Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

ACETOCHLOR ESA (CASRN 187022-11-3)

Health Effects Summary

Human health effects associated with low environmental exposures to acetochlor ESA are unknown. However, EPA has concluded that acetochlor degradates are significantly less toxic than acetochlor and are unlikely to be carcinogenic.

Limited toxicological data exists for acetochlor ESA. Four-week and thirteen-week feeding studies in rats reported fewer toxicological effects compared with similar studies conducted with acetochlor. The critical effects were identified as reduced body weight, body weight gains, and reduced food utilization (calculated as body weight gain per 100 grams food eaten).

Data used for Groundwater IMAC

US EPA has not established an RfD or carcinogenic potential classification for acetochlor ESA.

No odor threshold, taste threshold, federal maximum contaminant level or secondary drinking water standard has been established for this chemical.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 1,000 µg/L was established under 15A NCAC 02L .0202(c) for acetochlor ESA in 2010. This value was based on an RfD value of 0.2 mg/kg/day reported by Gadagbui et al., 2010. No new toxicological information relevant to the derivation of a North Carolina groundwater standard is available.

Gadagbui et al., 2010 pointed out that an argument for an RfD of 0.075 mg/kg/day could also be made based on database inadequacies for acetochlor degradates. Given the limited number of studies available for the degradates, including the lack of toxicological data from two species, use of 0.075 mg/kg/day rather than 0.2 mg/kg/day as the RfD is recommended in establishing groundwater standards.

Using an RfD of 0.075 mg/kg/day, the calculated groundwater threshold concentration for acetochlor ESA is 525 µg/L rounded down to 500 µg/L in accordance with rounding conventions.

Groundwater standards are to be the “lesser of” the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for acetochlor ESA is 500 ug/L (ppb) based on its calculated “non-cancer” systemic threshold.

Uses

Acetochlor is a chloroacetanilide type herbicide with restricted usage for preemergent control of grasses and broadleaf weeds on agricultural crop land. Acetochlor degrades in water to form acetochlor ethanesulfonic acid (ESA) and acetochlor oxanilic acid (OSA). Acetochlor ESA and Acetochlor OXA are the most commonly detected environmental degradates of acetochlor in groundwater and surface water. Their measured concentrations are generally much higher than acetochlor.

References

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

Gadagbui B, Maier A, Dourson M, Parker A, Willis A, Christopher JP, Hicks L, Ramasamy S, and Roberts SM. 2010. Derived reference doses for the environmental degradates of the herbicides alachlor and acetochlor: Results of an independent expert panel deliberation. Regulatory Toxicology and Pharmacology, 57: 220-234.

U.S. EPA (2009). Contaminant Information Sheets for the Final CCL 3 Chemicals, Office of Water (EPA 815-R-09-012). https://www.epa.gov/ccl/contaminant-candidate-list-3-ccl-3

U.S. EPA Report of the Food Quality Protection Act (FQPA) Tolerance Reassessment Progress and Risk Management Decision (TRED) for Acetochlor (March 2006) http://www.epa.gov/pesticides/reregistration/acetochlor/.

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Acetochlor ESA CASRN 187022-11-3

North Carolina Groundwater (GW) IMAC = 500 µg/L

Summary

The North Carolina GW IMAC for acetochlor ESA, a degradate of the herbicide, acetochlor, is based on a noncancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below). Critical health endpoint: Reduced body weight, body weight gains, and food utilization in rats following subchronic oral exposures (90-day study).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	7.50E-02	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**525**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.00E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 0.4 µg/L

References

[1] Gadagbui B, Maier A, Dourson M, Parker A, Willis A, Christopher JP, Hicks L, Ramasamy S, and Roberts SM. 2010. Derived reference doses for the environmental degradates of the herbicides alachlor and acetochlor: Results of an independent expert panel deliberation. *Regulatory Toxicology and Pharmacology*, 57: 220-234. Uncertainty factor of 3000 rather than 1000 used to derive RfD based on database insufficiency (Publication Footnote 2).

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] NA; Acetochlor ESA has not been classified for carcinogenicity by US EPA or IARC due to a lack of experimental data. A cancer potency factor is not available.

[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[7] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 5/2/2016).

[8] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

[9] PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. EPA method 535 (Table 5) cites a Lowest Concentration Minimum Reporting Level (LCMRL) for a triple quadrapole analysis of acetochlor ESA (https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=103915&simpleSearch=1&searchAll=535).

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History

May 18, 2010 - Request by manufacturer to establish NC IMAC for Acetochlor ESA
December 1, 2010 - IMAC of 1000 µg/L approved by DWR Director. Recommended IMAC rounded down from 1400 µg/L.

ACETOCHLOR OXA (CASRN 184992-44-4)

Health Effects Summary
Human health effects associated with low environmental exposures to acetochlor OXA are unknown. However, EPA has concluded that acetochlor degradates are significantly less toxic than acetochlor and are unlikely to be carcinogenic.

Limited toxicological data exists for acetochlor OXA. Four-week and thirteen-week feeding studies in rats reported fewer toxicological effects compared with similar studies conducted with acetochlor. The critical effects were identified as reduced body weight, body weight gains, and reduced food utilization (calculated as body weight gain per 100 grams food eaten).

No treatment-related developmental effects were noted in a two-week rat developmental toxicity study conducted with acetochlor OXA although maternal toxicity was reported. The NOAEL for developmental effects was the highest dose tested (1000 mg/kg/day).

Data used for Groundwater IMAC
US EPA has not established an RfD or carcinogenic potential classification for acetochlor OXA.

No odor threshold, taste threshold, federal maximum contaminant level or secondary drinking water standard has been established for this chemical.

Recommended Groundwater IMAC
An interim maximum allowable concentration (IMAC) of 1000 µg/L was established under 15A NCAC 02L .0202(c) for acetochlor OXA in 2010. This value was based on an RfD value of 0.2 mg/kg/day reported by Gadagbui et al., 2010. No new toxicological information relevant to the derivation of a North Carolina groundwater standard is available.

Gadagbui et al., 2010 pointed out that an argument for an RfD of 0.075 mg/kg/day could also be made based on database inadequacies for acetochlor degradates. Given the limited number of studies available for the degradates, including the lack of toxicological data from two species, use of 0.075 mg/kg/day rather than 0.2 mg/kg/day as the RfD is recommended in establishing groundwater standards.

Using an RfD of 0.075 mg/kg/day, the calculated groundwater threshold concentration for acetochlor OXA is 525 µg/L rounded down to 500 µg/L in accordance with rounding conventions.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for acetochlor OXA is 500 ug/L (ppb) based on its calculated noncancer systemic threshold.

Uses
Acetochlor is a chloroacetanilide type herbicide with restricted usage for preemergent control of grasses and broadleaf weeds on agricultural crop land. Acetochlor degrades in water to form acetochlor ethanesulfonic acid (ESA) and acetochlor oxanilic acid (OSA). Acetochlor ESA and Acetochlor OXA are the most commonly detected environmental degradates of acetochlor in groundwater and surface water. Their measured concentrations are generally much higher than acetochlor.

References

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

Gadagbui B, Maier A, Dourson M, Parker A, Willis A, Christopher JP, Hicks L, Ramasamy S, and Roberts SM. 2010. Derived reference doses for the environmental degradates of the herbicides alachlor and acetochlor: Results of an independent expert panel deliberation. Regulatory Toxicology and Pharmacology, 57: 220-234.

U.S. EPA (2009). Contaminant Information Sheets for the Final CCL 3 Chemicals, Office of Water (EPA 815-R-09-012). https://www.epa.gov/ccl/contaminant-candidate-list-3-ccl-3

U.S. EPA Report of the Food Quality Protection Act (FQPA) Tolerance Reassessment Progress and Risk Management Decision (TRED) for Acetochlor (March 2006) http://www.epa.gov/pesticides/reregistration/acetochlor/.

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Acetochlor OXA CASRN 184992-44-4

North Carolina Groundwater IMAC = 500 µg/L

Summary

The North Carolina GW IMAC for acetochlor OXA, a degradate of the herbicide, acetochlor, is based on a noncancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below).
Critical health endpoint: Reduced body weight, body weight gains, and food utilization in rats following subchronic oral exposures (90- day study).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	7.50E-02	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**525**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.00E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 0.5 µg/L

References

1 Gadagbui B, Maier A, Dourson M, Parker A, Willis A, Christopher JP, Hicks L, Ramasamy S, and Roberts SM. 2010. Derived reference doses for the environmental degradates of the herbicides alachlor and acetochlor: Results of an independent expert panel deliberation. *Regulatory Toxicology and Pharmacology*, 57: 220-234. Uncertainty factor of 3000 rather than 1000 used to derive RfD based on database insufficiency (Publication Footnote 2).

