Health Based Guidance for Air
Site Assessment and Consultation Unit
Environmental Health Division
651-201-4897

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Air Toxicological Summary for: PERFLUOROOCTANE SULFONATE (PFOS)

CAS: 1763-23-1
Synonyms: PFOS, Perfluorooctane sulfonic acid

Air Exposure Durations:
Acute - 1-hour and/or 24-hours
Intermediate - greater than 24-hours, up to approximately 1 year
Chronic - greater than 1 year to a lifetime

In 2024, the Minnesota Department of Health's (MDH) Health Risk Assessment (HRA) Unit completed a re-evaluation of health-based guidance for PFOS in groundwater that focused on epidemiological data. The 2024 air risk assessment advice for PFOS is derived from the updated 2024 PFOS groundwater health-based guidance data.

Noncancer Acute Risk Assessment Advice (RAA_{Acute}) = Not Derived (Insufficient Data)

Noncancer Intermediate, Chronic RAA ($RAA_{Intermediate, Chronic}$) = 0.0035 µg/m^3

Reference Dose (mg/kg-d) x Route-to-route scaling factor (kg/m^3) x (1000 µg/mg)

= 0.000001 (mg/kg-d) x (70 kg/20 m^3-d) x (1000 µg/mg)

= 0.0035 µg/m^3

Reference Dose:	RfSC * CR = 0.000001 mg/kg-d
Source of toxicity value:	Determined by MDH in 2024
Reference Serum Concentration (RfSC):	POD/UF = 2.6 ng/mL
Clearance Rate (CR):	0.39 mL/kg-d (CalEPA Office of Environmental Health Hazard Assessment 2023)

Point of Departure (POD):	7.7 ng/mL (equivalent to µg/L) serum concentration (US EPA 2023a,b), $BMDL_{5\%}$ for decreased birth weight from (Wikström 2020)
Dose Adjustment Factor (DAF):	Not applicable (POD is based on human serum level)
Human Equivalent Dose (HED):	Not applicable (POD is based on human serum level)
Total uncertainty factor (UF):	3
Uncertainty factor allocation:	A database UF of 3 was applied to account for remaining database uncertainties regarding potential adverse effects at or near the serum POD concentration (e.g., immune effects, liver effects, thyroid effects). An UF for human toxicodynamic (TD) variability was not applied because the POD is based on a sensitive life stage (i.e., neonates). Differences in human TK were determined to be adequately addressed through the exposure scenario and parameter values selected for use in the TK model.[#]
Critical effect(s):	Decreased birth weight
Co-critical effect(s):	Decreased antibody titers in children, increased cholesterol
Additivity endpoint(s):	Developmental, Hepatic (liver) system, Immune system

[#]Further detail regarding the MDH HRA Unit's 2024 PFOS serum concentration and toxicokinetic model can be found on MDH's Human Health-Based Water Guidance Table's Toxicological Summary for Perfluorooctane sulfonate: https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfos.pdf

Cancer Risk Assessment Advice = Not Derived (insufficient data)

Cancer classification:	via oral routes - Likely to be carcinogenic to humans (US EPA 2023a,b) (MDH 2023); Presents a carcinogenic hazard (CalEPA Office of Environmental Health Hazard Assessment 2023); Group 2B (possibly carcinogenic to humans) (IARC 2023)
Tumor site(s):	via oral route - liver tumors were identified in rodent data

Volatile: No

Summary of Guidance Value History: MDH previously developed air RAA for PFOS in 2021. The 2021 RAA was based on the previous 2020 MDH groundwater PFOS RfD.

Summary of toxicity testing for health effects identified in the Health Standards Statute (144.0751):
Note: MDH's HRA unit conducted a re-evaluation that focused on epidemiological data and sensitive health endpoints.

