-critical effects": Decreased bilirubin	--
Uncertainty Factors	**For short-term and subchornic/chronic RfD:** (3 x 10 x 10) = 300	UF (animal to human) = 3 UF (sensitive individuals) = 10 UF (data insufficiency) = 10
POD Method	**Short-term:** $BMDL_{1SD}$ **Subchronic/chronic:** $BMDL_{10\%}$	**Short-term:** BMDL1SD = 25.9 mg/kg/day **Subchronic and chronic:** BMDL10% = 22.5 mg/kg/day
Human Equivalent Concentration in TRV?	HED = POD x DAF Where DAF = Dose Adjustment Factor **Short-term:** POD/DAF = 25.9 mg/kg/day x 0.0037 = 0.0958 mg/kg/day **Subchronic/Chronic:** POD/DAF = 22.5 mg/kg/day x 0.0020 = 0.045 mg/kg/day	Chemical and Study-Specific Toxicokinetic Adjustment DAF = t½Human / t½MaleRat = 2.87 hrs/768 hrs = .0037
Duration of exposure	**Short-term:** 28 days **Subchronic/chronic:** 90 days; for reproductive subset dosed for 70 days prior to cohabitation	--
Time Adjustment in TRV?	No	"Dose Adjustment Factor" used based on relative half-life in humans and rats.

Developmental or Reproductive Effects?	Developmental and reproductive	MDH 2021; Decreases in pup body weight and increased pup mortality have been reported. These effects were observed at levels ~1500-fold higher than the subchronic/chronic RfD. A database uncertainty factor (DB UF) was incorporated into the RfD derivation, in part, to address the lack of a two-generation study MDH 2021; Significant decreases in maternal body weight gain during gestation and complete litter loss were reported at doses >3,000-fold higher than the subchronic/chronic RfD. Decreases in sperm count and seminiferous tubule spermatid retention were reported at doses 25,000-fold higher than the Subchronic/Chronic RfD.
Oral to inhalation extrapolation	Yes (see below)	
Additional notes	RAA = RfD (mg/kg-d) x Route-to-route scaling factor (kg/m3-d) x (1000 µg/mg) RfD = HED / Total UF **Short-term:** HED/Total UF = 0.0958/300 = 0.00032 mg/kg/day (laboratory animal – SD rats) RfD = 0.00032 mg/kg/day RAA = 0.00032 (mg/kg/day) x (70 kg/20 m3/day) x (1000 µg/mg) = 1.12 µg/m^3 = 1 µg/m^3 **Subchronic/Chronic:** HED/Total UF = 0.045/300 = 0.00015 mg/kg/day (laboratory animal – SD rats) RfD = 0.00015 mg/kg/day RAA = 0.00015 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 0.525 µg/m^3 rounded to 0.5 µg/m^3	

Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfhxa.pdf Short-term: https://cebs.niehs.nih.gov/cebs/publication/TOX-97 Subchronic/chronic: https://www.sciencedirect.com/science/article/abs/pii/S0300483X09003680

4.8. Perfluorohexanesulphonic acid (PFHxS) (CAS 355-46-4)

ERG identified non-carcinogenic health-based screening values for PFHxS. The identified values come from Minnesota and Texas and range from 0.013 to 0.034 µg/m^3. Cancer screening values were not identified.

Developmental or reproductive effects were not cited in the TRV source documentation for PFHxS. However, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with risk of preterm births among women; decreased birth weight; adiposity at birth; birth length; and neurodevelopmental outcomes in children. The Toxicological Profile also cited developmental or reproductive effects for numerous laboratory animal studies.

PFHxS is not present on the DOT list of inhalation hazards.

TABLE 32. INHALATION TRVS FOR PERFLUOROHEXANESULPHONIC ACID (PFHXS) (CAS 355-46-4)

State/Agency	TRV Type	TRV Value	Classification	DEQ Notes
Minnesota DH	RAA short-term	0.034 µg/m^3	Non-cancer, acute	Unmodified
	RAA sub-chronic	0.034 µg/m^3	Non-cancer, sub-chronic	Not needed because same as acute
	RAA chronic	0.034 µg/m^3	Non-cancer, chronic	Not needed because same as acute
Texas TCEQ	RfC	0.013 µg/m^3	Non-cancer, long-term	Derived from much older tox study than Minnesota DH value

4.8.1. Minnesota DH

TABLE 33. MINNESOTA DH RAA VALUE FOR PFHXS (CAS 355-46-4)

Variable	Value	Comment
Non-Cancer Risk Assessment Advice Value (RAA)	0.034 µg/m^3	Short-term (>24 hours; < 30 days), sub-chronic (>30days and <10% of lifetime), and chronic (>10% of lifetime) all have the same value of 0.034 µg/m^3 and same derivation.
Date	August 2021	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	--
Critical study	National Toxicology Program (NTP). 2018. TOX-96: Toxicity Report Tables and Curves for Short-term Studies: Perfluorinated Compounds: Sulfonates. https://tools.niehs.nih.gov/cebs3/views/?action=main.dataReview&bin_id=3874	--
Species	Rats	--
Target Organ / Effect	Thyroid and Liver	
Description of TRV endpoints/basis for points of departure (POD)	Decreased free T4	--
Other Endpoints	'Co-critical effects": Decreased free and total T4, triiodothyronine (T3), and changes in cholesterol levels and increased hepatic focal necrosis	--
Uncertainty Factors	Total UF = 3 x 10 x 10 = 300	Interspecies TD UF = 3 Intraspecies Variability UF = 10 Database UF = 10
POD Method	$BMDL_{20\%}$	32.4 µg/mL (or mg/L) serum concentration

Human Equivalent Concentration in TRV?	HED = POD x DAF Where DAF = Dose Adjustment Factor HED = 32.4 mg/L x 0.000090 L/kg-d = 0.00292 mg/kg-d	Toxicokinetic Adjustment based on Chemical-Specific Clearance Rate = Volume of Distribution (L/kg) x (Ln2/Half-life, days) = 0.25 L/kg x (0.693/1935 days) = 0.000090 L/kg-day. (Half-life from Li et al 2018)
Duration of exposure	28 days	--
Time Adjustment in TRV?	Yes	"Dose Adjustment Factor" used based on relative half-life in humans and rats.
Developmental or Reproductive Effects?	No	Tested for but not observed.
Oral to inhalation extrapolation	Yes	
Additional notes	RAA = RfD (mg/kg-d) x Route-to-route scaling factor (kg/m3-d) x (1000 µg/mg) RfD = HED / Total UF RfD = 0.0000097 mg/kg/day RAA = 0.0000097 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 0.034 µg/m^3	
Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfhxs.pdf https://tools.niehs.nih.gov/cebs3/views/?action=main.dataReview&bin_id=3874	

4.8.2. Texas TCEQ

TABLE 34. TEXAS TCEQ RFC FOR PFHXS (CAS 355-46-4)

Variable	Value	Comment
RfC	0.013 µg/m^3	--
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	RfC derived from oral RfD

Critical study	Hoberman AM, York RG. 2003. Oral (gavage) combined repeated dose toxicity study of T-7706 with the reproduction/developmental toxicity screening test. Argus Research.	TCEQ references ATSDR 2009 tox profile, which cites Hoberman and York 2003
Species	Rats	--
Target Organ	Hematological changes	--
Description of TRV endpoints/ basis for points of departure (POD)	Significantly decreased hemoglobin concentration, decreased erythrocyte count and decreased hematocrit	--
Other Endpoints	Hypertrophy-hyperplasia of thyroid follicular cells	--
Uncertainty Factors	For RfD: Total UF = 263 x 1 x 3 x 10 x 10 = 78900	Interspecies TK UF = 263 Interspecies TD UF = 1 LOAEL to NOAEL = 3 Intrahuman UF = 10 Database UF (data insufficiency) = 10
POD Method	LOAEL	LOAEL of 0.3 mg/kg/day for hematology findings
Human Equivalent Concentration in TRV?	Interspecies UF of 263	TCEQ used "a data-based TK interspecies extrapolation factor available for an 8-carbon PFAS (PFOS) as a surrogate for the 6-carbon PFHxS. This appears reasonable based on available half-life data since the human half-life for PFOS (1,053-2,701 days) is most similar to that for PFHxS (2,662 days) among PFAS with reported human half-lives (Table 3-8 of ATSDR 2009). Therefore, to derive an RfD for a chemical that may otherwise go unaddressed at a site, TCEQ will assume the ratio of human-to-rat half-lives for PFHxS is the same as that of PFOS, maintaining the human-to-rat half-life ratio of approximately 263"
Duration of exposure	Daily oral exposure from premating to post-natal day 21 (females)	--
Time Adjustment in TRV?	No	Not explicit in calculation.
Developmental or Reproductive Effects?	No significant developmental or reproductive effects	
Oral to inhalation extrapolation	Yes (see below)	

Additional notes	PFHxS RfD = 0.3 mg/kg/day / (263 x 1 x 3 x 10 x 10) = 3.8E-06 mg/kg/day = 0.0038 µg/m^3 Using RfD = 3.8E-06 mg/kg/day: PFHxS RfC = 3.8E-06 mg/kg/day x 70 kg/20 m^3/day = 1.3E-05 mg/m3 = 0.013 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome

4.9. Perfluorooctanoic acid (PFOA) (CAS 335-67-1)

ERG identified non-carcinogenic health-based screening values for PFOA. The identified values come from seven different state agencies and range from 0.005 to 0.063 µg/m^3. Cancer screening values were not identified.

Developmental and reproductive effects were observed for PFOA in various TRV source documents. In addition, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with effects on reproductive hormone levels, sperm, menstrual cycle length, menopause onset, endometriosis, breastfeeding duration, fertility, pregnancy outcomes, birth outcomes, neurodevelopmental outcomes, and development of the reproductive system. The Toxicological Profile also cites developmental or reproductive effects for numerous laboratory animal studies.

PFOA is not present on the DOT list of inhalation hazards.

TABLE 35. INHALATION TRVS FOR PFOA (CAS 335-67-1)

State/Agency	TRV	TRV	Classification	DEQ Notes
Michigan DE	24-hour ITSL	0.0001 µg/m3	Non-cancer, acute	Unmodified except applied as chronic rather than acute TRV
Minnesota DH	RAA	0.063 µg/m^3	Non-cancer, acute	Unmodified
	RAA	0.063 µg/m^3	Non-cancer, sub-chronic	Not needed because same as acute
	RAA	0.063 µg/m^3	Non-cancer, chronic	Not needed because same as acute
New Hampshire DES*	24-Hour AAL	0.05 µg/m^3	Non-cancer, acute	Derived from occupational

	Annual AAL	0.024 µg/m^3	Non-cancer, chronic	Derived from occupational
New Jersey DEP	RfC	0.007 µg/m^3	Non-cancer, chronic	Based on older critical study than Michigan
New York DEC	AGC	0.0053 µg/m^3	Non-cancer, chronic	Based on older critical study than Michigan
Texas TCEQ	Short-Term ESL	0.05 µg/m^3	Non-cancer, acute	No derivation information available
	Long-Term ESL	0.005 µg/m^3	Non-cancer, chronic	No derivation information available
	RfC	4.1 x 10^{-3} µg/m^3	Non-cancer, chronic	Based on inhalation study but very old (1986)
Wisconsin DNR*	24-Hour Ambient Air Standard	0.24 µg/m^3	Non-cancer, acute	Derived from occupational

**Reported for Ammonium perfluorooctanoate (APFO) (CAS # 3825-26-1)*

Michigan did not make any quantitative adjustments to their value to make it fit an acute exposure time frame, and the recent (March 2024) EPA oral RfD on which it is based is a chronic RfD. Therefore, DEQ proposes to use the unmodified Michigan value as a chronic, rather than acute, TRV.