2 Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

3 Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

4 Acetochlor OXA has not been classified for carcinogenicity by US EPA or IARC due to a lack of experimental data. A cancer potency factor is not available.

5 NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

6 NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

7 NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 5/2/2016).

8 NA; SMCL: https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

9 PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. EPA method 535 (Table 5) cites a Lowest Concentration Minimum Reporting Level (LCMRL) for a triple quadrapole analysis of acetochlor OXA (https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=103915&simpleSearch=1&searchAll=535).

NA = Not available

RSC = 0.1 for nonorganics, 0.2 for organics

History

May 18, 2010 - Request by manufacturer to establish NC IMAC for Acetochlor OXA.

December 1, 2010 - IMAC of 1000 µg/L approved by DWQ Director. Recommended IMAC rounded down from 1400 µg/L.

ALACHLOR (CASRN 15972-60-8)

Health Effects Summary

Human health effects associated with low environmental exposures to alachlor are unknown. Systemic effects were observed in the kidneys, spleens and livers of dogs exposed to alachlor for 1-year. Treatment-related nasal, stomach, and thyroid tumors were reported in two-year feeding studies in rats while broncheoalveolar adenomas and carcinomas were observed in 2-year mouse studies. Carcinogenic effects were observed at doses several fold larger than doses used in the chronic studies.

Data used for Groundwater IMAC

US EPA's Integrated Risk Information System (IRIS) established an oral reference dose (RfD) of 0.01 mg/kg-day for alachlor based on hemosiderosis (iron accumulation) in the kidney, liver, and spleen and hemolytic anemia (destruction of red blood cells) in the liver observed in a one-year feeding study in male dogs. (https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0129_summary.pdf)
A systemic threshold concentration of 70 ug/L (ppb) can be calculated using the oral reference dose for alachlor in accordance with 15A NCAC 02L .0202(d)(1).

US EPA classified alachlor as "likely" to be carcinogenic to humans at high doses but "not likely" at low doses according to EPA's proposed Guidelines for Cancer Risk Assessment (1996). The cancer slope factor used to calculate the 2010 IMAC has been withdrawn by EPA based on their re-evaluation and reclassification of alachlor carcinogenicity as a threshold effect. Therefore, a cancer potency factor is not available. A human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

No odor threshold or taste threshold has been established for alachlor. US EPA has established a federal drinking water maximum contaminant level (MCL) of 2 µg/L (ppb) for alachlor. A secondary drinking water standard has not been established.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 0.4 µg/L was established under 15A NCAC 02L .0202(c) for alachlor in 2010. This concentration was derived using a cancer potency factor that is no longer supported by EPA.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for alachlor is 2 ug/L (ppb) based on the federal maximum drinking water level (MCL).

Uses:

Alachlor is an herbicide used for control of annual grasses and broadleaf weeds in crops, primarily corn, sorghum, soybeans, peanuts, and beans. Products containing alachlor are classified as "restricted use" herbicides because of concern about groundwater contamination.

References

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. EPA Integrated Risk Information System. 1993. IRIS Summary for Alachlor. http://www.epa.gov/iris (accessed June 3, 2016)

U.S. EPA Pesticide Reregistration Status https://archive.epa.gov/pesticides/reregistration/web/html/status.html

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Alachlor CASRN 15972-60-8

North Carolina Groundwater (GW) IMAC = 2 µg/L

Summary The North Carolina GW IMAC for alachlor is based on the federal maximum contaminant level (MCL) in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below).
Critical health effect: Liver and blood toxicity effects in dogs (1-year study).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	1.00E-02	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**70**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.00E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**2**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 0.28 **µg/L**

References

[1] Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/ accessed 6/3/16). IRIS assessment last revised 9/1/93. Monsanto Company. 1984. MRID No. 00148923; HED Doc No. 004660.

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] NA; Alachlor has been classified by EPA as "likely" to be a human carcinogen at high doses, but "not likely" at low doses in accordance with the EPA proposed Guidelines for Carcinogen Risk Assessment (April 23, 1996). EPA determined that a non-linear margin of exposure (MOE) approach should be used for risk assessment rather than the q1* approach. EPA has withdrawn its calculated cancer potency factor for alachlor.

[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[7] MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 6/6/2016).

[8] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

[9] PQL established by North Carolina Water Quality lab. (ps://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/organic-chemistry- branch/methods-pqls-organics).

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History:
February 10, 2010 - Division of Waste Management requested IMAC for alachlor.
August 1, 2010 - IMAC of 0.4 µg/L approved by DWR Director.

N-BUTANOL (CASRN 71-36-3)

Health Effects Summary
Human health effects associated with low environmental exposures to n-butanol are unknown. There are limited toxicological data available for oral exposures to n-butanol. Rats exposed to n-butanol via gavage for 13 weeks exhibited central nervous system effects including hypoactivity and ataxia (lack of muscle coordination).

Data used for Groundwater IMAC
US EPA's Integrated Risk Information System (IRIS) established an oral reference dose (RfD) of 0.1 mg/kg-day for n-butanol (http://www.epa.gov/iris/). A systemic threshold concentration of 700 µg/L (ppb) can be calculated using the RfD for n-butanol in accordance with 15A NCAC 02L .0202(d)(1).

US EPA has not evaluated n-butanol for carcinogenicity via oral exposures. A cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

An odor threshold in aqueous solutions of 590 µg/L has been reported for n-butanol (Czerny et al., 2008). No taste threshold, federal maximum contaminant level or secondary drinking water standard has been established.

Recommended Groundwater IMAC
An interim maximum allowable concentration (IMAC) of 700 µg/L was established under 15A NCAC 02L .0202(c) for n-butanol in 2010. A more recent publication reporting a lower aqueous odor threshold for n-butanol than previously reported was located. Czerny et al., 2008 reported an aqueous threshold of 590 µg/L for n-butanol compared with 7,100 µg/L reported by Amoore et al., 1983.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for n-butanol is 590 µg/L (ppb) based on its aqueous odor threshold.

Uses
N-butanol is used as a solvent for dyes, as an additive for polishers, cleaners, de-icing fluids, and gasoline. It is used in the pharmaceutical industry as an extractant for naturally occurring antibiotics, hormones, vitamins, alkaloids, and camphor. It is also used as a feedstock in the industrial synthesis of glycol ethers, butyl monocarboxylates, and butyl xanthate.

References

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

Czerny M, Christlbauer M, Christlbauer M, Fisher A, Granvogl M, Hammer M, Hartl C, Noelia MH, and Schieberle. 2008. Re-investigation on odour thresholds of key food aroma compounds and development of an aroma language based on odour qualities of defined aqueous odorant solutions. European Food Research and Technology. 228:265-273.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. EPA Integrated Risk Information System. 1987. IRIS Summary for n-Butanol. http://www.epa.gov/iris/subst/0129.htm (accessed 7/29/2016).

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

n-Butanol CASRN 71-36-3

North Carolina Groundwater (GW) IMAC = 590 µg/L

Summary The North Carolina GW IMAC for n-butanol is based on its odor threshold in water in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below).
Critical health effect: Odor in aqueous solutions (not health-based).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	1.0E-01	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**700**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg /day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**590**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 20 µg/L

References

[1] Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/ accessed 7/26/16). IRIS assessment last revised 3/31/87. U.S. EPA. 1986. Butanol: Rat oral subchronic toxicity study. Office of Solid Waste, Washington, DC.

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] NA; n-Butanol is classified as Group Category D (not classifiable to human carcinogenicity). A cancer potency factor is not available.

[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[6] Czerny M, Christlbauer M, Christlbauer M, Fisher A, Granvogl M, Hammer M, Hartl C, Noelia MH, and Schieberle. 2008. Re-investigation on odour thresholds of key food aroma compounds and development of an aroma language based on odour qualities of defined aqueous odorant solutions. Eur Food Res Technol. 228:265-273.

[7] MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 7/26/2016)

[8] SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

[9] PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. New Jersey reports a PQL of 20 µg/L for n-butanol. http://www.nj.gov/dep/rules/rules/njac7_9c.pdf

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History:
February 2010 - Request by DWM to establish NC IMAC for n-butanol.
August 1, 2010 - IMAC of 700 µg/L approved by DWR Director.

2,4-DINITROTOLUENE (CASRN 121-14-2)
2,6-DINITROTOLUENE (CASRN 606-20-2)

Health Effects Summary
Human health effects associated with low environmental exposures to 2,4-dinitrotoluene and 2,6-dinitrotoluene are unknown. Both isomers may be absorbed through the skin. In humans, long-term occupational inhalation exposures to 2,4-dinitrotoluene have caused adverse effects to the central nervous system (CNS), heart, circulatory system, and liver. Oral administration of 2,4-dinitrotoluene and 2,6-dinitrotoluene to animals has produced adverse neurological, blood, reproductive, liver, and kidney effects. Cancer of the kidney, liver, and mammary glands has been reported in animals following long-term oral exposure to 2,4-dinitrotoluene, 2,6-dinitrotoluene and mixtures of nitrotoluenes.