	Endocrine	Immunotoxicity	Development	Reproductive	Neurotoxicity	Respiratory
Tested for specific effect?	Yes	Yes	Yes	Yes	Yes	Yes
Effects observed?	Yes[1]	Yes[2]	Yes[3]	Yes[4]	Yes[5]	Yes[6]

Comments on extent of testing or effects:

[1] MDH 2024; Evidence for endocrine effects in humans following PFOS exposure is largely based on increased TSH (thyroid stimulating hormone) and T3 (triiodothyronine) in adults and T4 (thyroxine) in children. However, findings in epidemiology studies were inconsistent, likely due in part to diurnal variations, differential effects across genders and age groups, timing of sampling, and limited number of studies. US EPA (2023a,b) considers the current level of evidence suggestive but not indicative of adverse endocrine effects due to PFOS exposure due to the uncertainty in results. A database uncertainty factor has been incorporated into the reference serum level to reflect the need for more data regarding thyroid effects. Studies of oral exposures in laboratory animals have demonstrated clear and consistent alterations in serum thyroid hormone levels, increased thyroid gland weight, and increased follicular cell hypertrophy in the thyroid gland. Previous MDH guidance was based, in part, on thyroid effects in animals.

[2] MDH 2024; In humans, it is widely accepted that PFOS exposure is likely associated with reduced antibody response, especially in infants and children. Immune effects are listed as a co-critical additivity endpoint based on a vaccine response study in young children. Additionally, there is some evidence for increases in asthma and respiratory infections. In animal models, there is consistent evidence of decreased antibody response, decreased spleen and thymus weight, and alterations in immune cell function after oral PFOS exposure.

[3] MDH 2024; In humans, it is widely accepted that decreased birth weight is likely associated with maternal PFOS serum levels. This likely association is supported by additional epidemiological evidence of related effects such as decreased birth length and postnatal growth. Low birth weight is the basis of the reference serum concentration. Among the animal studies, decreased postnatal growth leading to developmental effects (e.g., lower pup body weight, delayed eye opening) have been observed after oral PFOS exposure.

[4] MDH 2024; The evidence for male reproductive effects in humans is limited and largely based on suggestive associations between PFOS exposure and testosterone levels in male children and adults and decreased anogenital distance in children. Considerable uncertainties in these associations exist due to inconsistencies across studies and the limited number of studies available. The evidence for female reproductive effects in humans is limited and largely based on suggestive associations between PFOS exposure and increased odds of preeclampsia. Considerable uncertainties in these associations exist due to inconsistencies across studies and the limited number of available studies. Among the animal studies, there is evidence for decreased testicular and epididymal weight, for decreased sperm count, and for hormonal changes in pups, and for increased neonatal mortality after oral PFOS exposure.

[5] MDH 2024; There is inconsistent evidence for PFOS exposure and neurotoxicity in humans. Most studies focused on neurodevelopment of infants and toddlers; across studies, both negative and positive associations on various developmental assessments were reported. In a small number of available animal studies, there is limited evidence suggesting neurobehavioral alterations from oral PFOS exposure.

[6] A human epidemiology cancer study reported no increases in the risk ratio episodes of care were found for the respiratory tract (estimated serum PFOS levels of 390–890 ng/mL) or high (estimated PFOS serum levels of 1,300–1,970 ng/mL). Animal studies report inhalation exposure to PFOS nasal discharge, rales, and/or labored breathing at concentrations between 1890 – 45970 mg/m^3 for 1-hour in rats. Pulmonary congestion was reported for rats exposed to 5 mg/kg/d for 28 days. Rats dosed with up to 1.04 mg/kg/d in the diet for 104 weeks did not reveal significant effects in the lungs or trachea. Monkeys dosed via ingested 2 mg/kg/d PFOS capsules for four weeks had no gross or microscopic effects on the lungs. A lower dose of 0.75 mg/kg/d, also in monkeys, for 26 weeks also did not produce gross or microscopic effects on the lungs or trachea.

References and Resources Consulted

A comprehensive reference list can be found on the health-based guidance for water PFOS toxicological summary: https://www.health.state.mn.us/communities/environment/risk/docs/guidance/gw/pfos.pdf

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