4.9.1. Michigan EGL

TABLE 36. MICHIGAN EGLE ITSL FOR PFOA (CAS 335-67-1)

Variable	Value	Comment
ITSL	0.0001 µg/m^3	24-hour time averaging
Date	April 25, 2024	Originally set in February 5, 2018 then updated on April 25, 2024 when EPA updated its final Human Health Toxicity Assessment for PFOA.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Derived from 2024 EPA oral RfD of 3E^{-8} mg/kg/day	--

Critical study	Budtz-Jørgensen, E; Grandjean, P. (2018). Application of benchmark analysis for mixed contaminant exposures: Mutual adjustment of perfluoroalkylate substances associated with immunotoxicity. PLoS ONE 13: e0205388. http://dx.doi.org/10.1371/journal.pone.0205388 Wikström, S; Hussein, G; Lingroth Karlsson, A; Lindh, CH; Bornehag, CG. (2021). Exposure to perfluoroalkyl substances in early pregnancy and risk of sporadic first trimester miscarriage. Scientific Reports 11: 3568. http://dx.doi.org/10.1038/s41598-021-82748-6 Dong, Z; Wang, H; Yu, YY; Li, YB; Naidu, R; Liu, Y. (2019). Using 2003-2014 U.S. NHANES data to determine the associations between per- and polyfluoroalkyl substances and cholesterol: Trend and implications. Ecotoxicology and Environmental Safety 173: 461- 468.	--
Species	Human	Epidemiological studies.
Target Organ	Immune system, developmental, cholesterol	--
Description of TRV endpoints/ basis for points of departure (POD)	Decreased serum anti-tetanus and anti-diphtheria antibody concentrations in children (Budtz-Jørgensen and Grandjean, 2018), decreased infant birth weight (Wikström et al., 2020), and increased total cholesterol in adults (Dong et al., 2019).	--
Other Endpoints	Many other effects in toxicity assessment.	--
Uncertainty Factors	EGLE did not apply UFs to TRV calculation.	EPA applied uncertainty factors when deriving the oral RfD, but EGLE did not apply uncertainty factors in its calculation.
POD Method	EGLE used an oral RfD to RfC conversion;	EPA used benchmark dose modeling (BMDL) to derive multiple oral RfDs

Human Equivalent Concentration in TRV?	Yes in EPA oral RfD derivation.	--
Duration of exposure	Various	--
Time Adjustment in TRV?	No (see note)	ITSL is determined for a 24-hour time averaging; however, no explicit time-adjustment is present in the TRV derivation.
Developmental or Reproductive Effects?	Developmental and Reproductive in PFOA Toxicity Assessment	
Oral to inhalation extrapolation	ITSL = RfD x (avg. body weight)/(inhalation rate per day) x unit-conversion ITSL = (3E-8 mg/kg) x (70kg)/(20m³) x 1000µg/mg ITSL = 0.000105 µg/m³ rounded to 0.0001 µg/m³. Because the developmental effects of PFOA can occur over short periods of time, pursuant to Rule 232(2)(d) the averaging time is 24 hours.	
Additional notes	Multiple alternative RfC calculations were presented as well as potential ITSLs calculated from an OEL in the original EGLE 2018 source document.	
Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=335671&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/335-67-1/335-67-1_24hr_ITSL.pdf	

4.9.2. Minnesota DH

TABLE 37. MINNESOTA DH RAA VALUE FOR PFOA (CAS 335-67-1)

Variable	Value	Comment
Non-Cancer Risk Assessment Advice (RAA)	0.063 µg/m^3	Short-term (>24 hours; < 30 days), Sub-chronic (>30 days and <10% of lifetime), and chronic (>10% of lifetime) all have the same value of 0.063 µg/m^3. Insufficient data to derive an RAA for acute exposure (< 24 hours).
Date	June 2022	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral developmental mouse study	RfD derived by MDH in 2017.

Critical study	Lau C, Thibodeaux JR, Hanson RG, Narotsky MG, Rogers JM, Lindstrom AB, Strynar MJ. Effects of perfluorooctanoic acid exposure during pregnancy in the mouse. Toxicol Sci. 2006 Apr;90(2):510-8. doi: 10.1093/toxsci/kfj105.	EPA 2016a predicted average serum concentration for maternal animals from Lau et al 2006). Note: EPA 2016a is now out of date.
Species	Mouse	--
Target Organ	Developmental	--
Description of TRV endpoints/ basis for points of departure (POD)	Developmental delay	Delayed ossification, accelerated preputial separation in male offspring, trend for decreased pup body weight, and increased maternal liver weight
Other Endpoints	In offspring exposure during development, researchers observed changes in liver weight, histology, and triglycerides, and delayed mammary gland development in pups.	In adult animals, researchers observed liver weight changes, liver enzyme levels, changes in triglyceride and cholesterol levels, microscopic evidence of cellular damage and bile duct hyperplasia; decreased spleen weight and spleen lymphocytes; decreased IgM response; kidney weight changes and papilla urothelium hyperplasia; increased pancreatic acinar cell hyperplasia; and decreased serum thyroid hormone levels.
Uncertainty Factors	Total UF = 300	UF (sensitive individuals) = 10 UF (animal to human) = 3 UF (LOAEL to NOAEL) = 3 UF (data insufficiency) = 3
POD Method	LOAEL	LOAEL of 0.000018 mg/kg/day for adverse developmental effects
Human Equivalent Concentration in TRV?	Yes	HED = POD x DAF = 38 mg/L x 0.00014 L/kg/day = 0.0053 mg/kg-d *Where DAF is dose adjustment factor* RfD = HED/UF = 0.0053/300 = 0.000018 mg/kg-d
Duration of exposure	Gestation days 1 to 17	-
Time Adjustment in TRV?	Yes	-
Developmental or Reproductive Effects?	Developmental	--

Oral to inhalation extrapolation	RfD = 0.000018 mg/kg/day RAA = RfD * oral-inhalation scaling factor * unit conversion RAA = 0.000018 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = 0.063 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3
Additional notes	--
Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfoa.pdf https://pubmed.ncbi.nlm.nih.gov/16415327/

4.9.3. New Hampshire DES

TABLE 38. NEW HAMPSHIRE DES 24-HOUR AND ANNUAL AAL FOR AMMONIUM PERFLUOROOCTANOATE (APFO) (CAS 3825-26-1)

Variable	Value	Comment
24-Hour AAL	0.05 µg/m^3	24-hour ambient air limit
Annual AAL	0.024 µg/m^3	Annual ambient air limit
Date	--	Unclear when this was established. It was not listed in the most recent changes to regulation in 2022. Found in NHDES presentation in 2017.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit modified with toxicity data from an oral toxicity study	Regulatory approach calls for setting the AAL based on modifying the ACGIH value based on other available toxicity data. See additional notes below.
Critical study	ACGIH OEL	ACGIH is used as basis of AAL, and unclear what other studies are used to determine acute and chronic toxicity values to set a 'Toxicity Factor' and 'Time Adjustment Factor' to modify the ACGIH value according to the regulatory formula. (See additional notes below)
Species	--	The underlying source for the old ACGIH OEL value used is not available.
Target Organ	--	--

Description of TRV endpoints/ basis for points of departure (POD)	--	--
Other Endpoints	--	--
Uncertainty Factors	NH DES refers to a 'Safety Factor (SF)' of 100. A time adjustment factor is also applied of 4.2 for the annual AAL and 2 for the 24-hour AAL. (See below).	New Hampshire assigned APFO a Toxicity Factor = I and Time Adjustment Factor = B which correspond to safety factor (SF) = 100 and time adjustment factor (TAF) = 2
POD Method	OEL	OEL = 10 µg/m^3
Human Equivalent Concentration in TRV?	--	Not explicit in calculation from OEL.
Duration of exposure	--	--
Time Adjustment in TRV?	Yes For the Annual AAL, NHDES adjusted the OEL by a factor of 4.2 = 24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week) For the 24-hour AAL, NHDES assigned 1-methylnaphthalene a 'Time Adjustment Factor (TAF)' based on regulatory criteria 'B,' which corresponds to a TAF of 2.	Annual AAL = OEL / (4.2 * SF) Where: 4.2 = (24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week) -------- 24-Hour AAL = OEL / (SF * TAF) SF = safety factor TAF = time adjustment factor
Developmental or Reproductive Effects?	No	No mention of developmental or reproductive effects/studies.
Oral to inhalation extrapolation	No	Not explicit in calculation of TRV from OEL.

Additional notes	Calculations of AALs are shown below: Annual AAL = OEL / (4.2 * SF) = 10 µg/m^3 / (4.2 * 100) = 10 µg/m^3 / 420 = 0.024 /m^3 Where: 4.2 = (24 hrs per day / 8 hrs per work day) * (7 days per week / 5 days work week). 24-hour AAL = OEL / (SF * TAF) = 10 µg/m^3 / (100 * 2) = 10 µg/m^3 / (200) = 0.05 µg/m^3
Links to TRV Sources	See email from New Hampshire DES https://www.des.nh.gov/air/industrial-sources/air-toxics-compliance https://www.newmoa.org/wp-content/uploads/2022/08/NHDES_PFOA_AirModelingDepositionMarch2017.pdf https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/env-a-1400.pdf

4.9.4. New Jersey DEP

TABLE 39. NEW JERSEY DEP RFC FOR PFOA (CAS 335-67-1)

Variable	Value	Comment
RfC	0.007 µg/m^3	ITSLs are analogous to RfCs
Date	December 19, 2019	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral toxicity study	Oral RfD used to calculate an RfC.

Critical study	Loveless, S.E., Finlay, C., Everds, N.E., Frame, S.R., Gillies, P.J., O'Connor, J.C., Powley, C.R., Kennedy, G.L. (2006). Comparative responses of rats and mice exposed to linear/branched, linear, or branched ammonium perfluorooctanoate (APFO). Toxicology 220: 203–217.	--
Species	Mouse	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	10% increase in relative liver weight	--
Other Endpoints	--	--
Uncertainty Factors	Total UF = 10 x 10 x 3 = 300	UF (sensitive individuals) = 10 UF (animal to human) = 3 UF (data insufficiency) = 10
POD Method	BMDL	Serum level BMDL of 4,350 ng/ml
Human Equivalent Concentration in TRV?	The target human serum level is: 4350 ng/mL / 300 = 14.5 ng/mL	Where BMDL = 4,350 ng/mL and Combined UF = 300
Duration of exposure	14 days	--
Time Adjustment in TRV?	No	--
Developmental or Reproductive Effects?	Developmental and Reproductive	Effects from developmental exposures in mice include full litter resorptions, 10 decreased postnatal survival and growth, delayed development, accelerated sexual maturation in males, persistent liver toxicity (noted above), and delayed mammary gland development. PFOA also causes reproductive toxicity in male mice
Oral to inhalation extrapolation	ITSL calculated based on approach in Michigan's R232(1)(b) (see additional notes): ITSL = RfD * (average body weight) / (inhalation rate per day) * unit conversion ITSL = 2 x 10^{-6} mg/kg/day * (70 kg) / (20 m^3/day) * 1000µg/mg ISTL = 0.007 µg/m^3	

Additional notes	New Jersey Department of Environmental Protection (NJDEP) toxicologists reviewed the Michigan Department of Environmental Quality's (MDEQ) approach for calculating the ISTL for PFOA. They considered MDEQ's approach alongside alternative approaches, and selected MDEQ's approach as the most conservative (health protective), however they used the NJDEP PFOA RfD of 2 x 10^{-6} mg/kg/day (derived in DWQI, 2017) rather than the USEPA RfD of 2 x 10^{-5} mg/kg/day as used by MDEQ.
Links to TRV Sources	https://dep.nj.gov/wp-content/uploads/dsr/njdep-pfoa-pfos-rfc-memo.pdf https://www.nj.gov/dep/watersupply/pdf/pfoa-appendixa.pdf. https://casetext.com/regulation/michigan-administrative-code/department-environmental-quality/air-quality-division/part-2-air-use-approval/section-r-3361232-methodology-for-determining-initial-threshold-screening-level