Data used for Groundwater IMAC
U.S. EPA's Integrated Risk Information System (IRIS) established an oral reference dose (RfD) of 0.002 mg/kg-day for 2,4-dinitrotoluene based on neurotoxic effects (manifested as incoordination and paralysis), the presence of Heinz bodies (damaged hemoglobin within red blood cells), and biliary tract hyperplasia (increased cell production) in a 2-year dog feeding study (U.S. EPA, 1992; Ellis et al., 1979, https://www.epa.gov/iris). A systemic threshold concentration of 14 ug/L (ppb) can be calculated using the oral reference dose for 2,4-dinitrotoluene in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA established a Provisional Peer-Reviewed Toxicity Value (PPRTV) of 0.001 mg/kg-day as a provisional chronic oral RfD for 2,6-dinitrotoluene. This value was based on a NOAEL of 4 mg/kg-day reported from a 13-week oral-dosing dog study in which decreased body weight, neurological, hematological, and liver histopathological effects were reported (U.S. EPA, 2004; Lee et al., 1976, https://hhpprtv.ornl.gov/quickview/pprtv_papers.php). A systemic threshold concentration of 7 ug/L (ppb) can be calculated using the provisional oral reference dose for 2,6-dinitrotoluene in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA has classified the technical grade mixture of 2,4-dinitrotoluene and 2,6-dinitrotoluene isomers as B2 (probable human carcinogen based on sufficient evidence in animals and inadequate evidence in humans). EPA has classified 2,4-dinitrotoluene and 2,6-dinitrotoluene individually as likely to be carcinogenic to humans as referenced in the 2012 EPA Drinking Water Standards and Health Advisories.

U.S. EPA IRIS has calculated a cancer potency factor of 0.68 $(mg/kg\text{-}day)^{-1}$ for the isomeric mixture of 2,4-dinitrotoluene and 2,6-dinitrotoluene. A human exposure concentration of 0.05 µg/L associated with an incremental lifetime cancer risk estimate of 1×10^{-6} can be calculated for each isomer according to the requirements of 15A NCAC 02L .0202(d)(2).

Note: Experimental studies with 2,4-dinitrotoluene have included concurrent exposures to its isomers, including 2,6-dinitrotoluene. Studies evaluating the toxicological effects of pure (100%) individual isomers are not available. While U.S. EPA and Cal EPA have derived cancer slope factors for 2,4-dinitrotoluene, it is difficult to discern the isomeric contribution to the toxicological effects reported. It is recognized that there are uncertainties associated with the cancer slope factors available for dinitrotoluene isomers and mixtures. North Carolina has selected the cancer slope factor derived by U.S EPA (IRIS, 1990) and applied it for 2,4-dinitrotoluene and 2,6-dinitrotoluene based on EPA values reported in the 2012 Drinking Water Standards and Health Advisories Table. Other states, including Florida and Wisconsin have also used the same cancer slope factor for the individual isomers and the mixture (EPA Technical Fact Sheet, 2014).

No aqueous odor threshold, aqueous taste threshold, federal maximum contaminant level (MCL) or secondary drinking water standard are available for 2,4-dinitrotoluene or 2,6-dinitrotoluene.

Recommended Groundwater IMAC
An interim maximum allowable concentration (IMAC) of 0.1 µg/L was established under 15A NCAC 02L .0202(c) for 2,4-dinitrotoluene in 2011. This value was based on a cancer slope factor of 0.31 $(mg/kg\text{-}day)^{-1}$ derived by Cal OEHHA. U.S. The Cal OEHHA cancer slope factor was derived from the EPA cancer slope factor.

EPA calculated a cancer slope factor of 0.68 $(mg/kg\text{-}day)^{-1}$ for a mixture of 2,4-dinitrotoluene and 2,6-dinitrotoluene based on combined mammary and liver tumors reported in female rats in a long-term feeding study (Ellis et al., 1979). U.S. EPA equates the cancer slope factors for the individual isomers and the mixture. Since it is likely that 2,4-dinitrotoluene will co-exist with 2,6-dinitrotoluene, the slope factor derived by U.S EPA is used to derive a groundwater standard.

Chemical	Cancer Slope Factor (CSF)	Endpoint Modeled	CSF Reference
2,4-dinitrotoluene	0.31	Combined mammary and liver tumors (female rats)	Cal OEHHA, 2009
2,6-dinitrotoluene	Not derived	Not derived	US EPA PPRTV, 2004
98% 2,4 isomer, 2% 2,6-isomer mixture	0.68	Combined mammary and liver tumors (female rats)	US EPA IRIS, 1990
DNT Technical grade 76% 2,4 isomer, 19% 2,6 isomer, 5% other isomers	0.45 (provisional screening value)	Combined mammary and liver tumors, liver nodules, and subcutaneous fibromas (male rats)	US EPA PPRTV, 2013

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for 2,4-dinitrotoluene is 0.05 ug/L (ppb) based on the chronic drinking water concentration corresponding to an incremental lifetime cancer risk of 1 x 10^{-6}.

The recommended groundwater IMAC for 2,6-dinitrotoluene is 0.05 ug/L (ppb) based on the chronic drinking water concentration corresponding to an incremental lifetime cancer risk of 1 x 10^{-6}.

Uses:

Mixtures of dinitrotoluenes (DNT) are formed from the reaction of nitric acid and toluene with 2,4-dinitrotoluene generally formed in the largest proportion. 2,4-Dinitrotoluene is used as an intermediate in the manufacture of toluene diisocyanates used in polyurethane polymers, dyes, plastics, herbicides, and automobile airbags. It is also used in the manufacturing processes for explosives and propellants and as a modifier for smokeless gunpowder. DNT is commonly found at military ranges and near munitions manufacturing sites.

References

Agency for Toxic Substances and Disease Registry. Toxicological Profile for Dinitrotoluenes. 2016. US Department of Health and Human Services http://www.atsdr.cdc.gov/

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

Ellis HV III, Hagensen JH, Hodgson JR, Minor JL, and Hong CB. 1979. Mammalian toxicity of munitions compounds. Phase III: Effects of life-time exposure. Part I: 2,4-dinitrotoluene. Final report No.7. Fort Detrick, MD: US Army Medical Bioengineering Research and Development Laboratory. Order No. ADA077692. 281 pp. Midwest Research Institute Project No. 3900-B.

Ellis, H.V., C.B. Hong, C.C. Lee, J.C. Dacre and J.P. Glennon. 1985. Subchronic and chronic toxicity studies of 2,4-dinitrotoluene. Part I: Beagle dogs. J. Am. College Toxicol. 4(4): 233-242

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U.S. EPA Integrated Risk Information System. 1992. EPA IRIS Chemical Assessment Summary for 2,4-Dinitrotoluene. http://www.epa.gov/iris/ (accessed 10/27/16).

U.S. EPA Integrated Risk Information System. 1990. EPA IRIS Chemical Assessment Summary for 2,4-/2,6-Dinitrotoluene mixture. http://www.epa.gov/iris/ (accessed 10/31/16).

US EPA Drinking Water Health Advisory for 2,4-Dintrotoluene and 2,6-Dinitrotoluene. 2008. Office of Water. (822-R-08-010).

U.S. EPA Provisional Peer Reviewed Toxicity Value for 2,6-Dinitrotoluene (CASRN 606-20-2). 2004. Office of Research and Development, National Center for Environmental Assessment https://hhpprtv.ornl.gov/quickview/pprtv_papers.php

U.S. EPA Provisional Peer Reviewed Toxicity Value for 2,6-Dinitrotoluene (CASRN 606-20-2). 2013. Office of Research and Development, National Center for Environmental Assessment

U.S. EPA Provisional Peer Reviewed Toxicity Value for Technical Grade Dinitrotoluene (CASRN 25321-14-6). 2013. Office of Research and Development, National Center for Environmental Assessment https://hhpprtv.ornl.gov/quickview/pprtv_papers.php

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Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

2,4-Dinitrotoluene CASRN 121-14-2
2,6-Dinitrotoluene CASRN 606-20-2

North Carolina Groundwater (GW) IMAC (2,4-dinitrotoluene) = 0.05 µg/L
North Carolina Groundwater (GW) IMAC (2,6-dinitrotoluene) = 0.05 µg/L

Summary The North Carolina GW IMACs for 2,4-dinitrotoluene and 2,6-dinitrotoluene (2,4-DNT and 2,6-DNT) are based on a cancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below). Both isomers have been tested concurrently making it difficult to discern the isomeric contribution to reported adverse effects. Groundwater standards for each isomer are considered to be equivalent.
Critical health effect: Combined incidence of mammary and liver tumors in female rats (2-year feeding study).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

	2,4-DNT	2,6-DNT	
RfD = reference dose[1]	2.0E-03	1.0E-03	mg/kg/day
WT = average adult human body weight[2]	70	70	kg
RSC= relative source contribution[3]	0.2	0.2	unitless value
WI = average daily human adult water intake[4]	2	2	L/day
1000 = conversion factor	1000	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**14**	**7**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

	2,4-DNT	2,6-DNT	
RL = risk level	1.0E-06	1.0E-06	
WT = average adult human body weight[2]	70	70	kg
q1* = carcinogenic potency factor (slope factor)[5]	0.68	0.68	$(mg/kg /day)^{-1}$
WI = average daily human adult water intake[4]	2	2	L/day
1000 = conversion factor	1000	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**0.05**	**0.05**	**µg/L**

GW IMAC based on published values

	2,4-DNT	2,6-DNT	
Taste Threshold[6]	**NA**	**NA**	**µg/L**
Odor Threshold[7]	**NA**	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[8]	**NA**	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[9]	**NA**	**NA**	**µg/L**

	2,4-DNT	2,6-DNT	
Practical Quantitation Limit (PQL)[10]	10	10	µg/L

References

[1] 2,4-DNT - Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/ accessed 10/27/16). IRIS assessment for 2,4-dinitrotoluene last revised 6/1/92. Ellis, H.V., C.B. Hong, C.C. Lee, J.C. Dacre and J.P. Glennon. 1985. Subchronic and chronic toxicity studies of 2,4-dinitrotoluene. Part I. Beagle dogs. J. Am. College Toxicol. 4(4): 233-242. (Note that IRIS has a separate analysis for 2,4-dinitrotoluene/2,6-dinitrotoluene mixture).
2,6-DNT- Provisional Peer-Reviewed Toxicity Value (PPRTV) for 2,6-dinitrotoluene (2004). Lee, C-C., H.V. Ellis, J.J. Kowalski et al. 1976. Mammalian toxicity of munition compounds. Phase II: Effects of multiple doses. Part III: 2,6-Dinitrotoluene. Study conducted by the Midwest Research Institute for the U.S. Medical Bioengineering Research and Development Laboratory. Fort Detrick, Frederick, MD. AD A 062 015.

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] RSC=0.1 for nonorganics, 0.2 for organics in accordance with 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] Average adult water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[5] Technical grade dinitrotoluene (tg-DNT) is comprised of approximately 76% 2,4, dinitrotoluene, 20% 2,6-dinitrotoluene, and 5% other isomers. Technical grade DNT has been classified by EPA as "likely to be carcinogenic to humans". US EPA has calculated a cancer potency factor of 0.68 $(mg/kg\text{-}day)^{-1}$ for technical grade DNT. Individual cancer potency factors for 2,4-dinitrotoluene or 2,6-dinitrotoluene are not available.

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[7] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[8] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 10/27/16).

[9] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

[10] PQLs established by North Carolina Water Resources Laboratory under semi-volatiles. (https://ncdenr.s3.amazonaws.com/s3fs-public/Water%20Quality/Chemistry%20Lab/Operations/Organic%20Chemistry%20Branch/PQLsSVOA-20100212-DWQ-LAB-OPS.pdf)

NA = Not available

History

November 2010 - Request by DWM to establish NC IMAC for 2,4-dinitrotoluene.
April 1, 2011 - IMAC of 0.1 µg/L approved by DWR Director for 2,4-dinitrotoluene.

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

<u>DIPHENYL ETHER</u> (CASRN 101-84-8)

Health Effects Summary

Human health effects associated with low environmental exposures to diphenyl ether (phenyl ether) are unknown. Diphenyl ether is a dermal, respiratory, and ocular irritant. Toxicological data for oral exposures to diphenyl ether are limited to non-published or insufficiently reported research. In a 13-week feeding study, reduced food intake and body weight were observed according to a poorly reported study referenced by New Jersey Department of Environmental Protection.

Data used for Groundwater IMAC

U.S. EPA's Integrated Risk Information System (IRIS) has not established an oral reference dose (RfD) for diphenyl ether.

U.S. EPA has not established a provisional RfD for diphenyl ether. A systemic threshold concentration cannot be calculated for diphenyl ether in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA has not evaluated diphenyl ether for carcinogenicity via oral exposures. A cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

An aqueous odor threshold of 180 µg/L has been reported for diphenyl ether (Amoore et al., 1983). No aqueous taste threshold, federal maximum contaminant level (MCL) or secondary drinking water standard is available for diphenyl ether.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 100 µg/L was established under 15A NCAC 02L .0202(c) for diphenyl ether in 2010. This value was based on information included in the New Jersey Groundwater Standard for Diphenyl Ether (2008). There is low confidence in this IMAC given the limited and poorly referenced data available.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for diphenyl ether is 180 ug/L (ppb) based on its aqueous odor threshold.

Uses:

Diphenyl ether is used as a heat transfer agent in resins used for laminated electrical insulation and in the manufacture of high-temperature lubricants. It is also used as a fragrance for perfumes, soaps, and detergents and as a chemical intermediate in the manufacture of industrial chemicals.

References

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

European Commission Recommendation from the Scientific Committee on Occupational Exposure Limits for Diphenyl Ether. 2012.(SCOEL/SUM/182).

New Jersey Department of Environmental Protection. 2008. Groundwater Quality Standard for Diphenyl Ether. Water Monitoring and Standards, Bureau of Water Quality Standards and Assessment. http://www.nj.gov/dep/wms/bears/docs/diphenyl_ether.pdf.

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North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Diphenyl ether CASRN 101-84-8

North Carolina Groundwater (GW) IMAC = 180 µg/L

Summary The North Carolina GW IMAC for diphenyl ether (phenyl ether) is based on its aqueous odor threshold in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below).
Critical health effect: Aqueous odor threshold (not health-based).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	1.5E-02	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution[3]	0.2	unitless value
WI = average daily human adult water intake[4]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**105**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[5]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[4]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[6]	NA	**µg/L**
Odor Threshold (reported for phenyl ether)[7]	180	**µg/L**
Maximum Contaminant Level (MCL)[8]	NA	**µg/L**
Secondary Drinking Water Standard (SMCL)[9]	NA	**µg/L**

Practical Quantitation Limit (PQL)[10] 10 µg/L

References

1 No published RfD, p-RfD or similar toxicity value are available for diphenyl ether. An RfD was derived by the New Jersey Department of Environmental Protection (NJDEP) based on limited data. There is low confidence in this value given the limited and poorly referenced data available. (http://www.nj.gov/dep/wms/bears/docs/diphenyl_ether.pdf). 2 Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

3 RSC=0.1 for nonorganics, 0.2 for organics in accordance with 15A NCAC 02L .0202 (effective date April 1, 2013).

4 Average adult water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

5 NA; Diphenyl ether has not been evaluated for carcinogenicity. A cancer potency factor is not available.

6 NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

7 Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

8 NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 11/1/16).

9 NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

10 PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. New Jersey reports a PQL of 10 µg/L for diphenyl ether. (http://www.nj.gov/dep/wms/bears/docs/diphenyl_ether.pdf).

NA = Not available

History

November 8, 2010 - Request by DWM to establish NC IMAC for diphenyl ether.

April 1, 2011 - IMAC of 100 µg/L approved by DWR Director for diphenyl ether.

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

PERFLUOROOCTANE SULFONIC ACID (CASRN 1763-23-1)

Health Effects Summary

Human health effects associated with chronic, low environmental exposures to perfluorooctane sulfonic acid (PFOS) are unknown. Perfluorooctane sulfonic acid is slowly eliminated and therefore accumulates in the human body. Its estimated human serum biological half-life (time necessary for half of dose to be eliminated) is 4.8-5.4 years. The biological half-life of perfluorooctane sulfonic acid in other species, including rats and monkeys, is much smaller (48-121 days).

Animals exposed to perfluorooctane sulfonic acid via ingestion exhibited decreased body weight, decreased cholesterol, decreased liver weight, increased liver fat, and liver histopathology. Animal reproductive and developmental studies showed decrease survival and weight of offspring. Animals exposed during gestation and lactation had higher serum glucose levels and their offspring exhibit insulin resistance as adults

Epidemiological studies of workers exposed to perfluorooctane sulfonic acid via inhalation and general populations exposed via drinking water report increased cholesterol and high-density lipoproteins (HDLs), decreased female fertility and decreased weight of offspring.