4.9.5. New York DEC

TABLE 40. NEW YORK DEC AGC FOR PFOA (CAS 335-67-1)

Variable	Value	Comment
Annual Guideline Concentration (AGC)	0.0053 µg/m^3	--
Date	February 12, 2021	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral toxicity study	Oral RfD converted to inhalation value.
Critical study	Macon MB, Villanueva LR, Tatum-Gibbs K, Zehr RD, Strynar MJ, Stanko JP, White SS, Helfant L, Fenton SE. Prenatal perfluorooctanoic acid exposure in CD-1 mice: low-dose developmental effects and internal dosimetry. Toxicol Sci. 2011 Jul;122(1):134-45. doi: 10.1093/toxsci/kfr076.	--
Species	Mouse	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	Liver toxicity and enlargement	--

Other Endpoints	Hepatocellular adenoma, Leydig cell tumors, and pancreatic acinar cell tumors, delayed mammary gland development	--
Uncertainty Factors	For derivation of RfD: Total UF = 3 x 3 x 10 x 3 ~ 300	UF (use of LOEL) = 3 UF (animal to human) = 3 UF (sensitive individuals) = 10 UF (data insufficiency) = 3
POD Method	LOEL = 0.3 mg/kg-day	PFOA serum concentration at LOEL was 4.98 mg/L
Human Equivalent Concentration in TRV?	Human equivalent dose (HED_{LOEL}) = PFOA serum concentration x PFOA clearance rate = 4.98 mg/L x 0.000092 L/kg-day = 0.00046 mg/kg/day	PKAF = estimated PFOA serum clearance (CL) in humans Clearance Level (CL) = Volume of distribution x (ln 2 ÷ human PFOA serum ½ life estimate) = 0.17 L/kg x (0.693 / 1277.5 days) = 9.2 x 10-5 L/kg-day (0.092 mL/kg-day)
Duration of exposure	Daily exposure from GD 1 to GD 17	--
Time Adjustment in TRV?	No	No explicit time adjustment in calculation.
Developmental or Reproductive Effects?	Developmental	Citing USEPA assessment.
Oral to inhalation extrapolation	RfD = 1.5 x 10^{-3} µg/kg/day [See calculation in Additional Notes] Oral to inhalation extrapolation = 70kg / 20m^3/day RfC = 1.5 x 10^{-3} µg/kg/day * (70 kg) / (20 m^3/day) = 5.3 x 10^{-3} µg/m^3	
Additional notes	RfD derived using 6 NYCRR 702.5: RfD = HED_{LOEL} / UF RfD = 0.00046 mg/kg/day / 300 = 1.5 x 10-6 µg/kg-day NYDOH will be reevaluating the AGC for PFOA this year.	

Links to TRV Sources	US EPA (U.S. Environmental Protection Agency). 2016. Health Effects Support Document for Perfluorooctanoic Acid (PFOA). Office of Water. EPA 822-R-16-003. Last accessed (03/21/2019) at https://www.epa.gov/ground-water-and-drinking-water/supporting-documents-drinking-water-healthadvisories-pfoa-and-pfos. Tardiff RG, Carson ML, Sweeney LM, et al. 2009. Derivation of a drinking water equivalent level (DWEL) related to the maximum contaminant level goal for perfluorooctanoic acid (PFOA), a persistent water soluble compound. Food Chem Toxicol. 47:2557-2589. https://www.sciencedirect.com/science/article/abs/pii/S0278691509003433?via%3Dihub. Macon MB, Villanueva LR, Tatum-Gibbs K, Zehr RD, Strynar MJ, Stanko JP, White SS, Helfant L, Fenton SE. Prenatal perfluorooctanoic acid exposure in CD-1 mice: low-dose developmental effects and internal dosimetry. Toxicol Sci. 2011 Jul;122(1):134-45. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3143465/. NEW YORK STATE HUMAN HEALTH FACT SHEET1 Ambient Water Quality Value for Protection of Human Health and Sources of Potable Water SUBSTANCE: Perfluorooctanoic Acid (PFOA). https://extapps.dec.ny.gov/docs/water_pdf/pfoahumanhealth.pdf

4.9.6. Texas TCEQ

TABLE 41. TEXAS TCEQ SHORT- AND LONG-TERM ESLS AND RFC FOR PFOA (CAS 335-67-1)

Variable	Value	Comment
Short-Term ESL	0.05 µg/m^3	No supporting documentation for Short-Term ESL. Short-term ESL set on July 12, 2011. Information below for updated RfC.
Long-Term ESL	0.005 µg/m^3	No supporting documentation for Long-Term ESL. Long-term ESL set on July 12, 2011. Information below for updated RfC.
RfC	4.1 x 10^{-3} µg/m3	***Information for this row and below comes from a February 14, 2023 update to derivation of PFAS RfDs and RfCs.
Date	February 14, 2023	--

Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation study	--
Critical study	Kennedy GL, Hall GT, Brittelli MR, et al. 1986. Inhalation toxicity of ammonium perfluorooctanoate. Food Chem Toxicol 24(12):1325-1329.	--
Species	Rats	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	Increases in relative and absolute liver weights and histological alternations in the livers	--
Other Endpoints	10% decrease in newborn bodyweight and 37% decreased weight gain in dams	--
Uncertainty Factors	Total UF = 81 x 3 x 10 x 10 x 10 = 243,000	UF (animal to human TK) = 81 UF (animal to human TD) = 3 UF (subacute to chronic) = 10 UF (sensitive individuals) = 10 UF (data insufficiency) = 10
POD Method	NOAEL	--
Human Equivalent Concentration in TRV?	Not explicit in calculation	UF applied
Duration of exposure	Whole-body exposure to APFO dusts 6 hours/day on gestation days 6 to 15	--
Time Adjustment in TRV?	No	--
Developmental or Reproductive Effects?	Developmental	PFOA oral RfD in same document derived based on developmental endpoints.
Oral to inhalation extrapolation	No	
Additional notes	PFOA RfC = 1 mg/m^3 / (81 x 3 x 10 x 10 x 10) = 4.1E-06 mg/m^3 = 0.0041 µg/m^3 No information was available on the ESLs that were set by TCEQ. ERG emailed TCEQ for additional information and was provided the documentation for the updated RfC values described here.	

Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome

4.9.7. Wisconsin DNR

TABLE 42. WISCONSIN DNR 24-HOUR AAL FOR AMMONIUM PERFLUOROOCTANOATE (APFO) (CAS 3825-26-1)

Variable	Value	Comment
24-hour AAL	0.24 µg/m3	Ammonium perfluorooctanoate, salt of PFOA
Date	--	Not clear when added to list.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	ACGIH's TLV and biological indices for 2000
Critical study	--	--
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	-	
Oral to inhalation extrapolation	-	
Additional notes	Wisconsin DNR provided information on derivation. 24-hour averaging time ambient air standard set as 2.4% of the ACGIH 2000 TLV. ACGIH 2000 TLV documentation not available.	

Links to TRV Sources	See Email and documents from Wisconsin DNR http://docs.legis.wisconsin.gov/code/admin_code/nr/400/445.pdf https://dnr.wisconsin.gov/topic/AirQuality/Rules.html

4.10. Perfluorooctane sulfonic acid (PFOS) (CAS 1763-23-1)

ERG identified both carcinogenic and non-carcinogenic health-based screening values for PFOS. The identified values come from four different state agencies and range from 0.006 to 0.1 µg/m^3. Cancer screening values were not identified.

Developmental and reproductive effects were observed for PFOS in various TRV source documents. In addition, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with effects on reproductive hormone levels, sperm, menopause onset, endometriosis, breastfeeding duration, fertility, pregnancy outcomes, birth outcomes, neurodevelopmental outcomes, and development of the reproductive system. The Toxicological Profile also cites developmental or reproductive effects for numerous laboratory animal studies.

PFOS is not present on the DOT list of inhalation hazards.

TABLE 43. INHALATION TRVS FOR PFOS (CAS 1763-23-1)

State/Agency	TRV	TRV	Classification	DEQ Notes
Michigan EGLE	24-Hour ISTL	0.0004 µg/m^3	Non-cancer, acute	Unmodified but proposed for use as chronic rather than acute TRV
Minnesota DH	RAA	0.011 µg/m^3	Non-cancer, acute	Unmodified
	RAA	0.011 µg/m^3	Non-cancer, sub-chronic	Not needed because same as acute
	RAA	0.011 µg/m^3	Non-cancer, chronic	Not needed because same as acute
New Jersey DEP	RfC	0.006 µg/m^3	Non-cancer, chronic	Based on older tox study than Michigan
Texas TCEQ	Short-term ESL	0.1 µg/m^3	Non-cancer, acute	No derivation information available
	Long-term ESL	0.01 µg/m^3	Non-cancer, chronic	No derivation information available

	RfC	0.081 µg/m^3	Non-cancer, chronic	Based on older tox study than Michigan

The Michigan value is based on an oral RfD derived by EPA that is chronic, and Michigan did not make any quantitative adjustments to the value to make it an acute value. It is chosen over other options because it is based on the very newest EPA oral RfD (March 2024) and very recent studies in humans.

4.10.1. Michigan EGLE

TABLE 44. MICHIGAN EGLE ITSL FOR PFOS (CAS 1763-23-1)

Variable	Value	Comment
ITSL	0.0004 µg/m³	24-hour time averaging
Date	April 25, 2024	Original set in February 16, 2018 then updated on April 25, 2024 after EPA updated its final Human Health Toxicity Assessment for PFOS.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Derived from 2024 EPA RfD for PFOS of 1E-7 mg/kg/day,.	--
Critical study	Wikström, S; Hussein, G; Lingroth Karlsson, A; Lindh, CH; Bornehag, CG. (2021). Exposure to perfluoroalkyl substances in early pregnancy and risk of sporadic first trimester miscarriage. Scientific Reports 11: 3568. http://dx.doi.org/10.1038/s41598-021-82748-6 Dong, Z; Wang, H; Yu, YY; Li, YB; Naidu, R; Liu, Y. (2019). Using 2003-2014 U.S. NHANES data to determine the associations between per- and polyfluoroalkyl substances and cholesterol: Trend and implications. Ecotoxicology and Environmental Safety 173: 461- 468.	EPA RfD based on epidemiologic studies that showed developmental (decreased birth weight) and cardiovascular (increased total cholesterol) effects

Species	Human	Epidemiological studies.
Target Organ	Cardiovascular, developmental	--
Description of TRV endpoints/ basis for points of departure (POD)	Developmental (decreased birth weight) and cardiovascular (increased total cholesterol)	--
Other Endpoints	Many other effects in toxicity assessment.	--
Uncertainty Factors	EGLE did not apply UFs to TRV calculation.	EPA applied uncertainty factors when deriving the oral RfD, but EGLE did not apply uncertainty factors in its calculation.
POD Method	EGLE used an oral RfD to RfC conversion	EPA used benchmark dose modeling (BMDL) to derive multiple oral RfDs
Human Equivalent Concentration in TRV?	Yes in EPA oral RfD derivation.	--
Duration of exposure	Various	--
Time Adjustment in TRV?	No (see note)	ITSL is determined for a 24-hour time averaging; however, no explicit time-adjustment is present in the TRV derivation.
Developmental or Reproductive Effects?	Developmental and Reproductive in PFOS Toxicity Assessment	
Oral to inhalation extrapolation	ITSL = RfD x (Default Body weight)/(Default Inhalation rate) × unit conversion ITSL = 1E-7 mg/kg/day × 70kg/20m³ × 1000 µg/mg ITSL = 0.00035 µg/m³, rounded to 1 significant figure as 0.0004 µg/m³	
Additional notes	--	
Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=335671&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/1763-23-1/1763-23-1_24hr_ITSL.pdf	