Data used for Groundwater IMAC

U.S. EPA's Office of Water established an oral reference dose (RfD) of 0.00002 mg/kg-day for perfluorooctane sulfonic acid based on decreased rat pup body weight in a two-generation reproductive study (https://www.epa.gov/sites/production/files/2016-05/documents/pfos_hesd_final_508.pdf .
A systemic threshold concentration of 0.14 µg/L can be calculated using the oral reference dose for perfluorooctane sulfonic acid in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA considers perfluorooctane sulfonic acid as having "suggestive evidence of carcinogenic potential" according to its 2005 Guidelines for Carcinogen Risk Assessment. Liver tumors were reported at the highest dose tested in a long-term rat study. However, there is lack of demonstrated genotoxicity and comparable human epidemiological evidence from workers exposed to perfluorooctane sulfonic acid. The U.S. EPA Office of Water has not derived a cancer slope factor for perfluorooctane sulfonic because the weight of evidence for human carcinogenic is limited. A human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated per the requirements of 15A NCAC 02L .0202(d)(2).

No aqueous odor threshold, aqueous taste threshold, federal maximum contaminant level (MCL) or secondary drinking water standard has been established for perfluorooctane sulfonic acid.

Recommended Groundwater IMAC

U.S. EPA Office of Water issued a Health Advisory and Health Effects Support Document for Perfluorooctane Sulfonic Acid (PFOS) in 2016. The Health Advisory of 0.07 µg/L was calculated based on reduced pup body weight using the 90^{th} percentile drinking water intake and body weight of lactating women and represents the most recent evaluation published by the US EPA. Alternatively, the calculation provided by the derivation of the non-cancer endpoint (0.1 ug/L) is advised.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

The recommended groundwater IMAC for perfluorooctane sulfonic acid (PFOS) is 0.07 ug/L (ppb) based on the calculated noncancer systemic threshold using the 90th percentile drinking water intake and body weight of lactating women.

Uses

Perfluorooctane sulfonic acid is used as a water and oil repellent and as a surfactant in firefighting foams. It is used in carpet, upholstery, and textiles in waterproofing and stain resistance applications. It is also used in food packaging as a paper grease proofing agent. It is commonly used as the sodium or potassium form of the acid.

References

Agency for Toxic Substances and Disease Control. 2015. Toxicological Profile for Perfluoroalkyls. U.S. Department of Health and Human Services. (https://www.atsdr.cdc.gov/toxprofiles/index.asp)

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U.S. EPA Drinking Water Health Advisory for Perfluorooctane Sulfonic Acid (PFOS). 2016. Office of Water. (EPA 822-R-16-004) https://www.epa.gov/sites/production/files/2016-05/documents/pfos_hesd_final_508.pdf

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

PERFLUOROOCTANOIC ACID (PFOA) (CASRN 335-67-1)

Health Effects Summary

Human health effects associated with chronic, low environmental exposures to perfluorooctanoic acid (PFOA) are unknown. Perfluorooctanoic acid is slowly eliminated from humans and accumulates in the body. It has an estimated biological half-life (time necessary for half of dose to be eliminated) of 3.5-4 years.

Animals exposed to perfluorooctanoic acid via ingestion exhibited liver and kidney toxicity, immune effects, developmental effects and liver, testicular, and pancreatic cancer. Epidemiological studies of workers exposed to perfluorooctanoic acid via inhalation and general populations exposed via drinking water report high cholesterol, increased liver enzymes, decreased vaccination response, thyroid disorders, pregnancy induced hypertension and preeclampsia, and testicular and kidney cancer.

Data used for Groundwater IMAC

U.S. EPA's Office of Water established an oral reference dose (RfD) of 0.00002 mg/kg-day for perfluorooctanoic acid based on skeletal variations and accelerated puberty observed in male mice offspring (https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_hesd_final_508.pdf). A systemic threshold concentration of 0.14 µg/L can be calculated using the oral reference dose for perfluorooctanoic acid in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA considers perfluorooctanoic acid as having "suggestive evidence of carcinogenic potential" according to its 2005 Guidelines for Carcinogen Risk Assessment. U.S. EPA Office of Water derived a cancer slope factor of 0.07 $(mg/kg\text{-}day)^{-1}$ for perfluorooctanoic acid based on testicular cancer (Leydig cells) observed in rats. A human exposure concentration of 0.50 µg/L associated with an incremental lifetime cancer risk estimate of 1×10^{-6} can be calculated per the requirements of 15A NCAC 02L .0202(d)(2).

No aqueous odor threshold, aqueous taste threshold, federal maximum contaminant level (MCL) or secondary drinking water standard has been established for perfluorooctanoic acid.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 2 µg/L was established under 15A NCAC 02L .0202(c) for perfluorooctanoic acid in 2006. New toxicological information relevant to the derivation of a North Carolina groundwater standard is available. U.S. EPA Office of Water issued a Health Advisory and Health Effects Support Document for Perfluorooctanoic Acid (PFOA) in 2016. The Health Advisory of 0.07 µg/L was calculated based on potential adverse effects for fetuses during pregnancy and breastfed infants using the 90^{th} percentile drinking water intake and body weight of lactating women. Alternatively, the calculation provided by the derivation of the non-cancer endpoint (0.1 µg/L) is advised.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for perfluorooctanoic acid (PFOA) is 0.07 ug/L (ppb) based on the calculated noncancer systemic threshold using calculation parameters specific to lactating women.

Uses

Perfluorooctanoic acid is used as a water and oil repellent, a surfactant in firefighting foams, and as an intermediate in the synthesis of fluoroacrylic esters. It is used in Teflon, floor waxes and polishes, outdoor clothing and similar chemicals (known as fluorotelomers). According to the 2010/2015 EPA PFOA Stewardship Program, manufacture of PFOA was scheduled to be phased out by 2015.

References

Agency for Toxic Substances and Disease Control. 2015. Toxicological Profile for Perfluoroalkyls. U.S. Department of Health and Human Services. (https://www.atsdr.cdc.gov/toxprofiles/index.asp)

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

Lau, C., J.R. Thibodeaux, R.G. Hanson, M.G. Narotsky, J.M. Rogers, A.B. Lindstrom, and M.J. Strynar. 2006. Effects of perfluorooctanoic acid exposure during pregnancy in the mouse. Toxicological Sciences 90:510–518.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. EPA Guidelines for Carcinogen Risk Assessment. 2005. (EPA/630/P-03/001B). Risk Assessment Forum, Washington, DC. (https://www.epa.gov/risk/guidelines-carcinogen-risk-assessment).

U.S. EPA Health Effects Support Document for Perfluorooctanoic Acid (PFOA). 2016. Office of Water. (EPA 822-R-16-003) https://www.epa.gov/sites/production/files/201605/documents/pfoa_health_advisory_final-plain.pdf

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater
Interim Maximum Allowable Concentration (IMAC)
Calculation Sheet

Total Perfluorooctane sulfonic acid (PFOS) and Perfluorooctanoic acid (PFOA)

CASRNs 1763-23-1 and 335-67-1

North Carolina Groundwater (GW) IMAC = 0.07 µg/L*

Summary

The North Carolina GW IMAC for total perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA) is based on a noncancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202 (highlighted in yellow below). Critical health effect: Reduced pup body weight, 2-generation rat gavage study (PFOS) and reduced ossification of the forelimbs and hindlimbs and accelerated puberty in male mice pups (PFOA).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

	PFOS	PFOA	
RfD = reference dose[1]	2.0E-05	2.0E-05	mg/kg/day
WT = average adult human body weight[2]	70	70	kg
RSC= relative source contribution[3]	0.2	0.2	unitless value
WI = average daily human adult water intake[4]	2	2	L/day
1000 = conversion factor	1000	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**0.1**	**0.1**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

	PFOS	PFOA	
RL = risk level	1.0E-06	1.0E-06	
WT = average adult human body weight[2]	70	70	kg
q1* = carcinogenic potency factor (slope factor)[5]	NA	0.07	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[4]	2	2	L/day
1000 = conversion factor	1000	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**0.5**	**µg/L**

GW IMAC based on published values

	PFOS	PFOA	
Taste Threshold[6]	**NA**	**NA**	**µg/L**
Odor Threshold[7]	**NA**	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[8]	**NA**	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[9]	**NA**	**NA**	**µg/L**

Additional Information

	PFOS	PFOA	
US EPA Health Advisory for PFOA/PFOS (2016)[10]	**0.07**	**0.07**	**µg/L**

Practical Quantitation Limit (PQL)[11]

	PFOS	PFOA	
Practical Quantitation Limit (PQL)[11]	0.04	0.002	µg/L

References

[1] US EPA Drinking Water Health Advisory for Perfluorooctane sulfonic acid (PFOS). 2016. US EPA Office of Water (EPA 822-R-16-004); US EPA Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). 2016. US EPA Office of Water (EPA 822-R-16-005)

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] RSC=0.1 for nonorganics, 0.2 for organics in accordance with 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] Average adult water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[5] US EPA has not classified PFOS for carcinogenicity. A cancer slope factor is not available.
US EPA Office of Water derived a cancer slope factor for PFOA based on testicular cancer observed in rats. Human epidemiological studies evaluating the carcinogenicity of PFOA are equivocal for kidney and testicular cancer.US EPA Health Effects Support Document for Perfluorooctanoic Acid. 2016. US EPA Office of Water (EPA 822-R-16-003)

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[7] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[8] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic

[9] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals.

[10] US EPA Office of Water derived the Health Advisory for PFOS using the 90th percentile consumers-only estimate of combined direct and indirect community water ingestion for lactating women (Table 3-81 in US EPA 2011 Exposure Factors Handbook). A value of 0.054 L/kg-day was used in the calculation which equates roughly to 3.8 L of water consumed per day for a 65 Kg woman.

* EPA established equivalent Health Advisory Levels of 0.07 µg/L for PFOA and PFOS. The Health Advisory Level also applies to the sum total of both compounds if they co-occur.

[11] PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. Using EPA Method 537, Pace Analytical reports a PRL (ie- PQL) of 0.04 µg/L for PFOS and 0.002 µg/L for PFOA. (https://www.pacelabs.com/environmental-services/specialty-services/pfas-analysis.html)

NA = Not available

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

STRONTIUM (CASRN 7440-24-6)

Health Effects Summary

Human health effects associated with low environmental exposures to strontium are unknown. Strontium accumulates in bone and affects its growth; therefore, children are considered a sensitive population with regard to health effects associated with strontium exposures. Abnormal skeletal development (rickets) has been reported in animal studies following dietary exposures to strontium carbonate or chloride.

Data used for Groundwater IMAC

US EPA's Integrated Risk Information System (IRIS, 1992) established an oral reference dose (RfD) of 0.6 mg/kg-day for strontium. A systemic threshold concentration of 2100 ug/L (ppb) can be calculated using the oral reference dose for strontium in accordance with 15A NCAC 02L .0202(d)(1).

US EPA has not classified strontium and its compounds for its carcinogenic potential via ingestion. Therefore, a cancer potency factor is not available for oral exposures. A human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

No odor threshold, taste threshold, federal drinking water maximum contaminant level (MCL) or secondary drinking water standard has been established for strontium.

Recommended Groundwater IMAC

A groundwater standard of 2000 µg/L is recommended under 15A NCAC 02L .0202(c) for strontium. This value has been rounded down from the calculated value of 2100 µg/L in accordance with rounding convention. The groundwater standard is based on an RfD derived from a NOAEL of 190 mg/kg-day reported in a 20-day feeding study in young rats fed strontium carbonate in their diet. Longer-term term studies with adult rats have reported similar effects at higher doses.

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for strontium is 2000 ug/L (ppb) based on the calculated noncancer systemic threshold.

Uses

Strontium is used in ceramic and glass product manufacturing, aluminum alloys, and ferric magnets. It is also used to impart red color in fireworks.

References

Agency for Toxic Substances and Disease Registry. Toxicological Profile for Strontium. 2004. http://www.atsdr.cdc.gov/

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. EPA Integrated Risk Information System. 1992. IRIS Summary for Strontium. http://www.epa.gov/iris (accessed 7/15/16).

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Strontium — CASRN 7440-24-6

North Carolina Groundwater (GW) IMAC = 2000 µg/L

Summary

The North Carolina GW IMAC for strontium and compounds is based on a noncancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202. Groundwater standards are established as the least of the criteria in 15A NCAC 02L .0202(d)(1-6) (highlighted in yellow below).
Critical health effect: Bone toxicity (rickets) in young rats (20-day study) with supporting data from longer term studies.

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	6.00E-01	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.1	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**2100**	**µg/L** (rounded to 2000 to account for significant figures)

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.00E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 10 µg/L

References

[1] Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/ accessed 7/15/16). IRIS assessment last revised 10/1/92. Storey, E. 1961. Strontium "rickets" bone calcium and strontium changes. Austral. Ann. Med. 10: 213-222.

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] NA; Strontium has not been classified by EPA for carcinogenic potential via oral exposures. A cancer potency factor has not been established.

[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[7] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 7/16/16).

[8] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

[9] PQL established by North Carolina Water Quality lab for total strontium. (ps://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home- page/organic-chemistry-branch/methods-pqls-organics).

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History
July 13, 2016 - Request by Division of Water Resources for IMAC for strontium.

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

TETRAHYDROFURAN (THF) (CASRN 109-99-9)

Health Effects Summary

Human health effects associated with low, oral environmental exposures to THF are unknown. Potential human exposures most often result from occupational exposures related to its use as a solvent. These occupational exposures primarily occur through inhalation and dermal absorption. A number of occupational exposure studies reported health effects on the nervous system and liver and symptoms including nausea, headache, dizziness, chest pain, labored breathing, and cough.

Data used for IMAC

U.S. EPA's Integrated Risk Information System (IRIS) established an oral reference dose (RfD) of 0.9 mg/kg-day for THF based on a two-generation reproductive study in rats (Hellwig et al., 2002; BASF, 1996). Dose-response modeling resulted in a BMDL of 928 mg/kg-day, based on the critical effect of decreased pup weight gain in F1 and F2 pups. An uncertainty factor of 1000 was applied (10 for variation in sensitivity among the human population, 10 for interspecies extrapolation, and 10 for deficiencies in the oral database). A systemic threshold concentration of 6300 μg/L (ppb) can be calculated using the oral reference dose for THF in accordance with 15A NCAC 02L .0202(d)(1).

U.S. EPA's IRIS program has classified THF as having "suggestive evidence of carcinogenicity". However, no oral slope factor for THF was derived due to the absence of cancer assays involving oral exposures and lack of physiologically based pharmacokinetic models. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

A range of odor thresholds have been reported for THF from multiple sources. U.S. EPA's IRIS Toxicological Review of THF lists an odor threshold range of 2-7.4 ppm (2000-7400 ppb) (ACGIH, 2001).

A taste threshold, federal maximum contaminant level, or secondary drinking water standard have not been established for THF.

Recommended IMAC

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended IMAC for tetrahydrofuran is 2,000 ug/L (ppb) based on its reported odor threshold.

Uses:

Tetrahydrofuran is a synthesized organic compound. It is a colorless, volatile liquid that has an acetone-like smell. THF is used as a solvent for many substances including polyvinyl chlorides, vinylidene chloride polymers, and natural and synthetic resins, and in top coating solutions, polymer coatings, cellophane, protective coatings, adhesives, magnetic strips, and printing inks. THF is also used in the preparation of chemicals as an intermediate in chemical synthesis.

References

ACGIH (American Conference of Governmental Industrial Hygienists). (2001) Tetrahydrofuran. In: Documentation of the threshold limit values and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

BASF. (1996) Tetrahydrofuran: two-generation reproduction toxicity study in Wistar rats, continuous administration in the drinking water, with cover letter dated 8/30/96. Study No.71R0144/93038. Submitted under TSCA Section 8D. EPA Document No. 86960000573. NTIS No. OTS558774.

Hellwig, J; Gembardt, C; Jasti, S. (2002) Tetrahydrofuran: two-generation reproduction toxicity in Wistar rats by continuous administration in the drinking water. Food Chem Toxicol 40(10):1515–1523.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf.

U.S. EPA. (2012). Integrated Risk Information System (IRIS) Toxicological Review of Tetrahydrofuran. National Center for Environmental Assessment, Office of Research and Development (EPA/635/R-11/006F). https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/1023tr.pdf

North Carolina Groundwater
Interim Maximum Allowable Concentration (IMAC)
Calculation Sheet

Tetrahydrofuran (THF) CASRN 109-99-9

North Carolina Ground Water (GW) IMAC = 2000 µg/L

Summary

The North Carolina GW IMAC for tetrahydrofuran is based on its reported odor threshold in accordance with selection criteria defined in 15A NCAC 02L .0202. Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6) (highlighted in yellow below).
Critical health effect: odor threshold (not health-based)

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	9.0E-01	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily adult human water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**6300**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily adult human water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**2000**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 5 µg/L

References

[1] U.S. EPA Integrated Risk Information System (IRIS) (accessed 4/1/2019). IRIS assessment last revised 2/21/2012.
Link to IRIS document: https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/1023_summary.pdf
[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).
[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).
[4] THF has been classified by US EPA as having "suggestive evidence of carcinogenicity" based on the database. However, an oral slope factor has not been
[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.
[6] U.S. EPA Integrated Risk Information System (IRIS) (accessed 4/1/2019). IRIS assessment last revised 2/21/2012. Odor threshold reported as a range (2-7.4 ppm). The lowest reported value was selected in accordance with DWR's SOP for Reviewing Groundwater Standards.
Link to IRIS document: https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/1023tr.pdf
[7] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 4/1/2019)
[8] NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals (accessed 4/1/2019)
[9] PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. PQL estimated as 5 µg/L based on reported MDL of 1 µg/L from EPA method SW-846 8260.