4.10.2. Minnesota DH

TABLE 45. MINNESOTA DH RAA VALUE FOR PFOS (CAS 1763-23-1)

Variable	Value	Comment
Non-Cancer Risk Assessment Advice (RAA)	0.011 µg/m³	Short-term (>24 hours; < 30 days), sub-chronic (>30days and <10% of lifetime), and chronic (>10% of lifetime) all have the same value of 0.011 µg/m³
Date	June 2021	--

Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral mouse study	--
Critical study	Dong, G. H., Liu, M. M., Wang, D., Zheng, L., Liang, Z. F., & Jin, Y. H. (2011). Sub-chronic effect of perfluorooctanesulfonate (PFOS) on the balance of type 1 and type 2 cytokine in adult C57BL6 mice. Archives of toxicology, 85, 1235-1244.	--
Species	Mouse	--
Target Organ	Immune system	--
Description of TRV endpoints/ basis for points of departure (POD)	Increased IL-4 and decreased SRBC specific IgM levels	--
Other Endpoints	Decreased pup body weight; increased fasting serum insulin and glucose in pups; suppressed SRBC response, increased NK cell activity and decreased IgM; decreased total and free T4 (maternal and pups); decreased adrenal weight, decreased serum corticosterone and adrenocorticotropic hormone levels in serum, and corticotropin-releasing hormone concentration in hypothalamus; and changes in cholesterol and histological changes in the liver (adults)	--
Uncertainty Factors	Total UF = 100	UF (animal to human) = 3 UF (sensitive individuals) = 10 UF (data insufficiency) = 3
POD Method	NOAEL	NOAEL of 2.36 µg/mL
Human Equivalent Concentration in TRV?	Yes	HED = POD x DAF = 2.36 mg/L x 0.00013 L/kg-d = 0.000307mg/kg-d *Where DAF is dose adjustment factor* RfD = HED/Total UF = 0.000307/100 = 0.0000031 mg/kg-d
Duration of exposure	60 days	--

Time Adjustment in TRV?	Yes	--
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	RfD = 0.0000031 (mg/kg/day) RAA = RfD * oral-inhalation scaling factor * unit conversion RAA = 0.0000031 (mg/kg/day) x (70 kg/20 m^3/day) x (1000 µg/mg) = = 0.0108 rounded to 0.011 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3	
Additional notes	--	
Links to TRV Sources	https://www.health.state.mn.us/communities/environment/risk/docs/guidance/air/pfos.pdf https://pubmed.ncbi.nlm.nih.gov/21327619/	

4.10.3. New Jersey DEP

TABLE 46. NEW JERSEY RFC FOR PFOS (CAS 1763-23-1)

Variable	Value	Comment
RfC	0.006 µg/m^3	ITSLs are analogous to RfCs
Date	June 5, 2018	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral toxicity study	Oral RfD used to calculate an RfC.
Critical study	Dong GH, Zhang YH, Zheng L, Liu W, Jin YH, He QC. 2009. Chronic effects of perfluorooctanesulfonate exposure on immunotoxicity in adult male C57BL/6 mice. Arch Toxicol. 83:805-815	--
Species	Mouse	--
Target Organ	Immune system	--
Description of TRV endpoints/ basis for points of departure (POD)	Decreased plaque forming cell response	--
Other Endpoints	--	--
Uncertainty Factors	Total UF = 10 x 3 = 30	UF (sensitive individuals) = 10 UF (animal to human) = 3

POD Method	NOAEL	Where NOAEL = 674 ng/mL and
Human Equivalent Concentration in TRV?	The target human serum level is: POD / UF 674 ng/mL / 30 = 22.5 ng/mL where 674/ng/mL is the Animal POD_{serum} RfD = 22.5 ng/mL / 8.1 x 10^{-5} L/kg/day = 1.8 x 10^{-6} mg/kg/day	Combined UF = 30 Human clearance factor of 8.1 x 10^{-5} L/kg/day obtained from USEPA 2016
Duration of exposure	60 days	--
Time Adjustment in TRV?	No	--
Developmental or Reproductive Effects?	Various developmental and reproductive effects.	
Oral to inhalation extrapolation	ITSL calculated based on approach in Michigan's R232(1)(b) (see additional notes): ITSL = RfD * (average body weight) / (inhalation rate per day) * unit conversion ITSL = 1.8 x 10^{-6} mg/kg/day * (70 kg) / (20 m^3/day) * 1000µg/mg ISTL = 0.006 µg/m^3	
Additional notes	New Jersey Department of Environmental Protection (NJDEP) toxicologists reviewed the Michigan Department of Environmental Quality's (MDEQ) approach for calculating the ISTL for PFOS. They considered MDEQ's approach alongside alternative approaches, and selected MDEQ's approach as the most conservative (health protective), however they used the NJDEP PFOS RfD of 1.8 x 10^{-6} mg/kg/day (derived in DWQI, 2018) rather than the USEPA RfD of 2 x 10^{-5} mg/kg/day as used by MDEQ.	
Links to TRV Sources	https://dep.nj.gov/wp-content/uploads/dsr/njdep-pfoa-pfos-rfc-memo.pdf DWQI. 2018. New Jersey Water Quality Institute. Health-Based Maximum Contaminant Level Suport Document: Perfluorooctane Sulfonate (PFOS). https://www.nj.gov/dep/watersupply/pdf/pfos-recommendation-appendix-a.pdf https://casetext.com/regulation/michigan-administrative-code/department-environmental-quality/air-quality-division/part-2-air-use-approval/section-r-3361232-methodology-for-determining-initial-threshold-screening-level	

4.10.4. Texas TCEQ

TABLE 47. TEXAS TCEQ SHORT- AND LONG-TERM ESL AND RFC FOR PFOS (CAS 1763-23-1)

Variable	Value	Comment

Short-term ESL	0.1 µg/m^3	No supporting documentation for Short-Term ESL. Short-term ESL set on July 12, 2011. Information below for updated RfC.
Long-term ESL	0.01 µg/m^3	No supporting documentation for Long-Term ESL. Long-term ESL set on July 12, 2011. Information below for updated RfC.
RfC	0.081 µg/m^3	***Information for this row and below comes from a February 14, 2023 update to derivation of PFAS RfDs and RfCs.
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	--
Critical study	Zeng HC, Li YY, Zhang L, et al. 2011. Prenatal exposure to perfluorooctanesulfonate in rat resulted in long-lasting changes of expression of synapsins and synaptophysin. Synapse 65(3): 225-33.	--
Species	Rats	--
Target Organ	Brain (developmental neurotoxicity)	--
Description of TRV endpoints/ basis for points of departure (POD)	Adverse development of three structures of synapses in the hippocampus: active zone length, number of vesicles per area, and synaptic interface curvature	Maternal and offspring.
Other Endpoints	--	--
Uncertainty Factors	For deriving the RfD: Total UF = 263 x 1 x 10 x 10 x 1 = 26,300	Interspecies TK UF = 263 Interspecies TD UF = 1 LOAEL to NOAEL UF = 10 Intrahuman UF = 10 Database UF = 1
POD Method	LOAEL	LOAEL of 0.6 mg/kg/day for adverse effects to the hippocampus synaptic structures
Human Equivalent Concentration in TRV?	Not explicit in calculation	UFs applied.
Duration of exposure	Gestation days 0 to 20	--
Time Adjustment in TRV?	No	--

Developmental or Reproductive Effects?	Developmental	Critical effect is neurodevelopmental
Oral to inhalation extrapolation	PFOS RfD = 0.6 mg/kg/day / (263 x 1 x 10 x 10 x 1) = 2.3E-05 mg/kg/day Using PFOS RfD = 2.3E-05 mg/kg/day: PFOS RfC = 2.3E-05 mg/kg/day x 70 kg / 20 m3/day = 8.1E-05 mg/m^3 = 0.081 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3	
Additional notes	--	
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.11. Perfluorooctanesulfonamide (PFOSA) (CAS 754-91-6)

ERG identified a non-carcinogenic health-based RfC for PFOSA. The identified value comes from Texas (TCEQ), which uses PFOA as a surrogate for PFOSA.[1] Cancer screening values were not identified.

Developmental and reproductive effects were observed for PFOA in the source document but not PFOSA. In addition, ATSDR's 2022 Toxicological Profile cited a study that found an increased time to pregnancy associated with serum FOSA levels (though the author noted that the results should be interpreted with caution), birth weight in boys, and neurodevelopmental outcomes.

PFOSA is not present on the DOT list of inhalation hazards.

Did not use the TCEQ value but did apply the TCEQ rationale (highlighted in footnote) that PFOA can be used as a 1:1 surrogate for this TAC. Therefore, DEQ proposes to apply the DEQ-proposed TRVs and target organ information for PFOA to this TAC as well.

4.11.1. Texas TCEQ

TABLE 48. TEXAS TCEQ RFC FOR PFOSA (CAS 754-91-6)

Variable	Value	Comment
RfC	4.1 x 10^{-3} µg/m3	***TCEQ uses PFOA as a surrogate. Information in this table is for PFOA RfC derivation (see footnote).

[1] TCEQ's justification for using PFOA as a surrogate for PFOSA is as follows:"For perfluorooctane sulfonamide (PFOSA), only LD50 data were found in the Registry of Toxic Effects of Chemical Substances (RTECS). The rodent oral LD50 of > 172 mg/kg for PFOSA may be similar to that for PFOA (LD50 of 189 mg/kg), another 8-carbon PFAS for which the toxicity database is more robust. The RfD for PFOA has a more scientifically defensible basis than using an uncertain LD50 value to derive an RfD for PFOSA. The RfD for PFOA was used as the surrogate for PFOSA."

Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation study	--
Critical study	Kennedy GL, Hall GT, Brittelli MR, et al. 1986. Inhalation toxicity of ammonium perfluorooctanoate. Food Chem Toxicol 24(12):1325-1329.	--
Species	Rats	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	Increases in relative and absolute liver weights and histological alternations in the livers	--
Other Endpoints	10% decrease in newborn bodyweight and 37% decreased weight gain in dams	--
Uncertainty Factors	Total UF = 81 x 3 x 10 x 10 x 10 = 243,000	UF (animal to human TK) = 81 UF (animal to human TD) = 3 UF (subacute to chronic) = 10 UF (sensitive individuals) = 10 UF (data insufficiency) = 10
POD Method	NOAEL	--
Human Equivalent Concentration in TRV?	Not explicit in calculation	UF applied
Duration of exposure	Whole-body exposure to APFO dusts 6 hours/day on gestation days 6 to 15	--
Time Adjustment in TRV?	No	--
Developmental or Reproductive Effects?	Developmental	PFOA oral RfD in same document derived based on developmental endpoints.
Oral to inhalation extrapolation	No	
Additional notes	PFOA RfC = 1 mg/m^3 / (81 x 3 x 10 x 10 x 10) = 4.1E-06 mg/m^3 = 0.0041 µg/m^3 No information was available on the ESLs that were set by TCEQ. ERG emailed TCEQ for additional information and was provided the documentation for the updated RfC values described here.	

Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome

4.12. Perfluorononanoic acid (PFNA) (CAS 375-95-1)

ERG identified a non-carcinogenic health-based RfC for PFNA. The identified value comes from Texas (TCEQ). Cancer screening values were not identified.