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History

February 28, 2019 - IMAC for THF requested by DWM

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

<u>THALLIUM</u> (CASRN 7440-28-0)

Health Effects Summary

Human health effects associated with low environmental exposures to thallium are unknown. Severe neurological, gastrointestinal, cardiovascular, and respiratory effects leading to death as well as alopecia (hair loss) have been reported in humans and animals following large, acute doses. Changes in blood chemistry, kidney and adrenal weights, and sperm quality in addition to alopecia, developmental delays and increased mortality have been reported in animal studies following oral administration of thallium compounds.

Data used for Groundwater IMAC

US EPA's Integrated Risk Information System (IRIS, 1988) established oral reference doses (RfDs) for soluble thallium (I) compounds ranging from 0.00008 to 0.00009 mg/kg-day. The RfDs were withdrawn and replaced with a "qualitative discussion" in 2009 due to the poor quality of the toxicology studies available for thallium.

US EPA's National Center for Environmental Assessment (NCEA, 2012) declined calculating a chronic, oral provisional peer-reviewed toxicity value (PPRTV) due to the lack of good quality toxicology studies available for thallium. They chose instead to derive the following screening levels:

Screening Chronic p-RfD for thallium (I) sulfate	0.00002 mg/kg-day
Screening Chronic p-RfD for soluble thallium	0.00001 mg/kg-day

US EPA determined there are inadequate data to assess the carcinogenic potential of thallium. A cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1 x 10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

The ATSDR (1992) declined to establish a chronic MRL for thallium due to a lack of adequate data.

A federal Maximum Contaminant Level (MCL) of 2 µg/L has been established for thallium. This value is based on a 3-month rat study with alopecia as the critical effect.

California established a Public Health Goal (PHG) of 0.1 µg/L and an MCL of 2 µg/L for thallium.

No odor threshold, taste threshold, or secondary drinking water standard has been established for thallium.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 0.2 µg/L was established for thallium under 15A NCAC 02L .0202(c) in 2010. This value was based on the EPA IRIS RfD current at that time which has since been withdrawn and replaced with a "qualitative discussion". No new toxicological information relevant to the derivation of a North Carolina groundwater standard is available. The National Toxicology Program (NTP) has proposed additional studies to assess the toxicity of thallium compounds.

The screening levels developed by US EPA NCEA for thallium sulfate and soluble thallium are not appropriate for developing groundwater standards due to the high level of uncertainty associated with such values.

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

Groundwater standards are to be the "lesser of" the criteria in 15A NCAC 02L .0202(d)(1-6).

The recommended groundwater IMAC for thallium and its soluble compounds is 2 ug/L (ppb) based on the federal Maximum Contaminant Level (MCL).

Uses

Prior to its ban in the United States in 1972, thallium was used as a rodent and insect pesticide. Thallium is currently used primarily in the semiconductor industry and in the manufacture of optic lenses. When alloyed with mercury, thallium is used in the manufacture of low-melting glass, low-temperature thermometers and switches/closures that operate at subzero temperatures. Its radioisotopes are used in medical procedures for the diagnosis of melanoma and scintography.

References

Agency for Toxic Substances and Disease Registry. Toxicological Profile for Thallium. 1992. http://www.atsdr.cdc.gov/

Amoore, JE and Hautala E. 1983. Odor as an aid to chemical safety: Odor thresholds compared with threshold limit values and volatiles for 214 industrial chemicals in air and water dilution. Journal of Applied Toxicology, Volume 3. No. 6.

MRI (Midwest Research Institute). 1988. Toxicity of thallium (I) sulfate (CAS NO. 7446-18-6) in Sprague-Dawley rats. Volume 2: Subchronic (90-day) study [revised final report]. Docket ID: EPA-HQ-ORD-2008-0057-0002 and EPA-HQ-ORD-2008-0057-0003.

U.S. EPA Drinking Water Standards and Health Advisories. 2012. Office of Water (EPA 822-S-12-001) https://www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf

U.S. EPA. Provisional Peer Reviewed Toxicity Values for Thallium and Compounds. 2012. Office of Research and Development, National Center for Environmental Assessment https://hhpprtv.ornl.gov/quickview/pprtv_papers.php.

U.S. EPA Integrated Risk Information System. Chemical Assessment Summary for Thallium (I), soluble salts. 2009. http://www.epa.gov/iris (accessed July 6, 2016).

U.S. EPA Contaminant Information Sheets for the Final CCL 3 Chemicals. 2009. Office of Water (EPA 815-R-09-012). https://www.epa.gov/sites/production/files/2014-05/documents/final-ccl-3-contaminant-information-sheets.pdf

U.S. National Library of Science Toxicology Data Network (TOXNET) https://toxnet.nlm.nih.gov/

Young WF, Horth H, Crane R, Ogden T and Arnott M. 1996. Taste and odour threshold concentrations of potential potable water contaminants. Water Research, 30:2, pp. 331-340.

North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Thallium CASRN 7440-28-0

North Carolina Groundwater (GW) IMAC =	**2 µg/L**

Summary

The North Carolina GW IMAC for thallium is based on the federal maximum contaminant level (MCL) in accordance with selection criteria defined in 15A NCAC 02L .0202. Groundwater standards are established as the least of the criteria in 15A NCAC 02L .0202(d)(1-6) (highlighted in yellow below).

Critical health effect: Alopecia (hair loss).

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	NA	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.2	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**NA**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.00E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**2**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Practical Quantitation Limit (PQL)[9] 2 µg/L

References

1 Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/ accessed 7/6/16). IRIS assessment last revised 9/30/09. RfDs withdrawn and replaced by "qualitative assessments".

2 Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

3 Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

4 NA; EPA has determined there are inadequate data to assess the carcinogenic potential of thallium. A cancer potency factor has not been established.

5 NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

6 NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

7 MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 7/6/16)

8 NA; SMCL : https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

9 PQL established by North Carolina Water Quality lab for total thallium /deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/organic- chemistry-branch/methods-pqls-organics).

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History
April 27, 2010 - Request by DWM to establish IMAC for thallium.
October 1, 2010 - IMAC of 0.2 µg/L approved by DWR Director.

VANADIUM (CASRN 7440-62-2)

Health Effects Summary
Human health effects associated with low environmental exposures to vanadium are unknown. Quadravalent and pentavalent vanadium (V^{+4} and V^{+5}), considered the most toxic oral forms of vanadium, are the forms most commonly found in aquatic environments. Average estimated adult dietary exposures to vanadium range from 10-30 µg/day, excluding supplementation. Ingested vanadium compounds are not well absorbed with more than 95% excreted in the feces.

Vanadyl sulfate mimics insulin and reduces blood glucose. Gastrointestinal effects have been reported in humans ingesting large doses of vanadyl sulfate. In animal studies, oral doses of vanadium compounds have produced mild histopathological changes in the kidney, spleen, and lung of rats, increased blood pressure, changes in blood chemistry, reduced body weight, maternal toxicity, decreased survival, and skeletal malformations and growth delays in offspring.

Data used for Groundwater IMAC
Reliable and good quality chronic studies assessing the oral toxicity of vanadium and compounds are lacking. There is little consensus on oral toxicity values for vanadium established by governmental agencies.

The U.S. EPA's Integrated Risk Information System (IRIS, 1988) established an oral reference dose (RfD) of 0.009 mg/kg-day for vanadium pentoxide based on a study in rats identifying decreased cystine in hair as the critical effect (Stokinger et al., 1953). This RfD was deemed unsuitable for calculating a groundwater standard because it is based on a non peer-reviewed study evaluating only growth rate, survival, and hair cystine content. The biological relevance of hair cystine level is unclear.

The U.S. EPA published a chronic oral RfD of 0.005 mg/kg-day for vanadium and compounds in its 2016 Regional Screening Level Table for Contaminants at Superfund Sites. However, this value is based on a recalculation of the 1988 IRIS RfD for vanadium pentoxide and is therefore also considered unsuitable for developing a groundwater standard.

The U.S. EPA established a provisional oral reference dose (p-RfD) of 0.00007 mg/kg-day for vanadium and its soluble inorganic compounds excluding vanadium pentoxide in 2009 (https://hhpprtv.ornl.gov/issue_papers/Vanadium.pdf). This value was based on kidney effects observed in a 6-month subchronic study in male rats (Boscolo et al., 1994). However, the relevance of the reported kidney effects in male rats with regard to potential α_{2u} globulin accumulation mechanisms is unknown. In addition, uncertainties associated with the dose calculation including non-reporting of water consumption and estimation of vanadium content in the diet support consideration of alternative studies for deriving a groundwater standard (US EPA, 2009; US FDA, 2001).