Developmental or reproductive effects were not observed for PFNA the TCEQ TRV source document. However, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with effects on reproductive hormone levels, menopause onset, breastfeeding duration, and fertility, pregnancy outcomes, birth outcomes, neurodevelopmental outcomes, and development of the reproductive system. The Toxicological Profile also cites developmental or reproductive effects for multiple laboratory animal studies.

PFNA is not present on the DOT list of inhalation hazards.

This TCEQ RfC is the only value available. DEQ proposes to modify and apply it as an acute rather than a chronic TRV. The exposure was only 4 hours long, and that leaves too much uncertainty to use it for a chronic value as TCEQ has done. DEQ also proposes to adjust exposure time from 4 to 24 hours. See Document 4: Proposed TRVs Where DEQ is the Authoritative Source for details on these modifications. No other values available to choose from for inhalation. One strength of the study upon which this value is based is that it was an inhalation toxicity study, so no route-to-route extrapolation was necessary.

4.12.1. Texas TCEQ

TABLE 49. TEXAS TCEQ RFC FOR PFNA (CAS 375-95-1)

Variable	Value	Comment
RfC	0.028 µg/m^3	--
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Acute inhalation rat study	--

Critical study	Kinney LA, Chromey NC, Kennedy Jr GL. 1989. Acute inhalation toxicity of ammonium perfluorononanoate. Food Chem Toxicol 21(1):46-68.	--
Species	Rats	--
Target Organ	Lungs	--
Description of TRV endpoints/ basis for points of departure (POD)	Lung noise and labored breathing	--
Other Endpoints	18% reduced body weight five-days post exposure	--
Uncertainty Factors	Total UF = 81 x 3 x 10 x 10 x 10 = 243,000	Interspecies TK UF = 81 Interspecies TD UF = 3 Subacute to chronic UF = 10 Intrahuman UF = 10 Database UF (data insufficiency) = 10
POD Method	NOAEL	NOAEL of 67 mg/m^3
Human Equivalent Concentration in TRV?	Not explicit in calculation	UF applied.
Duration of exposure	4 hours	
Time Adjustment in TRV?	No	
Developmental or Reproductive Effects?	No	
Oral to inhalation extrapolation	No	
Additional notes	PFNA RfC = 67 mg/m3 / (81 x 3 x 10 x 10 x 10) = 2.8E-05 mg/m3 = 0.028 µg/m3	
Links to TRV Sources	TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.13. Perfluorodecanoic acid (PFDA) (CAS 335-76-2)

ERG identified a non-carcinogenic RfC for PFDA. The identified value comes from Texas (TCEQ). Cancer screening values were not identified.

Developmental or reproductive effects were not observed for PFDA the TCEQ TRV source document. However, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with effects on reproductive hormone levels, sperm, breastfeeding duration, pregnancy outcomes, birth outcomes, neurodevelopmental outcomes, and development of the reproductive system. The Toxicological Profile also cites developmental or reproductive effects for multiple laboratory animal studies.

PFDA is not present on the DOT list of inhalation hazards.

DEQ proposes to adopt this TCEQ value without modification as the chronic TRV for this TAC. There were no other options available from sources researched by ERG.

4.13.1. Texas TCEQ

TABLE 50. TEXAS TCEQ RFD FOR PERFLUORODECANOIC ACID (PFDA) (CAS 335-76-2)

Variable	Value	Comment
RfC	0.053 µg/m^3	--
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral rat study	RfC derived from oral RfD
Critical study	Kawashima Y, Kobayashi H, Miura H, et al. 1995. Characterization of hepatic responses of rat to administration of perfluorooctanoic and perfluorodecanoic acids at low levels. Toxicology 99(3):169178.	TCEQ references USEPA 2022 tox assessment, which cites Kawashima et al. 1995
Species	Rat	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	Increased liver weight	--
Other Endpoints	Body weight gain reduction, food consumption reduction	--
Uncertainty Factors	For calculating RfD: Total UF = 81 x 1 x 10 x 10 x 10 = 81,000	UF (animal to human TK) = 81 UF (animal to human TD) = 1 UF (subacute to chronic) = 10 UF (sensitive individuals) = 10 UF (data insufficiency) = 10
POD Method	NOAEL	The LOAEL for increased liver weight (≈ 30% greater than control) was 2.4 mg/kg/day, with an associated NOAEL of 1.2 mg/kg/day

Human Equivalent Concentration in TRV?	Interspecies UF of 81	"TCEQ will use the most conservative data-based TK interspecies extrapolation factor available from other RfD derivations for longer carbon chain PFAS as a surrogate for PFDA (i.e., the TK interspecies extrapolation factor of 81 for PFOA [8- carbon] is the most conservative surrogate value for PFDA [10-carbon]). TCEQ will assume the ratio of human-to-rodent half-lives for PFDA is the same as that for PFOA (i.e., the PFDA half-lives for both humans and rats/mice are assumed to be increased by the same factor over those for PFOA, maintaining the human-to-rat half-life ratio of approximately 81)"
Duration of exposure	1 week (sub-acute)	--
Time Adjustment in TRV?	Not explicit in calculation	Subacute to chronic UF applied.
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	Yes (see below)	
Additional notes	PFDA RfD = 1.2 mg/kg/day / (81 x 1 x 10 x 10 x 10) = 1.5E-05 mg/kg/day Using PDFA RfD = 1.5E-05 mg/kg/day PFDA RfC = 1.5E-05 mg/kg/day x 70 kg/20 m^3/day = 5.3E-05 mg/m^3 = 0.053 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3	
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.14. Perfluorododecanoic acid (PFDoDA) (CAS 307-55-1)

ERG identified a non-carcinogenic health-based screening value for PFDoDA. The identified value comes from Texas. Cancer screening values were not identified.

Developmental or reproductive effects were not observed for PFDoDA the TCEQ TRV source document. However, ATSDR's 2022 Toxicological Profile found multiple epidemiological studies with developmental or reproductive effects including associations with effects on reproductive hormone levels and birth

outcomes. The Toxicological Profile also cites developmental or reproductive effects for multiple laboratory animal studies.

PFDoDA is not present on the DOT list of inhalation hazards.

DEQ proposes to adopt this TCEQ value unmodified as chronic TRV for this TAC. No other options are available.

4.14.1. Texas TCEQ

TABLE 51. TEXAS RFC FOR PERFLUORODODECANOIC ACID (PFDODA) (CAS 307-55-1)

Variable	Value	Comment
RfC	0.042 µg/m^3	*Note TCEQ abbreviates this is PFDoA
Date	February 14, 2023	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Subacute oral rat study	--
Critical study	Shi Z, Zhang H, Liu Y, et al. 2007. Alterations in gene expression and testosterone synthesis in the testes of male rats exposed to perfluorododecanoic acid. Toxicol Sci 98(1):206-215.	TCEQ references ATSDR 2009 tox profile, which cites Shi et al. 2007
Species	Rat	--
Target Organ	Body weight	--
Description of TRV endpoints/ basis for points of departure (POD)	25% reduction in body weight	--
Other Endpoints	Decreased serum testosterone and estradiol	--
Uncertainty Factors	For calculating RfD: Total UF = 81 x 10 x 10 x 10 = 81,000	UF (animal to human TK) = 81 UF (subacute to chronic) = 10 UF (sensitive individuals) = 10 UF (data insufficiency) = 10
POD Method	NOAEL	NOAEL of 1 mg/kg/day for reduced body weight

Human Equivalent Concentration in TRV?	Interspecies UF of 81	"TCEQ will use the most conservative data-based TK interspecies extrapolation factor available from other RfD derivations for longer carbon chain PFAS as a surrogate for PFDoA (i.e., the TK interspecies extrapolation factor of 81 for PFOA [8-carbon] is the most conservative surrogate value for PFDoA [12-carbon]). TCEQ will assume the ratio of human-to-rat halflives for PFDoA is the same as that for PFOA (i.e., the PFDoA half-lives for both humans and rats are assumed to be increased by the same factor over those for PFOA, maintaining the human-to-rat half-life ratio of approximately 81)."
Duration of exposure	14 day daily oral gavage	--
Time Adjustment in TRV?	Not explicit in calculation.	Subacute to chronic UF applied.
Developmental or Reproductive Effects?	No	
Oral to inhalation extrapolation	Yes (see below)	
Additional notes	PFDoA RfD = 1 mg/kg/day / (81 x 1 x 10 x 10 x 10) = 1.2E-05 mg/kg/day Using PFDoA RfD = 1.2E-05 mg/kg/day: PFDoA RfC = 1.2E-05 mg/kg/day x 70 kg / 20 m^3/day = 4.2E-05 mg/m^3 = 0.042 µg/m^3 Where the human adult body weight is 70 kg, and the human daily ventilation volume is 20 m^3	
Links to TRV Sources	https://www.tceq.texas.gov/downloads/toxicology/pfc/pfcs.pdf TAMIS database: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome	

4.15. 6:2-Fluorotelomersulfonic acid (6:2 FTS) (CAS 27619-97-2)

ERG identified non-carcinogenic health-based screening values for 6:2 FTS. The identified values come from Michigan and ECHA and range from 1 to 1,080 µg/m^3. Cancer screening values were not identified.

Developmental and reproductive effects were not observed for 6:2 FTS.

6:2 FTS is not present on the DOT list of inhalation hazards.

TABLE 52. INHALATION TRVS FOR 6:2 FTS (CAS 27619-97-2)

State/Agency	TRV	TRV	Classification	DEQ Notes
Michigan EGLE	Annual ISTL	1 µg/m^3	Non-cancer, long-term	Unmodified – no other appropriate values available
ECHA	Occupational DNEL	1,080 µg/m^3 (1.08 mg/m^3)	Non-cancer, long-term	Derived based on and for occupational exposures

4.15.1. Michigan EGLE

TABLE 53. MICHIGAN EGLE ITSL FOR 6:2 FTS (CAS 27619-97-2)

Variable	Value	Comment
ITSL	1 µg/m^3	Annual Averaging time
Date	September 24, 2020	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	RfD derived from 90-day (subchronic) oral rat study conducted by ECHA	--
Critical study	ECHA, 2020	--
Species	Rats	--
Target Organ	Liver, skin, developmental	--
Description of TRV endpoints/ basis for points of departure (POD)	Skin encrustations, sparsely haired areas, and encrustations around the eyes).	No statistically significant developmental findings
Other Endpoints	--	--
Uncertainty Factors	Total UF = 3 x 10 x 10 x 10 = 3000	UF (animal to human) = 3 UF (sensitive humans) = 10 UF (subchronic to chronic) = 10 UF (data insufficiency) = 10
POD Method	NOAEL	NOAEL = 5 mg/kgBW/day
Human Equivalent Concentration in TRV?	Yes	A human equivalent dose ($NOAEL_{HED}$) is calculated from the rats using a dosimetric adjustment factor (DAF) based on the human to animal body weight ratios.
Duration of exposure	90-days	--
Time Adjustment in TRV?	Yes, annual time averaging	--

Developmental or Reproductive Effects?	Developmental and reproductive studies with mixed results. "The higher T4 levels in male pups in low- and mid-dose groups could be indicative of an adverse effect at the 5 mg/kg (low-dose) group."
Oral to inhalation extrapolation	Yes
Additional notes	Chronic ITSL = RfD × body weight/daily inhalation rate × unit conversion Chronic ITSL = 0.00039 mg/kgBW/day × 70kg/20m³ × 1000µg/mg Chronic ITSL = 1.37 µg/m³ Chronic ITSL = 1 µg/m³; rounded to 1 significant figure
Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=27619972&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/27619-97-2/27619-97-2_annual_ITSL.pdf

4.15.2. ECHA

TABLE 54. ECHA OCCUPATIONAL DNEL FOR 6:2 FTS (CAS 27619-97-2)

Variable	Value	Comment
Occupational Long-term DNEL	1,080 µg/m³ (1.08 mg/m³)	Derived No Effect Level
Date	September 26, 2019	Derived No Effect Level
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Combined repeated oral dose toxicity study with the reproduction/developmental toxicity screening test	--
Critical study	Key study not named	--
Species	Rat	--
Target Organ	Kidney	--
Description of TRV endpoints/ basis for points of departure (POD)	Mild to moderate multifocal tubular dilatation	--
Other Endpoints	--	--
Assessment Factors	Total AF = 2 x 2.5 x 5 = 25	AF (subchronic to chronic) = 2 AF (oral to inhalation) = 2.5 AF (animal to human) = 5
POD Method	NOAEL	NOAEL = 15 mg/kg bw/day LOEC= 45 mg/kg bw/day

Human Equivalent Concentration in TRV?	Original NOAEL = 15 mg/kg bw/day Corrected NOAEL = 15 mg/kg bw/day * (1/0.38 m^3/kg/day) * 6.7m^3/10m^3 = 26.45 mg/m3	Calculated using R.8.4.2 of ECHA guidelines: https://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf/e153243a-03f0-44c5-8808-88af66223258
Duration of exposure	90 days	--
Time Adjustment in TRV?	Through Assessment Factors.	--
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	Accounted for in UF	
Additional notes	Long-term DNEL = Corrected NOAEL / Total AF = 26.45/25 = 1.06 mg/m^3 (Note DNEL set at 1.08, unclear why there is a difference).	
Links to TRV Sources	Dossier: https://chem.echa.europa.eu/100.044.149/dossier-view/618aa105-1c47-4bc7-9633-bb54ae800bcd/b4ff75f2-02a8-43b2-8ab3-86580b6aaf07_96ab02e6-6a70-4f8e-b823-912bd773ffad?searchText=27619-97-2 ECHA Calculation Guidelines: https://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf/e153243a-03f0-44c5-8808-88af66223258	

4.16. Hexafluoropropylene oxide dimer acid (HFPO-DA/Gen-X) (CAS 62037-80-3)

ERG identified non-carcinogenic health-based screening values for HFPO-DA/Gen-X. The identified values come from New Jersey and ECHA and range from 0.01 to 140 µg/m^3. Cancer screening values were not identified.

Developmental and reproductive effects were observed for HFPO-DA/Gen-X in TRV source documents.

HFPO-DA/Gen-X is not present on the DOT list of inhalation hazards.

TABLE 55. INHALATION TRVS FOR HFPO-DA/GEN-X (CAS 62037-80-3)

State/Agency	TRV	TRV	Classification	DEQ Notes
New Jersey DEP	RfC	0.01 µg/m^3	Non-cancer, chronic	Unmodified
ECHA	Occupational DNEL	140 µg/m^3 (0.14 mg/m^3)	Non-cancer, chronic	Derivation not transparent and occupational value
	General Population DNEL	40 µg/m^3 (0.04 mg/m^3)	Non-cancer, chronic	Derivation not transparent

4.16.1. New Jersey DEP

TABLE 56. NEW JERSEY DEP ITSL / RFC FOR HFPO-DA/GEN-X (CAS 62037-80-3)

Variable	Value	Comment
RfC	0.01 µg/m^3	--
Date	January 25, 2022	
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Oral reproductive and developmental mouse study	Adopted USEPA assessment and RfD of 3 ng/kg/day
Critical study	DuPont-18405-1037. (2010). An Oral (Gavage) Reproduction/Developmental Toxicity Screening Study of H-28548 in Mice. U.S. EPA OPPTS 870.3550; OECD Test Guideline 421. E.I. du Pont de Nemours and Company. Study conducted by WIL Research Laboratories, LLC (Study Completed: December 29, 2010), Ashland, OH	As assessed by USEPA Toxicity Assessment of GenX
Species	Mouse	
Target Organ	Liver	
Description of TRV endpoints/ basis for points of departure (POD)	Combined incidence of several histopathological changes	
Other Endpoints	--	--
Uncertainty Factors	Total UF for RfD = 3 x 10 x 10 x 10 = 3000	Animal to human UF = 3 Sensitive individuals UF = 10 Subchronic to chronic UF = 10 Data insufficiency UF = 10
POD Method	BMDL10	BMDL10 = 0.09 mg/kg/day
Human Equivalent Concentration in TRV?	POD_{HED} of 0.01 mg/kg/day	Dose to animals (ng/kg/day) x dosimetric adjustment factor (DAF) (unitless) = HED (ng/kg/day) 0.09 mg/kg/day x 0.14 = 0.01 mg/kg/day
Duration of exposure	F0 female mice: Daily doses 2 weeks prior to mating through LD20 (total of 53-64 days).	--

Time Adjustment in TRV?	No expected duration adjustment, but sub-chronic to chronic UF applied.	--
Developmental or Reproductive Effects?	Developmental and Reproductive	
Oral to inhalation extrapolation	POD (mg/kg/day) / UF = RfD (mg/kg/day) 0.01 mg/kg/day / 3000 = $3x10^{-6}$ mg/kg/day RfC (µg/m3) = RfD (µg/kg/day) x [(body weight, kg) ÷ (inhalation rate per day, m^3/day)] RfC = 0.003 µg/kg/day * (70kg) / (20 m^3/day) = 0.01 µg/m^3	
Additional notes	Based on USEPA Toxicity Assessment for Genx.	
Links to TRV Sources	https://dep.nj.gov/wp-content/uploads/dsr/hfpo-da-genx-tsd.pdf USEPA, 2021. Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3), Also Known as "GenX Chemicals". U.S. Environmental Protection Agency Office of Water (4304T), Health and Ecological Criteria Division Washington, DC 20460. EPA Document Number: 822R-21-010. October 2021. https://www.epa.gov/system/files/documents/2021-10/genx-chemicals-toxicity-assessment_tech-edited_oct-21-508.pdf	

4.16.2. ECHA

TABLE 57. ECHA OCCUPATIONAL AND LONG-TERM DNEL FOR HFPO-DA/GEN-X (CAS 62037-80-3)

Variable	Value	Comment
Occupational Long-term DNEL	140 µg/m^3 (0.14 mg/m^3)	Derived No Effect Level
General Population Long-term DNEL	40 µg/m^3 (0.04 mg/m^3)	Derived No Effect Level
Date	May 31, 2022	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Chronic oral toxicity study	--

Critical study	Confidential Dupont study Not publicly available	According to ECHA: "The key study for DNEL calculation is an OECD 453 rat chronic toxicity study via oral administration." https://chem.echa.europa.eu/100.124.803/dossier-view/44e19448-3d8b-41cd-8d89-135229e77d95/IUC5-6d5b492b-6918-42cb-8907-3e5677c2df4d_30e1ec53-b1c5-4c8e-987c-453439169baa
Species	Rat	--
Target Organ	Liver	--
Description of TRV endpoints/ basis for points of departure (POD)	Focal cystic degeneration, focal necrosis, and centrilobular necrosis of the liver, with associated increases in cytotoxic liver enzymes	--
Other Endpoints	Pancreatic acinar cell tumours and testicular interstitial (Leydig) cell tumours	--
Assessment Factors	Total AF(workers) = 2.5 x 5 = 12.5 Total AF (general population) = 2.5 x 5 x 10 = 25	AF (oral to inhalation) = 2.5 AF (animal to human, workers) = 5 AF (animal to human, general population) = 10
POD Method	NOAEC	NOAEL = 1.0 mg/m^3
Human Equivalent Concentration in TRV?	$NOAEL_{workers}$= 1.76 mg/m^3 $NOAEL_{general}$ = 0.87 mg/m^3	$NOAEL_{workers}$ = NOAEL * 1/0.38m^3 * 0.67 Where, 1/0.38 m^3 is the standard respiratory volume conversion from rat to human, and 0.67 is the increased respiratory volume in active workers as compared to individuals at rest $NOAEL_{general}$ = NOAEL * 1/1.15 m^3 Where, 1/1.15m^3 is the conversion factor for 24-hour respiratory volume from rat to human
Duration of exposure	Daily exposure for up to 104 weeks (males) or 101 weeks (females)	--
Time Adjustment in TRV?	Unclear	--
Developmental or Reproductive Effects?	No	--

Oral to inhalation extrapolation	"Since the substance was determined to be completely absorbed from the gastrointestinal tract, no modification of the starting point was needed to correct for oral administration as compared to inhalation."
Additional notes	$DNEL_{workers}$ = $NOAEL_{workers}$ / $AF_{workers}$ = 1.76 mg/m^3 / 12.5 = 0.14 mg/m^3 $DNEL_{general}$ = $NOAEL_{general}$ / $AF_{general}$ = 0.87 mg/m^3 / 25 = 0.04 mg/m^3
Links to TRV Sources	ECHA Calculation Guidelines: https://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf/e153243a-03f0-44c5-8808-88af66223258 Dossier: https://chem.echa.europa.eu/100.124.803/dossier-view/44e19448-3d8b-41cd-8d89-135229e77d95/f3fb00e0-3ca7-42c5-8b37-3b37b4127349_f3fb00e0-3ca7-42c5-8b37-3b37b4127349?searchText=62037-80-3

4.17. Perfluorobutylethylene (PFBE) (CAS 19430-93-4)

ERG identified non-carcinogenic health-based screening values for PFBE. The identified values come from Michigan and ECHA and range from 2,600 µg/m^3 to 1,031,400 µg/m^3 (1,031.4 mg/m^3). Cancer screening values were not identified.

Developmental and reproductive effects were observed for PFBE in various TRV source documents.

PFBE is not present on the DOT list of inhalation hazards.

TABLE 58. INHALATION TRVS FOR PERFLUOROBUTYLETHYLENE (PFBE) (CAS 19430-93-4)

State/Agency	TRV	TRV	Classification	DEQ Notes
Maryland DE	8-hour* Screening Level	10,065.4 µg/m^3	Non-cancer, chronic	Derived from occupational
Michigan EGLE	8-Hour ITSL**	10,000 µg/m^3	Non-cancer, chronic	Derived from occupational
	Annual ITSL	2,600 µg/m^3	Non-cancer, chronic	Unmodified
ECHA	Occupational DNEL	1,031,400 µg/m^3 (1,031.4 mg/m^3).	Non-cancer, chronic	Derived from and for occupational exposures
	General Population DNEL	256,600 µg/m^3 (256.6 mg/m^3)	Non-cancer, chronic	Not transparently derived – no critical study named

* Calculated from an occupational exposure limit that assumes an 8-hour workday and a 40-hour workweek

** Described as 'short-term' by EGLE compared to 'annual' ITSL; however, calculated from ACIGH TLV based on 8-hour workday assumptions.

4.17.1. Maryland DE

TABLE 59. MARYLAND DE 8-HOUR SCREENING LEVEL FOR PFBE (CAS 19430-93-4)

Variable	Value	Comment
8-hour Screening Level	10,065.4 µg/m^3	Non-carcinogenic, 8-hour screening level. Calculated from a TLV-TWA, "for a conventional 8-hour workday and a 40-hour workweek"
Date	--	Calculated from an ACGIH TLV but year/date not provided.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	Calculated from an ACGIH TLV.
Critical study	--	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation?	--	No information on derivation.
Additional notes	ERG reached out to Maryland DE to obtain the Agency's current TRV values and their derivations. MDE responded by noting that the TRV was set by the ACGIH TLV. Other information was not provided. According to regulation: "If a toxic air pollutant (TAP) has a threshold limit value-time weighted average (TLV-TWA), divide the TLV-TWA by 100 to calculate an 8-hour time-weighted average screening level".	