The California Office of Environmental Health Hazard Assessment (OEHHA) established a Notification Level for Vanadium of 50 µg/L in 2000 based on reduced weight and length in offspring reported in animal studies. (https://oehha.ca.gov/water/notification-level/proposed-notification-level-vanadium and http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notificationlevels.pdf). It is noted that California used a relative source contribution of 0.6 in the calculation to derive a notification level for soluble vanadium.

ATSDR (2012) determined there were insufficient data to calculate a chronic Maximum Contaminant Level (MCL) for vanadium.

The European Food Safety Authority (EFSA, 2004) declined to establish a tolerable upper intake level for vanadium compounds based on lack of adequate study data.

The U.S. FDA established a Tolerable Upper Intake Level (UL) for adults of 1.8 mg/day for vanadium based on a 3-month subchronic study in rats (Domingo et al., 1986). It is important to note that the derivation of a chronic RfD using a subchronic study underscores the lack of reliable and good quality chronic studies for vanadium.

The U.S. EPA has not classified vanadium pentoxide or soluble vanadium inorganic compounds for carcinogenicity for oral exposures. A cancer potency factor is not available. Therefore, a human exposure concentration associated with an incremental lifetime cancer risk estimate of 1×10^{-6} cannot be calculated according to the requirements of 15A NCAC 02L .0202(d)(2).

No odor threshold, taste threshold, federal maximum contaminant level or secondary drinking water standard has been established for vanadium or its compounds.

Recommended Groundwater IMAC

An interim maximum allowable concentration (IMAC) of 0.3 µg/L was established under 15A NCAC 02L .0202(c) for vanadium (excluding vanadium pentoxide) in 2010. This value was calculated using the 2009 US EPA provisional RfD of 0.00007 mg/kg-day for soluble inorganic forms of vanadium (excluding vanadium pentoxide).

Further review of the basis for US EPA's RfD for vanadium pentoxide and provisional RfD for soluble inorganic forms of vanadium identified inconsistencies and study deficiencies that support using alternative values for the derivation of a North Carolina groundwater standard. However, reliable and well-reported chronic oral toxicological studies with vanadium and its soluble compounds are lacking.

The recommended groundwater IMAC for vanadium is 7 ug/L (ppb). This standard is based on the RfD value of 0.002 mg/kg-day adopted by the California Water Resources Control Board. The RfD was calculated using a LOAEL of 2.1 mg/kg reported in a developmental and reproductive study (Domingo et al., 1986) and an uncertainty factor of 1000 (10 for extrapolation from animals to human, 10 for human variability, and 10 for use of an LOAEL).

Groundwater Interim Maximum Allowable Concentration (IMAC) Summary Document

Division of Water Resources

Table 1. Summary of toxicity values for vanadium

Agency	Date	Critical Animal Study	Critical Endpoint	Vanadium Toxicity Value	Calculated NC GW Standard[a]
ATSDR	2012	Not identified	Not identified	NA	NA
California EPA Water Resources Control Board Notification Level for Vanadium	2000	Domingo et al., 1986	↓ weight and length in offspring	0.002 mg/kg-day	7 µg/L
European Food Safety Association (EFSA)	2004	Not identified	Not identified	NA	NA
US EPA Health Reference Level (HRL) for CCL3 contaminants (vanadium)	2009	Not identified	Minor renal effects (1992 ATSDR subchronic MRL Domingo et al.,1985)	0.003 mg/kg-day	11 µg/L
US EPA IRIS (vanadium pentoxide)	1988	Stokinger et al. 1957,1981	↓ Cystine in hair	0.009 mg/kg-day	32 µg/L
US EPA PPRTV (soluble vanadium compounds excluding vanadium pentoxide)	2009	Boscolo et al. 1994	Kidney toxicity	p-RfD = 0.00007 mg/kg-day	0.3 µg/L
US EPA Regional Screening Levels (vanadium and compounds)	2016	Stokinger et al. 1957,1981	↓ Cystine in hair	0.005 mg/kg-day (calculated value based on vanadium pentoxide RfD)	18 µg/L
US EPA Regional Screening Levels (vanadium pentoxide)	2016	Stokinger et al. 1957,1981	↓ Cystine in hair	0.009 mg/kg-day	32 µg/L
US FDA	2001	Domingo et al. 1985	Histopath findings in kidney, spleen, and lung	Tolerable Upper Intake Level (UL)[b] = 1.8 mg/day (equivalent to 0.026 mg/kg-day)	90 µg/L

[a] Relative source contribution = 0.1 for inorganics in accordance with 15A NCAC 02L .0202.
[b] UL calculated for adults as insufficient information available for pregnant women and children.

Uses

Vanadium alloys are used primarily as stabilizing, strengthening, and anti-corrosive agents in steel manufacturing. Oxides of vanadium (ammonium metavanadate, vanadium pentoxide, sodium vanadate, and vanadyl sulfate) are used in the paint/ceramic industry to impart yellow and blue color. Vanadium is also used as an industrial catalyst and in the manufacture of sulfuric acid.

Vanadyl sulfate and sodium metavanadate are used as nutritional and bodybuilding supplements. Vanadyl sulfate has been used in human and animal research studies investigating the insulin reducing effects of vanadium.

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North Carolina Groundwater Interim Maximum Allowable Concentration (IMAC) Calculation Sheet

Vanadium CASRN 7440-62-2

North Carolina Groundwater (GW) IMAC = 7 µg/L

Summary

The North Carolina GW IMAC for vanadium and compounds is based on a noncancer endpoint in accordance with selection criteria defined in 15A NCAC 02L .0202. Groundwater standards are established as the least of the criteria in 15A NCAC 02L .0202(d)(1-6) (highlighted in yellow below).
Critical health effect: Reduced weight and length in rat offspring.

GW IMAC based on noncancer endpoint

GWQS = [(RfD x WT x RSC) / WI] * 1000

RfD = reference dose[1]	2.0E-03	mg/kg/day
WT = average adult human body weight[2]	70	kg
RSC= relative source contribution	0.1	unitless value
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using noncancer endpoint	**7**	**µg/L**

GW IMAC based on cancer endpoint

GWQS = [(RL x WT) / (q1* x WI)] * 1000

RL = risk level	1.0E-06	
WT = average adult human body weight[2]	70	kg
q1* = carcinogenic potency factor (slope factor)[4]	NA	$(mg/kg/day)^{-1}$
WI = average daily human adult water intake[3]	2	L/day
1000 = conversion factor	1000	µg/mg
Calculated GW IMAC using cancer endpoint	**NA**	**µg/L**

GW IMAC based on published values

Taste Threshold[5]	**NA**	**µg/L**
Odor Threshold[6]	**NA**	**µg/L**
Maximum Contaminant Level (MCL)[7]	**NA**	**µg/L**
Secondary Drinking Water Standard (SMCL)[8]	**NA**	**µg/L**

Additional Information

FDA Tolerable Upper Intake Level[9]	**1,800**	**µg/day**
California Water Board Notification Level[10]	**50**	**µg/L**

Practical Quantitation Limit (PQL)[11] 10 µg/L

References

[1] California Water Resources Control Board, Drinking Water Notification Levels (accessed 9/18/2017) https://oehha.ca.gov/water/notification-level/proposed-notification-level- vanadium /www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notificationlevels.pdf. Based on Domingo, J.L., Paternain J.L., Llobet J.M., and Corbella J. 1986. Effects of vanadium on reproduction, gestation, parturition, and lactation in rats upon oral administration. Life Sciences. 39(9): 819-824.

[2] Average adult body weight from 15A NCAC 02L .0202 (effective date April 1, 2013).

[3] Average water consumption from 15A NCAC 02L .0202 (effective date April 1, 2013).

[4] NA; Vanadium and its compounds have not been classified for carcinogenicity. A cancer potency factor has not been established.

[5] NA; Contact NC DEQ Groundwater Standards Coordinator for list of taste threshold resources examined.

[6] NA; Contact NC DEQ Groundwater Standards Coordinator for list of odor threshold resources examined.

[7] NA; MCL: https://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants#Organic (accessed 7/6/16)

[8] NA; SMCL: https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

[9] U.S. FDA Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. 2001. National Academy of Sciences, pp. 532-553. https://www.nal.usda.gov/sites/default/files/fnic_uploads//vitamin_a_full_report.pdf

[10] California Water Resources Control Board, Drinking Water Notification Levels (accessed Sept 18, 2017) 2016) http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notificationlevels.pdf

[11] PQL provided for informational purposes only. PQL not established by North Carolina Water Resources Laboratory. PQL from ENCO Laboratories, Cary, NC. (http://www.encolabs.com/news/docs/VFA_Detection.html)

NA = Not available
RSC = 0.1 for nonorganics, 0.2 for organics

History:
April/June 2010 - Request by DWM to establish NC IMAC for vanadium.