Links to TRV Sources	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx https://www.law.cornell.edu/regulations/maryland/COMAR-26-11-16-03 (see email from MDE).

4.17.2. Michigan EGLE

TABLE 60. MICHIGAN EGLE 8-HOUR AND ANNUAL ISTL FOR PFBE (CAS 19430-93-4)

Variable	Value	Comment
8-Hour ITSL	10,000 µg/m^3	8-hour averaging time ITSL
Annual ITSL	2,600 µg/m^3	annual averaging time ITSL
Date	July 9, 2021	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Short-term ITSL: Occupational Exposure limit derived a TWA for PFBE of 100 ppm based on hematological effects in 2001 Long-term ITSL: ECHA rat inhalation study.	Short-term: ACGIH TWA
Critical study	Long-term: ECHA 2021 Study report dated 2001	Short-term: ACGIH TWA, unclear of original study
Species	Long-term: Rat	Short-term: Unclear original study
Target Organ	Short-term: Hematological system Long-term: Respiratory	--
Description of TRV endpoints/ basis for points of departure (POD)	Short-term: Hematological effects Long-term: Congestion and weight loss	--
Other Endpoints	Additional chronic endpoints: urine chemistry changes, kidney, and liver changes	
Uncertainty Factors	Short-term: 100 Long-term: "Safety Factors" = 20 x 10 x 10 = 2000	Short-term: unclear source of 100 in formula. Long-term: UF (subacute to chronic) = 20 UF (animal to human) = 10 UF (sensitive humans) = 10
POD Method	Short-term: OEL Long-term: NOAEC	Short-term ITSL = OEL/100 Long-term ITSL = NOAEC / SF * Dosimetric Adjustment
Human Equivalent Concentration in TRV?	Short-term ITSL: No Long-term ITSL: Yes	--

Duration of exposure	Short-term: Single exposure Long-term: 28 consecutive days	
Time Adjustment in TRV?	Short-term ITSL: No Long-term ITSL: Yes	Long-term: Dosimetric adjustment of 6 hours exposed per day divided by 24 hours.
Developmental or Reproductive Effects?	A developmental study was discussed in the supporting documentation, but "no treatment-related fetal effects" were observed.	
Oral to inhalation extrapolation	--	
Additional notes	Short-term: ACGIH OEL = 100 ppm ITSL = OEL/100 ppm to µg/m3: Y µg/m^3 = (100 ppm)(246.076)/(24.45) x 1000 µg/m3 = 1.0 x 10^6 µg/m^3 (rounded) ITSL = 1,000,000/100 = 10,000 µg/m^3 Annual: NOAEC = 2069 ppm x 6 hours/24 hours = 517 ppm PPM to µg/m3: Y µg/m3 = (X ppm)(molecular weight)/24.45 x 1000 µg/mg Y µg/m3 = (517 ppm)(246.076 MW)/24.45 x 1000 µg/mg = 5.2 x 10^6 µg/m3 Annual ITSL = 5.2 x 10^6 µg/m^3 / UFs Annual ITSL = 5.2 x10^6 µg/m^3/(20 x 10 x 10)= 2600 µg/m^3 (annual)	
Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=19430934&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/19430-93-4/19430-93-4_annual_ITSL.pdf	

4.17.3. ECHA

TABLE 61. ECHA OCCUPATIONAL AND GENERAL POPULATION DNEL FOR PFBE (CAS 19430-93-4)

Variable	Value	Comment
Occupational Long-term DNEL	1,031.4 mg/m^3	Derived No Effect Level
General Population Long-term DNEL	256.6 mg/m^3	Derived No Effect Level
Date	June 26, 2017	--

Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Inhalation toxicity study	--
Critical study	Key study not named	--
Species	Rat	--
Target Organ	--	--
Description of TRV endpoints/ basis for points of departure (POD)	Total white blood cell count reduction; reduction in body weight gain [neither considered toxicologically significant]	--
Other Endpoints	--	--
Assessment Factors	Total $AF_{workers}$= 2 x 2.5 x 5 x 2 = 50 Total $AF_{general}$ = 2 x 2.5 x 10 x 2 = 100	AF (subchronic to chronic) = 2 AF (animal to human) = 2.5 AF (sensitive individuals, workers) = 5 AF (sensitive individuals, general population) = 10 AF (data insufficiency) = 2
POD Method	NOAEC = 102,625.8 mg/m^3	
Human Equivalent Concentration in TRV?	Corrected $NOAEL_{workers}$ = 102625.8 x 0.67 x 0.75 = 51569.5 mg/m^3 Corrected $NOAEL_{general}$ = 102625.8 x 0.25 = 25656.5 mg/m^3	<u>Workers:</u> Correct for respiratory volume (from resting rat to active human): 6.7 m^3 / 10 m^3 = 0.67 Correct for exposure time (from 6 hour rat to 8 hour human): 6 / 8 = 0.75 <u>General population:</u> Correct for exposure from 6 hour rat to 24 hour human: 6/24 = 0.25
Duration of exposure	90 days, 6 hours/day for 5 days/week	--
Time Adjustment in TRV?	Subchronic to chronic UF	--
Developmental or Reproductive Effects?	No	--
Oral to inhalation extrapolation	No	

Additional notes	Occupational DNEL = Corrected $NOAEL_{workers}$ / $AF_{workers}$ = 51569.5 mg/m³ / 50 = 1,031.4 mg/m³ General Population DNEL = Corrected $NOAEL_{general}$ / $AF_{general}$ = 25656.5 mg/m³ / 100 = 256.6 mg/m³ "At the time of registration a proposal was submitted to ECHA to perform a 90 -day (subchronic) study by inhalation in the rat, which was accepted. The study has now been completed and is reported in the update. The NOAEC in this 90 -day study is 102,625.8 mg/m3 (10,200 ppm). This is an increase in NOAEC when compared to the previous key study, a 28 -day inhalation study in rat (NOAEC 20123.0 mg/m3) (DuPont Study Number 02 G01001). Moreover, histopathological changes that were observed in the larynx, lungs and the liver of rats exposed to 9879 ppm in the 28 -day study, which at the time were thought to be treatment related, were not observed in the 90 -day study. As a result the DNEL is revised accordingly."
Links to TRV Sources	Dossier: https://chem.echa.europa.eu/100.039.124/dossier-view/e817a741-c3b7-4675-a2fc-8fe904f3d7cc/6dccbce2-14c2-4023-b848-b9f405a09134_de42cf1b-213b-46f9-b438-8258d9fef067?searchText=19430-93-4 ECHA Calculation Guidelines: https://echa.europa.eu/documents/10162/13632/information_requirements_r8_en.pdf/e153243a-03f0-44c5-8808-88af66223258

4.18. Perfluoroisobutene (PFIB) (CAS 382-21-8)

ERG identified non-carcinogenic health-based screening values for PFIB. The identified values come from Maryland, Michigan, and Wisconsin and range from 0.8 to 8.18 µg/m³. Cancer screening values were not identified.

Developmental and reproductive effects were not observed for PFBE in TRV source documents.

PFIB is not present on the DOT list of inhalation hazards.

DEQ does not propose to establish a TRV for this TAC. No suitable values available.

TABLE 62. INHALATION TRVS FOR PERFLUOROISOBUTYLENE (PFIB) (CAS 382-21-8)

State/Agency	TRV	TRV	Classification	DEQ Notes
Maryland DE	1-Hour Screening Level	0.82 µg/m³	Non-cancer, acute	Derived from occupational
	8-Hour Screening Level*	0.41 µg/m³	Non-cancer, chronic	Derived from occupational
Michigan EGLE	1-Hour ITSL	0.8 µg/m³	Non-cancer, acute	Derived from occupational

Wisconsin DNR	1-Hour Ambient Air Standard	8.18 µg/m^3	Non-cancer, acute	Derived from occupational

** Calculated from an occupational exposure limit that assumes an 8-hour workday and a 40-hour workweek

4.18.1. Maryland DE

TABLE 63. MARYLAND DE 8-HOUR SCREENING LEVEL FOR PFIB (CAS 382-21-8)

Variable	Value	Comment
1hr Screening Level	0.82 µg/m^3	Non-carcinogenic, 1-hour screening level. Calculated from a ceiling TLV (TLV-C) or a short term exposure limit (TLV-STEL).
8hr Screening Level	0.41 µg/m^3	Non-carcinogenic, 8-hour screening level. Calculated from a TLV-TWA, "for a conventional 8-hour workday and a 40-hour workweek"
Date	--	Year/date of derivation or study not provided.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	1-hour: Occupational Exposure Limit 8-hour: LC50	1-hour: ACGIH ceiling TLV (TLV-C) or a short-term exposure limit (TLV-STEL), 8-hour: Calculated from an LC50 approach.
Critical study	--	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation?	--	No information on derivation.

Additional notes	ERG reached out to Maryland DE to obtain the Agency's current TRV values and their derivations. MDE responded by noting that the 8-hour screening level was set by an LC50, and the 1-hour screening level was set by an ACGIH value. Other information was not provided. According to regulation, to calculate an 8-hour screening level: "If a TAP has neither a TLV, nor a special screening level, nor an acceptable ambient level,… Divide an LC50 in milligrams/cubic meter for rats, mice, or rabbits by 10,000". For a 1-hour screening level: "If a TAP has a ceiling TLV (TLV-C) or a short term exposure limit (TLV-STEL), divide the TLV-C or TLV-STEL by 100 to calculate a 1-hour time-weighted average screening level"
Links to TRV Sources	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx https://www.law.cornell.edu/regulations/maryland/COMAR-26-11-16-03 (see email from MDE).

4.18.2. Michigan EGLE

TABLE 64. MICHIGAN EGLE ITSL FOR PFIB (CAS 382-21-8)

Variable	Value	Comment
ITSL	0.8 µg/m^3	1-hour averaging time
Date	August 1, 2003	Based on ACGIH value from 1992
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	ACGIH TLV-Ceiling value of 0.01 ppm (0.082 mg/m^3)
Critical study	NA – ACGIH value	No information on derivation.
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	100	Facto of 1/100 included in regulatory formula when using OEL. No explanation of source of 100.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.

Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	--	No information on derivation.
Oral to inhalation extrapolation	--	No information on derivation.
Additional notes	ITSL = OEL/100 = 0.082 mg/m^3 / 100 = 0.8 µg/m^3	
Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=382218&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/382-21-8/382-21-8_1hr_ITSL.pdf	

4.18.3. Wisconsin DNR

Table 65. Wisconsin DNR 1-hour Ambient Air Standard for PFIB (CAS 382-21-8)

Variable	Value	Comment
1-hour AAL	8.18 µg/m^3	--
Date	--	Not clear when added to list.
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Occupational Exposure Limit	ACGIH's TLV and biological indices for 2000
Critical study	--	--
Species	--	No information on derivation.
Target Organ	--	No information on derivation.
Description of TRV endpoints/ basis for points of departure (POD)	--	No information on derivation.
Other Endpoints	--	No information on derivation.
Uncertainty Factors	--	No information on derivation.
POD Method	--	No information on derivation.
Human Equivalent Concentration in TRV?	--	No information on derivation.
Duration of exposure	--	No information on derivation.
Time Adjustment in TRV?	--	No information on derivation.
Developmental or Reproductive Effects?	-	

Oral to inhalation extrapolation	-
Additional notes	Wisconsin DNR provided information on derivation. 1-hour averaging time Ambient Air Standard set as 10% of the ACGIH 2000 TLV. ACGIH 2000 TLV documentation not available.
Links to TRV Sources	See Email and documents from Wisconsin DNR http://docs.legis.wisconsin.gov/code/admin_code/nr/400/445.pdf https://dnr.wisconsin.gov/topic/AirQuality/Rules.html

4.19. Perfluorobutylethylmethyldichlorosilane (CAS 38436-16-7)

ERG identified a non-carcinogenic health-based screening value for Perfluorobutylethylmethyldichlorosilane. The identified value comes from Michigan EGLE. Cancer screening values were not identified.

Developmental and reproductive effects were not reported for Perfluorobutylethylmethyldichlorosilane in the Michigan EGL TRV source document.

Perfluorobutylethylmethyldichlorosilane is not present on the DOT list of inhalation hazards.

DEQ does not propose a TRV for this TAC. The only available tox value is from Michigan EGLE (below) and is based on an oral LD50 as the point of departure. DEQ considers this too uncertain to derive a TRV.

4.19.1. Michigan EGLE

TABLE 66. MICHIGAN EGLE ISTL FOR PERFLUOROBUTYLETHYLMETHYLDICHLOROSILANE (CAS 38436-16-7)

Variable	Value	Comment
ITSL	2 µg/m^3	Annual
Date	June 16, 2021	--
Source of TRV derivation (e.g., oral/inhalation study, occupational exposure limit, nontoxicological endpoint)	Acute oral toxicity studies in rats reported by ECHA	--

Critical study	ECHA, 2021	ECHA (European Chemical Authority). 2021. Dossier on Perfluorobutylethylmethyldichlorosilane. Available at: https://echa.europa.eu/registration-dossier/-/registered-dossier/21967
Species	Rats	--
Target Organ	Systemic, death	--
Description of TRV endpoints/ basis for points of departure (POD)	Death	-
Other Endpoints	Lethargy, ataxia, righting response, piloerection, and prostration	--
Uncertainty Factors	--	ITSL formula divides LD50 by multiple factors but there is no explanation on what those factors are for: 1/500, 1/40, and 1/100 (see formula below).
POD Method	LD50	--
Human Equivalent Concentration in TRV?	--	Unclear from formula if there is an explicit Human Equivalent concentration (see formula below).
Duration of exposure	Acute exposure (once)	--
Time Adjustment in TRV?	--	Unclear from formula if there is an explicit time adjustment (see formula below).
Developmental or Reproductive Effects?	No	-
Oral to inhalation extrapolation	Yes	(see notes below).
Additional notes	ITSL = 1/500 x 1/40 x 1/100 x (LD50 mg/kg x W_A) / (0.167 x I_A) LD50 = 890 mg/kg W_A = Body weight of the experimental animal in kilograms = 0.273-0.307 kg Initial wt. I_A = Daily inhalation rate of experimental animal in m3/day using Cal EPA regression model equation I = 0.702 x $bw^{2/3}$ in m^3/day or 0.702 x $0.273^{2/3}$ = 0.298 m^3/day and 0.702 x $0.307^{2/3}$ = 0.322 m^3/day of 0.31 m^3/day average Therefore: ITSL = 1/500 x 1/40 x 1/100 x (890 mg/kg x 0.29 kg) / (0.167 x 0.31 m^3/day) = 0.00249 mg/m3 or 2 µg/m^3 (rounded to 1 significant figure).	

Links to TRV Sources	https://www.egle.state.mi.us/itslirsl/results.asp?Chemical_Name=&CASNumber=38436167&cmdSubmit=Submit https://www.egle.state.mi.us/aps/downloads/ATSL/38436-16-7/38436-16-7_annual_ITSL.pdf

Appendix A – List of government agency websites reviewed for inhalation toxicity values

State	Agency	Website
Alabama	Alabama Department of Environmental Management	https://adem.alabama.gov/programs/air/airquality.cnt
Alaska	Department of Environmental Conservation / Division of Air Quality	https://dec.alaska.gov/air/anpms/toxics/health/
Arizona	Arizona Department of Environmental Quality	https://www.azdeq.gov/SIP
Arkansas	Arkansas Department of Energy and Environment / Office of Air Quality	https://www.adeq.state.ar.us/air/
California	CalEPA California Air Resources Board (CARB) Department of Pesticide Regulation	https://oehha.ca.gov/air/general-info/toxic-air-contaminant-list-staff-reportsexecutive-summaries https://ww2.arb.ca.gov/resources/documents/toxic-air-contaminant-identification-reports https://www.cdpr.ca.gov/docs/legbills/calcode/040201.htm#a6860
Colorado	Colorado Department of Public Health and Environment	https://cdphe.colorado.gov/air-toxics https://cdphe.colorado.gov/toxic-air-contaminant-list
Connecticut	Department of Energy and Environmental Protection	https://portal.ct.gov/DEEP/Air/Planning/Toxics/Air-Toxics---Background-Information
Delaware	Department of Natural Resources and Environmental Control / Division of Air Quality	https://dnrec.delaware.gov/air/quality/air-toxics/#:~:text=Gaseous%20air%20toxic%20pollutants%20include,a%20solvent%20by%20various%20industries.
Florida	Department of Environmental Protection/ Division of Air Resources Management	https://floridadep.gov/Air

Georgia	Georgia Environmental Protection Division	https://epd.georgia.gov/air-protection-branch-technical-guidance-0/toxic-impact-assessment-guideline https://epd.georgia.gov/document/document/appendix-list-tap-aac-and-mer/download
Hawaii	Hawaii Department of Health / Clean Air Branch	https://health.hawaii.gov/cab/
Idaho	Idaho Department of Environmental Quality	https://www.deq.idaho.gov/air-quality/
Illinois	Illinois Pollution Control Board	https://pcb.illinois.gov/
Indiana	Indiana Department of Environmental Management / Air Toxics Program	https://www.in.gov/idem/toxic/
Iowa	Iowa Department of Natural Resources	https://www.iowadnr.gov/environmental-protection/air-quality/air-pollutants
Kansas	Department of Health and Environment / Division of Environment	https://www.kdhe.ks.gov/166/Air
Kentucky	Kentucky Energy and Environment Cabinet	https://eec.ky.gov/Environmental-Protection/Air/Pages/Air-Quality-Regulations.aspx
Louisiana	Louisiana Department of Environmental Quality	https://deq.louisiana.gov/faq/category/19
Maine	Maine Department of Environmental Protection	https://www.maine.gov/dep/air/monitoring/index.html
Maryland	Maryland Department of the Environment	https://mde.maryland.gov/programs/permits/airmanagementpermits/pages/toxicairpollutantregulationdocuments.aspx
Massachusetts	Massachusetts Department of Environmental Protection	https://www.mass.gov/info-details/massdep-ambient-air-toxics-guidelines
Michigan	Department of Environment, Great Lakes, and Energy	https://www.michigan.gov/egle/about/organization/air-quality/air-toxics
Minnesota	Minnesota Pollution Control Agency / Minnesota Department of Health	https://www.pca.state.mn.us/business-with-us/pollutant-categories-for-air-toxics https://www.health.state.mn.us/communities/environment/risk/guidance/air/table.html
Mississippi	Mississippi Department of Environmental Quality	https://www.mdeq.ms.gov/air/air-emissions-standards/national-emission-standards-for-hazardous-air-pollutants/
Missouri	Missouri Department of Natural Resources / Division of Environmental Quality / Air Pollution Control Program	https://dnr.mo.gov/air/hows-air/pollutants-sources/hazardous-air-pollutants-haps https://dnr.mo.gov/document-search/table-

		hazardous-air-pollutants-screening-model-action-levels-risk-assessment-levels
Montana	Montana Department of Environmental Quality	https://deq.mt.gov/air/index
Nebraska	Nebraska Department of Environment and Energy	http://dee.ne.gov/NDEQProg.nsf/OnWeb/AirToxics
Nevada	Nevada Division of Environmental Protection	https://ndep.nv.gov/air/air-pollutants
New Hampshire	New Hampshire Department of Environmental Services	https://www.des.nh.gov/air/industrial-sources/air-toxics-compliance
New Jersey	New Jersey Department of Environmental Protection	https://dep.nj.gov/airplanning/airtoxics/ PFOA and PFOS: https://dep.nj.gov/wp-content/uploads/dsr/njdep-pfoa-pfos-rfc-memo.pdf
New Mexico	New Mexico Environment Department	https://www.env.nm.gov/air-quality/
New York	New York Department of Environmental Conservation / Air Toxics Program	https://dec.ny.gov/environmental-protection/air-quality/controlling-pollution-from-facilities/air-toxics-program
North Carolina	North Carolina Department of Environmental Quality	https://www.deq.nc.gov/about/divisions/air-quality/air-quality-planning/air-quality-rules-regulations/hazardous-air-pollutants-and-toxic-air-pollutants-haps-taps
North Dakota	North Dakota Department of Environmental Quality	https://deq.nd.gov/aq/permitting/HAPs.aspx
Ohio	Ohio Environmental Protection Agency	https://epa.ohio.gov/divisions-and-offices/air-pollution-control/reports-and-data/air-toxics
Oklahoma	Oklahoma Department of Environmental Quality	https://www.deq.ok.gov/air-quality-division/emissions-inventory/oklahoma-regulated-air-pollutants/
Pennsylvania	Pennsylvania Department of Environmental Protection	https://www.dep.pa.gov/Business/Air/BAQ/MonitoringTopics/ToxicPollutants/pages/default.aspx
Rhode Island	Rhode Island Department of Environmental Management	https://dem.ri.gov/environmental-protection-bureau/air-resources/air-monitoring
South Carolina	South Carolina Department of Health and Environmental Control	https://scdhec.gov/environment/air-quality/compliance-monitoring/hazardous-air-pollutants-reporting-standards-major
South Dakota	South Dakota Department of Agriculture and Natural Resources	https://danr.sd.gov/Environment/AirQuality/PermitForms/default.aspx
Tennessee	Tennessee Department of Environment and Conservation	https://www.tn.gov/environment/air.html
Texas	Texas Commission on Environmental Quality	https://www.tceq.texas.gov/toxicology/index.html

Utah	Utah Department of Environmental Quality	https://deq.utah.gov/air-quality/macts-and-other-neshaps-air-toxics-lead-and-asbestos-section-atlas
Vermont	Vermont Department of Environmental Conservation	https://dec.vermont.gov/air-quality/pollutants-health/haz-air-contaminants
Virginia	Virginia Department of Environmental Quality	https://www.deq.virginia.gov/our-programs/air/monitoring-assessments/air-monitoring/pollutant-monitoring
Washington	Washington Department of Ecology	https://ecology.wa.gov/Air-Climate/Air-quality/Air-quality-targets/Air-quality-standards#:~:text=Lead%20(Pb),Particle%20or%20particulate%20matter%20(PM)
West Virginia	West Virginia Department of Environmental Protection	https://dep.wv.gov/daq/small%20business/Pages/HazardousAirPollutants.aspx
Wisconsin	Wisconsin Department of Natural Resources	https://dnr.wisconsin.gov/topic/AirQuality/Rules.html
Wyoming	Wyoming Department of Environmental Quality	https://deq.wyoming.gov/aqd/
International Organizations		
Australia	Australian Government / Department of Climate Change, Energy, the Environment and Water	https://www.dcceew.gov.au/environment/protection/air-quality/air-pollutants
Canada	Government of Canada / Environment and Natural Resources	https://www.canada.ca/en/environment-climate-change/services/air-pollution/pollutants/toxic.html https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances/list-canadian-environmental-protection-act.html
European Union	European Environment Agency / European Chemicals Agency	https://www.eea.europa.eu/en/topics/in-depth/air-pollution?activeAccordion= https://environment.ec.europa.eu/topics/air/air-quality/eu-air-quality-standards_en https://echa.europa.eu/air-annexes-2008-50?p_p_id=eucleflegislationlist_WAR_euclefportlet&p_p_lifecycle=0 https://chem.echa.europa.eu/
World Health Organization	Air quality, energy and health	https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants