Tod Creek watershed: Water quality report for the 2023/24 wet season

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RAINCOAST
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Contributions by Capital Regional District (CRD): Glenn Harris, Chris Lowe, Barri Rudolph and Peter Kickham; W̱SÁNEĆ Leadership Council (WLC): Joni Olsen; Tsartlip First Nation: William Morris and Franklyn Sampson; Pam Mackenzie and Richard Grace (SGS Axys); Xiangjun Liao and Andrew Ross (Fisheries and Oceans Canada).

Financial support by Capital Regional District (Victoria)

About Raincoast

Raincoast is a team of scientists and conservationists dedicated to safeguarding the land, waters, and wildlife of coastal British Columbia.

Our vision for coastal British Columbia is to protect the habitats and resources of umbrella species. We believe this approach will help safeguard all species, including people, and ecological processes that exist at different scales. Central to our efforts are long-term partnerships with Indigenous communities.

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Executive summary

Water is essential for life, and steps are needed to understand, protect and restore its health in fish habitat throughout British Columbia. The Raincoast Healthy Waters program was launched in 2023 to establish community-oriented water pollution monitoring in select BC watersheds. Two Healthy Waters sampling events take place every year in each watershed: the dry season (summer), and the wet season (winter). This report highlights results from one sampling event: the first wet (winter) season sampling, carried out with the support and participation of the Capital Regional District (CRD) and Tsartlip First Nation. Briefly, the Healthy Waters team sampled the Tod Creek watershed on December 13, 2023. The team worked with CRD, Tsartlip First Nation and community volunteers to first determine basic water properties (temperature, conductivity, pH, dissolved oxygen and turbidity) in situ. Water samples were collected from six water categories, including source water (3 samples), stream and river water (3 samples), road runoff (3 samples), tap water (10 samples - 9 from the Sooke supply and 1 from groundwater were pooled into a single composite sample) and marine water (3 samples), alongside surface water samples collected in the areas surrounding the Hartland landfill (3 samples). Samples were then pooled into a single composite sample for each of the six water categories and analysed for coliform, metals, nutrients, physical parameters, pesticides, polycyclic aromatic hydrocarbons (PAHs), pharmaceuticals and personal care products (PPCPs), polychlorinated biphenyls (PCBs), alkylphenol ethoxylates, bisphenols, per- and poly-fluoroalkyl substances (PFAS), sucralose and 6-PPD Quinone. This initial sampling with a limited number of samples suggests that, overall, Tod Creek water quality was **relatively good.** Additional sampling and analysis planned will provide additional insight into any sources or activities that may be impacting the health of this valued watershed.

Key findings

- This preliminary assessment of water quality in Tod Creek reflects the first of several site visits; our understanding of water quality in the Tod Creek watershed will grow with additional sampling over the coming two years (2024-26).
- Our study design was not designed to explicitly address the performance of Hartland Landfill, but rather to provide an integrated 'snapshot' of water

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quality in six categories of water in the Tod Creek watershed, including source, stream & river, road runoff, tap, marine and Hartland drainage.

- The Hartland drainage water sample had the highest wet season concentrations of nutrients, per- and polyfluoroalkyl substances (PFAS), and 6PPD-quinone among water categories analysed. Some of these may be attributed to quarry activities and aggregate storage, with CRD working to address concerns that had been previously noted. Additional influences from vehicular and machine operations in the landfill may contribute to some of the water quality issues noted here, with further sampling helping to confirm and build on observations.
- Stream and river water had the highest concentration of coliform bacteria and pesticides; further sampling and analysis may provide insight into the extent to which local agriculture and septic systems may be impacting water quality in Tod Creek.
- Alongside marine water, the stream and river sample had the highest concentration of metals and pharmaceuticals and personal care products (PPCPs); some of the metals are from natural sources. In addition, historical cement factory operations, vessel discharges in Tod Inlet, and land-based septic systems likely explain some of these observations.
- The pooled tap water sample had the highest concentrations of polycyclic aromatic hydrocarbons (PAHs) but were within safe limits established by Health Canada; alkylphenol ethoxylates (APEs) were also detected but were at levels considered safe.
- Source water, and road runoff water were less contaminated than the other water categories in the wet season.
- Overall, the Tod Creek watershed had relatively good water quality in the wet season:
    - There were 8 exceedances of Canadian Environmental Quality Guidelines for the protection of aquatic life (the Hartland water sample exceeded both the CCME and BC long-term guidelines for nitrate concentration, five out of six water samples (all except the tap sample) exceeded the CCME Long Term Guideline for the protection of aquatic life of 0.1 mg/L, and the Hartland water sample exceeded the BC WQG of 100 pg/L for Total PCBs).
    - There were 0 exceedances of Health Canada Drinking Water Quality Guidelines.

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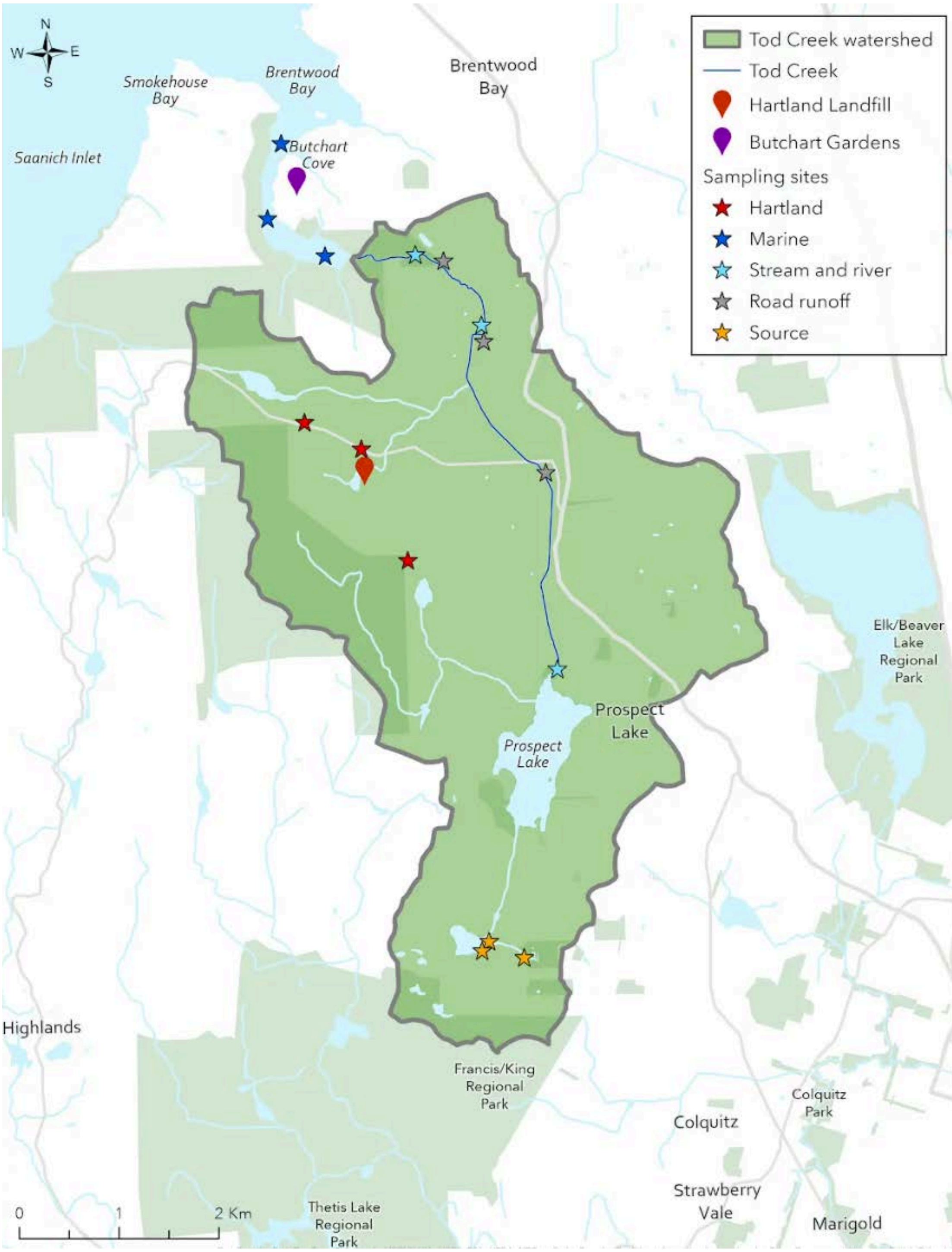
Figure 1: The Tod Creek Watershed



The Tod Creek watershed runs north from Prospect Lake, along West Saanich Road down to Tod Inlet, and covers an area of 24 km^2. Sampling sites (detailed in Table 1 below) were distributed throughout the watershed in order to capture a wide spatial range for our assessment of the health of fish habitat (Map by Brooke Gerle / Raincoast Conservation Foundation).

Acknowledgements

We acknowledge the financial support of the Capital Regional District (Victoria). We thank Glenn Harris, Chris Lowe, Barri Rudolph and Peter Kickham for feedback before and during sampling. We thank Joni Olsen at the W̱SÁNEĆ Leadership Council (WLC) and William Morris at Tsartlip First Nation for their support and guidance. We acknowledge the expert analytical support of Pam MacKenzie and Richard Grace at SGS-AXYS, and Xiangjun Liao and Andrew Ross at Fisheries and Oceans Canada. We thank Alex Harris and Sherwin Arnott for report design. Photo credits: Sam Scott and Peter Ross. Photo of Franklyn Sampson in Tod Inlet.

Sampling team

- Raincoast Healthy Waters: Sam Scott and Peter Ross
- Winona Pugh, Francis Pugh and Carmel Thomson (Friends of Tod Creek)
- Tsartlip First Nation: Franklyn Sampson, Will Morris
- CRD Stormwater Quality Staff: Barri Rudolph
- CRD Hartland Landfill Staff: Dan Lyons and Jason Wolting

Photo of Franklyn Sampson, Stewardship Guardian and member of Tsartlip First Nation. Photo Credit Peter S. Ross

General introduction

Background

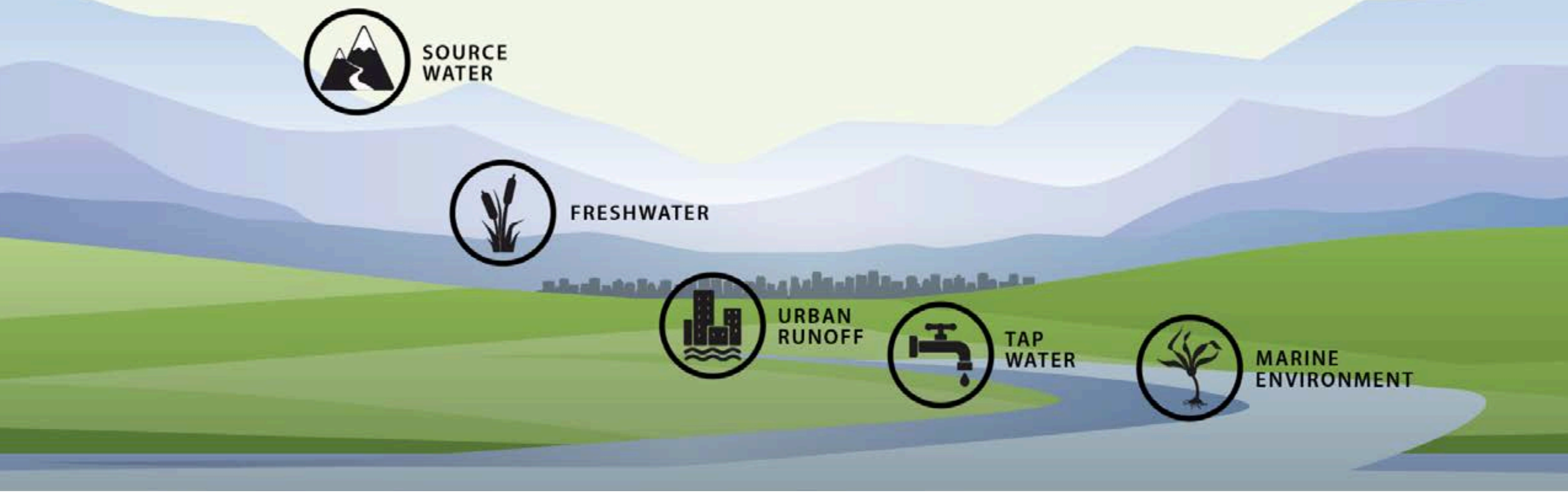
Raincoast's Healthy Waters Program (https://www.raincoast.org/waters/) delivers high-resolution, community-oriented water quality analysis to watersheds across southern British Columbia. The goal of Healthy Waters is to empower communities with the understanding of the status of water quality in their watersheds, to allow for local advocacy regarding both point and nonpoint source pollution.

The Capital Regional District (CRD) serves approximately 440,000 people from 13 municipalities and three electoral areas on southern Vancouver Island and the Gulf Islands. The traditional territories of many First Nations span portions of the region and 11 of those Nations hold reserve lands throughout the capital region.

Community and Indigenous concerns expressed about possible threats to water quality in Tod Creek sparked interest in this project, but Tod Creek is at the receiving end of numerous activities and potential contaminant sources. Of note is that local agriculture, the Heals Rifle Range as a federal contaminated site, domestic septic fields, the Hartland Landfill operation, and other sectors also are likely to influence water quality in Tod Creek. Findings from this and future sampling events will provide insight into the potential for each of these sectors to explain any degradation of water quality - an important element of protection and restoration.

Tsartlip First Nation is one of two current members of the W̱SÁNEĆ Leadership Council (WLC); the second is Tseycum First Nation. The Tsartlip reserve is situated in Brentwood Bay, BC. The WLC was formed to create a unified entity responsible for representing the common interests of the W̱SÁNEĆ Nations. The W̱SÁNEĆ Peoples have been responsible for stewardship of the land since time immemorial.

A watershed based approach to sampling



Healthy Waters

We collect samples from five different categories of water in each of our partner watersheds for our Healthy Waters program: source water, upstream of human impacts, down to the marine environment. Our Tod Creek partnership entails additional sampling from Hartland landfill drainage.

Source water serves as an upstream reference sample, allowing us to determine which contaminants are being introduced as water traces its path down through the watershed.

Stream and river samples allow us to investigate the quality of fish habitat directly, by collecting samples from streams, creeks, and rivers used by salmon and other fish species (either currently or historically).

Road runoff serves as an impacted sample category of current concern, as many contaminants, including PAHs, metals, surfactants and chemicals such as 6PPD quinone can be washed off roadways and into fish habitat during rain events.

We include **tap water** samples in our analysis as a way to bring our homes into the conversation - we borrow water from the environment in the form of municipal or well water, and generally return it to aquatic habitats in a more-degraded state in the form of storm and sewage effluent (treated or untreated).

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Marine water samples provide insight into those contaminants that may degrade fish and whale habitat in the ocean, and enable an understanding of the contribution of land-based pollutants from the adjacent watershed to the marine environment.

A sixth composite sample from the **Hartland** Landfill drainage was also included in this project.

Collectively, the lessons learned from our partnering watersheds will contribute to a greater understanding of threats to water quality across British Columbia, and ultimately what policy changes can be implemented to preserve the quality of water for the future of salmon, whales, and people.

Methods

Field sampling

A total of 15 surface water samples were collected from locations in the Tod Creek watershed on December 13, 2023 by the Raincoast Healthy Waters team along with representatives of CRD Hartland Landfill staff, Tsartlip First Nation, and Friends of Tod Creek following the *Raincoast Healthy Waters – Standard Operating Procedure (SOP) for water sample collection* (Appendix 1). An additional 10 samples of tap water were obtained from homes and businesses within the Tsartlip First Nation Reserve (which represent a combination of municipal and well water sources) on February 6, 2024.

A portable water properties meter (YSI-ProDSS) was deployed to measure temperature, pH, conductivity, dissolved oxygen and turbidity in situ following the *Raincoast Healthy Waters – Standard Operating Procedure (SOP) for in situ determination of basic water properties* (Appendix 2). A VTSYIQI water velocity meter was used to take three spot measurements from the shoreline where the samples were collected.

Samples were submitted to four service labs for additional analyses: ALS Environmental, SGS-AXYS, Fisheries and Oceans Canada, and the Raincoast Conservation Genetics Lab. Contaminant analytes were determined in water samples according to established protocols (see Table 2).

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Table 1: Sampling sites in the Tod Creek watershed

Site Number	Water Type	Site Name	Lat/Long
1	Source	Maltby Lake - Carmel's Dock	N 48.496813, W 123.449331
2	Source	Trevlac Pond	N 48.495230, W 123.444669
3	Source	Maltby Lake - A Frame Dock	N 48.495974, W 123.450316
4	River	Tod Creek @ Prospect Lake	N 48.521186, W 123.438774
5	River	Tod Creek @ Gowland Tod	N 48.559102, W 123.455963
6	River	Tod Creek @ Durrance Bridge	N 48.552520. W 123.447359
7	Runoff	Wallace Drive Ditch	N 48.551040, W 123.447130
8	Runoff	Ditch @ Wallace and Garden	N 48.558439, W 123.452182
9	Runoff	Tod Creek @ Farmington	N 48.538990, W 123.439361
10	Marine	Tod Inlet 1	N 48.559291, W 123.468188
11	Marine	Tod Inlet 2	N 48.562825, W 123.475803
12	Marine	Tod Inlet 3	N 48.569584, W 123.473602
13	Hartland	South Hartland Drainage Ck	N 48.531494, W 123.458465
14	Hartland	Willis Point Roadside ditch	N 48.544298, W 123.471783
15	Hartland	Creek in Hartland Proper	N 48.541726, W 123.464216
16	Tap	Tap 10	Various - 9 CRD water and 1 well

Water samples were collected from 15 field sites in the Tod Creek watershed, as well as 10 homes within the Tsartlip First Nation Reserve. These were then pooled into composite samples and submitted for analysis, or retained for specialised analyses.

Water quality analyses

Table 2: List of analytes, service lab, analytical methods, instruments, and number of samples submitted

Analyte	Laboratory	Analytical Method	Instruments	No. samples analysed
Tier 1				
Temperature (℃)	in situ		YSI ProDSS	12
Dissolved Oxygen (%, mg/L)	in situ	optical sensor	YSI ProDSS	12
Turbidity (FNU)	in situ		YSI ProDSS	12
Conductivity (uS/cm)	in situ		YSI ProDSS	12
pH	in situ		YSI ProDSS	12
Tier 2				
Total Suspended Solids (TSS)	ALS Environmental	APHA 2540 D (mod)	gravimetry	5
Total Dissolved Solids (TDS)	ALS Environmental	APHA 2540 C (mod)	gravimetry	5
Hardness	ALS Environmental	APHA 2340B	calculated	5
Total Organic Carbon (TOC)	ALS Environmental	APHA 5310 B (mod)	combustion	5
Chemical Oxygen Demand (COD)	ALS Environmental	APHA 5220 D (mod)	colourimetry	5
Biological Oxygen Demand (BOD)	ALS Environmental	APHA 5210 B (mod)	dissolved oxygen meter	5
Nitrate	ALS Environmental	EPA 300.1 (mod)	ion chromatography	5
Ammonia	ALS Environmental	Method Fialab 100, 2018	fluorometry	5
Phosphate	ALS Environmental	APHA 4500-P F (mod)	colourimetry	5

Total Metals	ALS Environmental	EPA 200.2/6020B (mod)	Collision/Reaction Cell ICPMS	5
Total coliform	ALS Environmental	APHA 9223 (mod)	MPN	5
Fecal coliform	ALS Environmental	APHA 9223 (mod)	MPN	5
E. coli	ALS Environmental	APHA 9223 (mod)	MPN	5
MST (in Development)	RCF Conservation Genetics Lab (PSEC)	In development		5
Tier 3				
Polycyclic Aromatic Hydrocarbons (PAHs)	SGS Axys Analytical	EPA 8270/ EPA 1625	GC-MS	5
Multiresidue Pesticides	SGS Axys Analytical	EPA 1699 (mod)	HRMS	5
Pharmaceuticals and Personal Care Products (PPCPs)	SGS Axys Analytical	EPA 1694	HPLC/MS/MS	5
Per and Poly-fluoroalkyl substances (PFAS)	SGS Axys Analytical	EPA 1633 Draft	LC-MS/MS	5
Polychlorinated biphenyls (PCBs)	SGS Axys Analytical	SGS AXYS METHOD MLA-210 Rev 01	GC-MS/MS	5
Alkylphenol Ethoxylates (APEs)	SGS Axys Analytical	SGS AXYS METHOD MLA-004 Rev 07	GC-MS	5
Bisphenols	SGS Axys Analytical	SGS AXYS METHOD MLA-113 Rev 01	LC-MS/MS	5
Sucralose	SGS Axys Analytical	MLA-116	LC-MS/MS	5
6PPD-quinone	DFO Institute of Ocean Science		LCMS	5

Data handling

In some cases, contaminants were not detected in our water samples and concentrations were therefore considered to be 0 for the calculations of totals.

With each batch of samples, analytical laboratories ran blank samples (e.g. samples that go through the same laboratory processes as our environmental samples) that should, in theory, not contain any contaminants. However, in some cases, blank samples contained low concentrations of contaminants. These levels in blanks were subtracted from the concentrations measured in each of our environmental samples ('blank correction').

Environmental Quality Guidelines

We interpreted contaminant concentrations using three sets of Canadian environmental quality guidelines (EQGs): provincial (British Columbia (BC)), federal, and those developed by the Canadian Council of the Ministers of the Environment (CCME). The latter CCME guidelines are derived in consultation with the environment ministers from the federal, provincial and territorial governments. Relevant EQGs and DWQGs are summarized in Appendix 3.

The British Columbia Ministry of Environment and Climate Change Strategy (BC MoECCS) has developed Water Quality Guidelines (WQGs) that are considered as protective for different water uses. We apply WQGs for the protection of stream and rivers aquatic life (source, stream and rivers and Road runoff samples) and marine aquatic life (marine water samples). All approved BC WQGs can be found on the BC MoECCS website.

Federal Environmental Quality Guidelines (FEQGs) are developed to support emerging federal environmental quality monitoring, risk assessment and risk management activities, and are derived to complement those developed by the CCME. They are only available for a limited number of chemicals captured in this list of EQGs (Government of Canada, 2024).

In addition, Working Water Quality Guidelines (WWQGs) are available for some contaminants for which a completed WQG is not yet available and are obtained from various Canadian provincial and federal jurisdictions (primarily the Canadian Council of the Ministers of the Environment (CCME)). WWQGs can be found on the CCME website.

It is important to note that exceeding a WQG/EQG or WWQG does not imply that unacceptable risk exists but rather that the potential for adverse effects is increased (BC MoECCCS, 2023). Conversely, WQGs may not fully capture the sensitivity of all species to different contaminants, such that adverse effects may occur in some species even at levels below a WQG. WQGs, therefore, serve as a benchmark based on best available evidence, and are subject to change as new evidence emerges.

Drinking Water Quality Guidelines

Guidelines are available to protect human health from different contaminants in drinking water. These have been developed at the federal level by Health Canada in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water (CDW) and other federal government departments (Health Canada, 2022). Guidelines for Canadian Drinking

Water Quality are developed specifically for contaminants that meet all of the following criteria (Health Canada, 2022):

- Exposure to the contaminant could lead to adverse health effects in humans;
- The contaminant is frequently detected or could be expected to be found in a large number of drinking water supplies throughout Canada; and,
- The contaminant is detected, or could be expected to be detected, in drinking water at a level that is of possible human health significance.

In BC, the First Nations Health Authority (FNHA) oversees drinking water safety on reserves, where Chief and Council are responsible for drinking water infrastructure and monitoring. Monitoring of drinking water relies on meeting the Health Canada DWQGs. Drinking water quality guidelines can be found on the Health Canada website.

Table 3: Analyte classes and number of available Environmental (or Water) Quality Guidelines (EQGs or WQGs) and Drinking Water Quality Guidelines (DWGs)

Analyte Class	Number of Analytes Measured	Drinking WQGs	Federal EQGs	BC WQGs	CCME EQGs
Basic Water Properties	5	1	0	4	5
Coliform	3	2	0	0	0
Nutrients	4	3	0	4	4
Metals	37	20	4	20	17
PAHs	76	1	0	10	10
Pesticides	62	6	0	10	7
PPCPs	141	0	1	1	0
PFAS	40	2	1	1	0
PCBs	209	0	0	5	0
Alkylphenols	4	0	0	0	0
Bisphenols	6	0	1	1	0
Sucralose	1	0	0	0	0
6PPD-quinone	1	0	0	0	0
Total	*587*	*35*	*7*	*56*	*43*

We applied three sets of EQGs and one set of DWQGs to our water quality data: The Federal government's *Federal Environmental Quality Guidelines* (FEQGs), the BC Government's Approved *Water Quality Guidelines* (BC WQGs), and the Canadian Council of Ministers of the Environment's (CCME) *Canadian Environmental Quality Guidelines* (CCME CEQGs); and Health Canada's Drinking Water Quality Guidelines. . These guidelines were all designed to protect aquatic life and human health.

International Guidelines and emerging PFAS concerns

There exist several thousand PFAS compounds, but only two are regulated in Canada: PFOA and PFOS, which were banned in 2011. Given the increasing concern over the presence, persistence and toxicity of per- and poly-fluoroalkyl substances (PFAS), Health Canada has developed screening values for a number of PFAS compounds (Appendix 4). These are considered as approved guidelines for drinking water quality, and are based on risk assessment approaches that are similar to formal guidelines (Health Canada, 2023). They therefore serve as guidance when evaluating the risk of PFAS exposure from tap water consumption and are considered in the present report.

Given the limited guidance afforded by Canadian guidelines for the rapidly emerging PFAS concerns, we have included guidelines derived internationally (USA, European Union and WHO).

Table 4: Environmental Quality Guidelines for PFAS (USA and Canada)

Compound	Guideline (mg/L)	Issuing Agency	Notes
PFOS	0.0068	Canadian FEQG	EQG - PFOA under development
PFOS	3	US EPA	DRAFT EQG - Acute
PFOS	0.0084	US EPA	DRAFT EQG - Chronic
PFOA	49	US EPA	DRAFT EQG - Acute
PFOA	0.094	US EPA	DRAFT EQG - Chronic

Very few Environmental Quality Guidelines are available for PFAS. A Canadian Federal EQG was set for PFOS, while a guideline value for PFOA is currently in development.

Table 5: Drinking Water Quality Guidelines for PFAS

Compound	Guideline (ng/L)	Issuing Agency
PFOS	600	Health Canada
PFOS	4	US EPA
PFOA	200	Health Canada
PFOA	4	US EPA
PFHxS	10	US EPA
PFNA	10	US EPA
HFPO-DA	10	US EPA
Total PFAS	500	EU - Drinking Water Directive

Any "guidelines" which used other language, or which were not enforceable (recommended limits, etc.) were omitted from this table. Most available guidelines address the two PFAS compounds of greatest concern to human health: PFOA and PFOS.

Water properties

Capsule

Basic water properties provided elementary information on the quality of fish habitat in the Tod Creek watershed. Source water sites were found to have the lowest temperature. The highest dissolved oxygen (% and mg/L) was measured in the Hartland sites. Source sites were found to have the lowest dissolved oxygen (% and mg/L). The highest conductivity and turbidity among non-marine samples was measured in the Hartland sites, which may reflect a combination of road runoff and Hartland operations.

Introduction

Water properties including temperature (℃), dissolved oxygen, conductivity, pH, and turbidity are commonly measured as a preliminary method of assessing the quality of fish habitat. Temperature and dissolved oxygen are of particular significance to fish - as increased temperatures and low dissolved oxygen are often associated with summertime fish kills. Conductivity and turbidity measurements can act as proxies for total dissolved solids (TDS) and total suspended solids (TSS) respectively. These parameters can be relevant as increased TDS and TSS in a body of water can indicate contamination from road salt or flushing of disturbed sediments into the waterway. Unusual conductivity measurements suggest the need for more in-depth analysis for contaminants.

Methods

A YSI ProDSS was used to take three measurements at each site of the following parameters: temperature (°C), dissolved oxygen (mg/L and %), specific conductivity (uS/cm), pH, and turbidity (FNU). A VTSYIQI water velocity meter was used to take three spot measurements from the shoreline where the samples were collected.

Results

Table 6: Average water property results for five categories of water sampled in the Tod Creek watershed (WET Season)

Analyte	Source (n=3)	Stream and river (n=3)	Road runoff (n=3)	Marine (n=3)	Hartland (n=3)
Temperature (℃)	5.8 ± 0.1 (5.6-6.1)	6.4 ± 0.11 (6.1-6.8)	7.3 ± 0.44 (5.8-8.9)	6.9 ± 0.09 (6.6-7.4)	9.0 ± 0.02 (9.0-9.2)
DO %	71 ± 2.27 (59.1-79.5)	78.2 ± 2.17 (69.4-90.4)	86.5 ± 2.82 (72.6-94.2)	90.6 ± 0.58 (88.1-94.1)	90.1 ± 1.23 (84.2-96.5)
DO (mg/L)	8.79 ± 0.288 (7.42-9.83)	9.85 ± 0.277 (8.59-11.2)	10.3 ± 0.283 (9.05-11.3)	10.0 ± 0.109 (9.59-10.6)	10.3 ± 0.113 (9.71-10.6)
pH	7.31 ± 0.130 (6.78-8.02)	7.33 ± 0.088 (7.03-7.84)	7.45 ± 0.081 (7.07-7.79)	7.65 ± 0.009 (7.61-7.69)	7.39 ± 0.150 (6.79-7.72)
Conductivity (uS/cm)	102 ± 3.96 (93.5-123)	143 ± 6.96 (115-164)	198 ± 19.4 (138-271)	23,500 ±1250 (19,100-28,900)	421 ± 53.0 (288-630)
Turbidity (FNU)	1.33 ± 0.149 (1.06-2.12)	2.3 ± 0.32 (1.2-4.2)	3.1 ± 0.32 (2.21-4.34)	2.2 ± 0.03 (2.05-2.40)	4.3 ± 0.59 (2.1-6.2)
Flow (m/s)	NA	0.224 ± 0.006 (0.212-0.232)	0.065 ± 0.016 (0.035-0.089)	NA	0.045 ± 0.045 (0.045-0.045)

Data represent the mean +/- Standard Error of the Mean (SEM), with the Range in parentheses (min-max). DO = Dissolved Oxygen. uS/cm = MicroSiemens per cm. FNU = Formazin Nephelometric Units. We did not collect water properties data on the tap water samples collected due to logistical difficulties in securing samples from individual homes and delivering them to our partner labs on time.

Conclusions

- Water, temperature, pH, and dissolved oxygen were all in acceptable ranges when evaluated against Environmental Quality Guidelines designed to protect aquatic life.
- Turbidity could not be assessed in relation to Environmental Quality Guidelines as it requires knowledge of background turbidity, but it was higher in those water categories that were downstream of source water.
- Conductivity was highest - as expected with naturally occurring ions and metals - in the marine sample, but was also elevated in the Hartland drainage samples when

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compared to the other freshwater categories. This could be due to a combination of road runoff with deicing activities as well as Hartland operations.

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Coliform bacteria

Capsule

Coliform bacteria in water indicate a potential threat to human health. The highest concentration of total coliform was detected in the road runoff sample. The highest concentration of fecal coliform and E. coli were detected in the stream and river sample. No coliform bacteria were detected in the pooled tap water sample. Relative low counts in the surface water samples may reflect human, pet or wild animal sources. Future Microbial Source Tracking results will be useful in identifying the host species for this observation. There were no exceedances of Water Quality Guidelines designed for recreational use of water for E. coli.

Introduction

Coliform bacteria have historically been used to gauge water quality with respect to implications for human recreational use and drinking water consumption. Most recently, the spotlight has been on counts (MPN of CFU) of the gram-negative coliform bacteria species *Escherichia coli* as an indicator of recent contamination with wastewater, and to determine the risk to human health posed by consumption and recreational use of waterways. There are no Environmental Quality Guidelines for coliform bacteria, reflecting the general idea that these potentially pathogenic bacteria are not likely to present a risk to aquatic life. Further work to measure Enterococci bacteria in future marine water samples will strengthen the evaluation of microbial contamination in water.

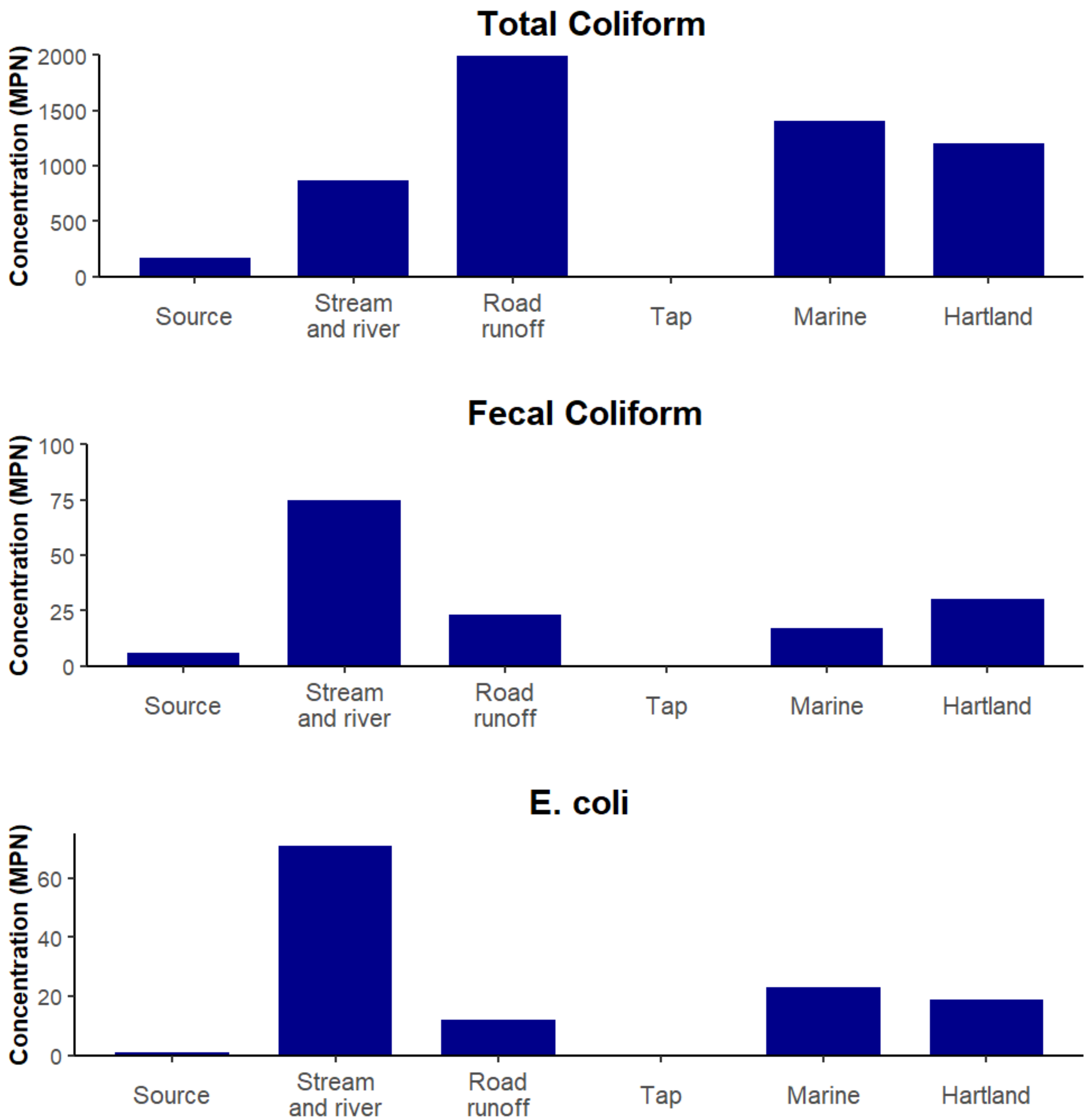
Results

Table 7: Concentration (MPN/100mL) of coliform bacteria in six water categories in the Tod Creek watershed (WET Season)

Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
Coliform, Total	172	866	1990	0	1410	1200
Coliform, Fecal	6	75	23	0	17	30
E. coli	1	71	12	0	23	19

The highest concentration of total coliform were detected in the road runoff sample, while the highest concentrations of fecal coliform and E. coli were detected in the stream and river sample.

Figure 2: Coliform concentration (MPN/100mL) in six water categories in the Tod Creek watershed (WET Season)



The highest concentration of total coliform bacteria was detected in the road runoff sample, while the highest concentrations of fecal coliform and E. coli were both detected in the stream and river sample. No coliform bacteria were detected in the tap water sample.

Conclusions

- Total E. coli concentrations for the five water categories were ranked from highest to lowest as follows: stream and river > marine > Hartland > road runoff > source > tap.

- E. coli values in all water samples were well below Recreational Use Guidelines set by Health Canada (>235 CFU/100ml).

- the inherent variability of coliform measurements in environmental samples (over time, place and among analyses) underscore the value in generating larger sample sizes or a modified approach to study design.

- No coliform were detected in the pooled tap water sample, indicating that there is no pathogenic risk to drinking water safety in the homes tested.

Nutrients and physical parameters

Capsule

Excess nutrients from fertilizers, wastewater and other human activities can readily degrade fish habitat by increasing plant and algal growth and causing a reduction in dissolved oxygen. Nitrate concentrations in the Hartland drainage sample exceeded the long-term Environmental Quality Guideline for the protection of aquatic life, but not the short-term acute Guideline.

Introduction

Nutrients such as nitrogen and phosphorus compounds can be naturally occurring, and are critical for the health and growth of plants and animals. However, nutrients from fertilizers and wastewater that are released into a body of water can put it at risk of eutrophication - a process which is characterized by an overgrowth of plants and algae and resulting in oxygen depletion. Eutrophication poses a significant risk to aquatic life, as low oxygen levels create an inhospitable environment for the survival of fish - in particular salmonids who require relatively high levels of dissolved oxygen for survival and reproduction.

In addition, some nutrients such as total ammonia are considered to be acutely toxic to freshwater fish species at concentrations that vary with the temperature and pH of the water.

Results

Table 8: Average concentrations (mg/L) of physical and chemical properties in each water category for the Tod Creek watersheds (WET Season)

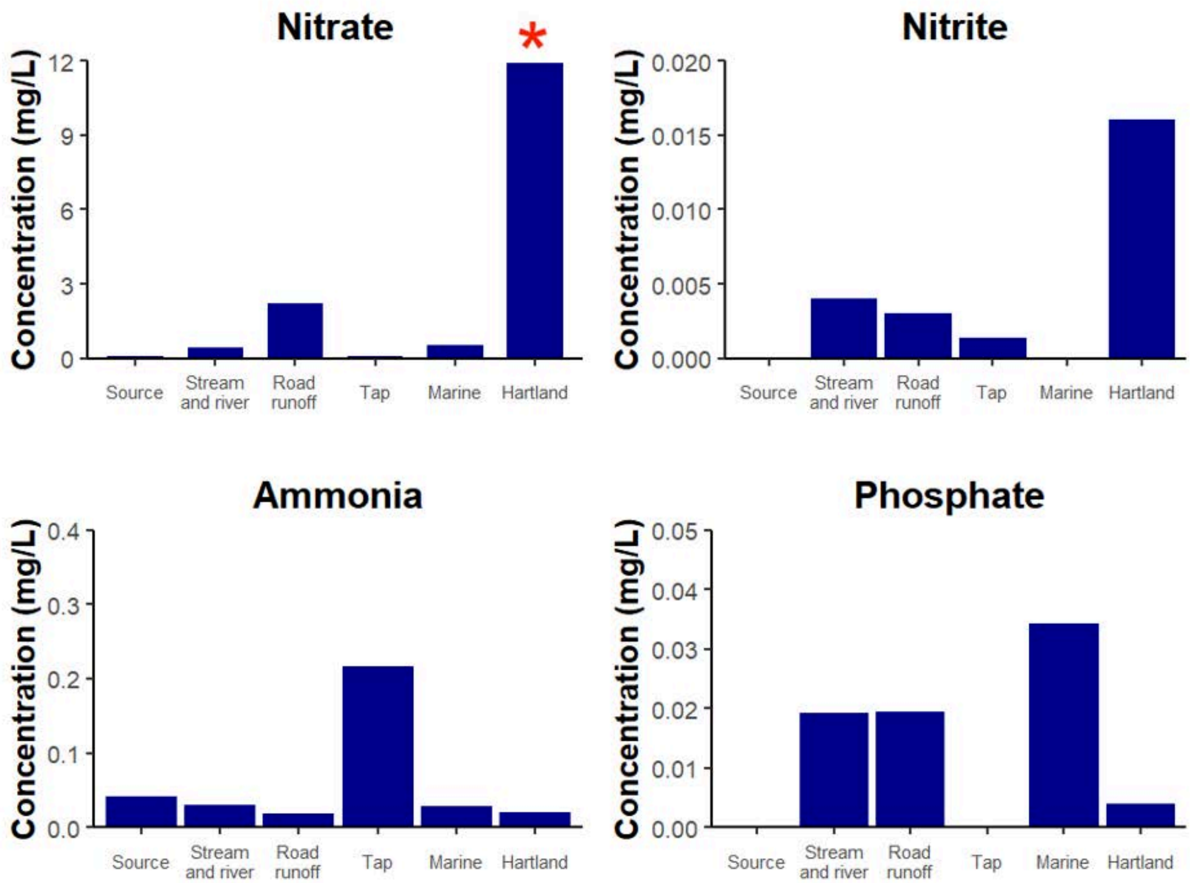
Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
Hardness, Total (as CaCO3)	32	53.5	73.1	17.8	1550	194
Carbon, Total Organic	12	7.92	9.36	2.11	5.03	8.7
Solids, Total Dissolved	80	94	125	40	8090	369
Solids, Total Suspended	0	0	0	0	7.4	0
Biological Oxygen Demand (BOD)	8.3	5	6.8	0	0	27.8

Table 9: Average nutrient concentrations (mg/L) in each water category for the Tod Creek watersheds (WET Season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)	Hartland (n=1)
Ammonia, total (as N)	0.0413	0.0292	0.0187	0.216	0.0278	0.0194
Nitrate (as N)	0.0646	0.422	2.23	0.0614	0.536	**11.9**
Nitrate + Nitrite (as N)	0.0646	0.426	2.23	0.0628	0.536	11.9
Nitrogen, total	0.424	0.803	2.4	0.441	0.754	11.6
Nitrite (as N)	0	0.004	0.003	0.0014	0	0.0161
Phosphate, ortho-, dissolved (as P)	0	0.0193	0.0195	0	0.0343	0.0039

Water samples were analyzed for the following nutrients: total nitrogen, nitrate (NO^{-3}), ammonia (NH_3), phosphate (PO_4^{3}) and nitrite (NO^{-2}). The Hartland drainage water sample had a nitrate (NO^{-3}) concentration that exceeded the BC WQG long-term chronic guideline of 3.0, but did not exceed the short-term acute (32.8 mg/L), or CCME guideline for the protection of aquatic life (550 mg/L) for the protection of aquatic life. n=1 is a composite of 3 sample locations of the same water type.

Figure 3: Mean Nutrient concentrations (mg/L) in five water categories in the Tod Creek watershed (WET Season)



Nitrate (NO^{-3}) and ammonia (NH_3) were the most commonly detected nutrients in water samples from the Tod Creek watershed, each present in all six samples. The highest concentration (11.9 mg/L) of nitrate (NO^{-3}) was detected in the Hartland drainage sample which exceeded the CCME long-term exposure guideline for the protection of aquatic life (3.0 mg/L). Ammonia (NH_3) was detected at the highest concentration in the tap water sample. Phosphate (PO_4^{3}) and nitrite (NO^{-2}) were detected in four out of the six samples, with the highest concentrations being in marine and Hartland samples respectively.

Conclusions

- The nitrate concentrations ranked from highest to lowest in the six water samples were as follows: Hartland > road runoff > marine > stream and river > source > tap.
- Nitrate and ammonia were the most frequently detected nutrients in samples across the Tod Creek watershed.

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- The Hartland sample had the highest concentrations of nitrate (NO^{-3}) and nitrite (NO^{-2}).
- Tap water had the highest concentration of ammonia (NH_3).
- The nitrate concentration in the Hartland water sample (11.9 mg/L) exceeded the CCME Guideline for long-term exposure of 3.0 mg/L (NO^{-3} as N) by almost 4x.
- None exceed the CCME Guidelines except the nitrate concentration in the Hartland water sample (11.9 mg/L) exceeded the CCME Guideline for long-term exposure of 3.0 mg/L (NO^{-3} as N) by almost 4x.
- Nitrate exceeds the BCWQG long term chronic (3.0 mg/L), but does not exceed the short term BVWQG of 32.8 or the CCME guideline of 550 mg/L.

Metals

Capsule

Metals can be present in water due to both natural and anthropogenic inputs. Sixteen metals were detected in all of the water samples collected in the Tod Creek watershed. Aside from the marine sample, total metal concentrations were highest in the Hartland water sample, consistent with our observation of higher levels of conductivity. Aluminum concentrations exceeded Environmental Quality Guidelines in all water samples except tap water.

Introduction

Metals are present in aquatic environments as a result of both natural and anthropogenic sources, with baseline levels reflecting the unique geology of the area surrounding a body of water. Anthropogenic sources of metal contamination in waterways may originate from industrial effluent, municipal wastewater, agricultural practices, and urban runoff.

Many metals are capable of impacting the health of aquatic life, with some representing a priority concern in fish habitat, including Zinc and Copper.

Results

Table 10: Total concentrations (mg/L) of the 16 metals that were detected in all six water categories in the Tod Creek watershed (WET Season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)	Hartland (n=1)
Aluminum, total	0.105	0.0981	0.193	0.0165	0.135	0.107
Antimony, total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00100	0.0001
Arsenic, total	0.00019	0.00035	0.00029	<0.00010	<0.00100	0.00021
Barium, total	0.00536	0.00585	0.00883	0.00348	0.00839	0.00838
Beryllium, total	<0.000020	<0.000020	<0.000020	<0.000020	<0.000200	<0.000020
Bismuth, total	<0.000050	<0.000050	<0.000050	<0.000050	<0.000500	<0.000050
Boron, total	0.023	0.025	0.024	0.012	1.04	0.082
Cadmium, total	<0.0000050	0.0000078	0.0000076	<0.0000050	<0.0000500	0.0000127
Calcium, total	9.14	15.5	21.7	5.22	101	63.5
Chromium, total	<0.00050	<0.00050	0.00058	<0.00050	<0.00500	0.00054

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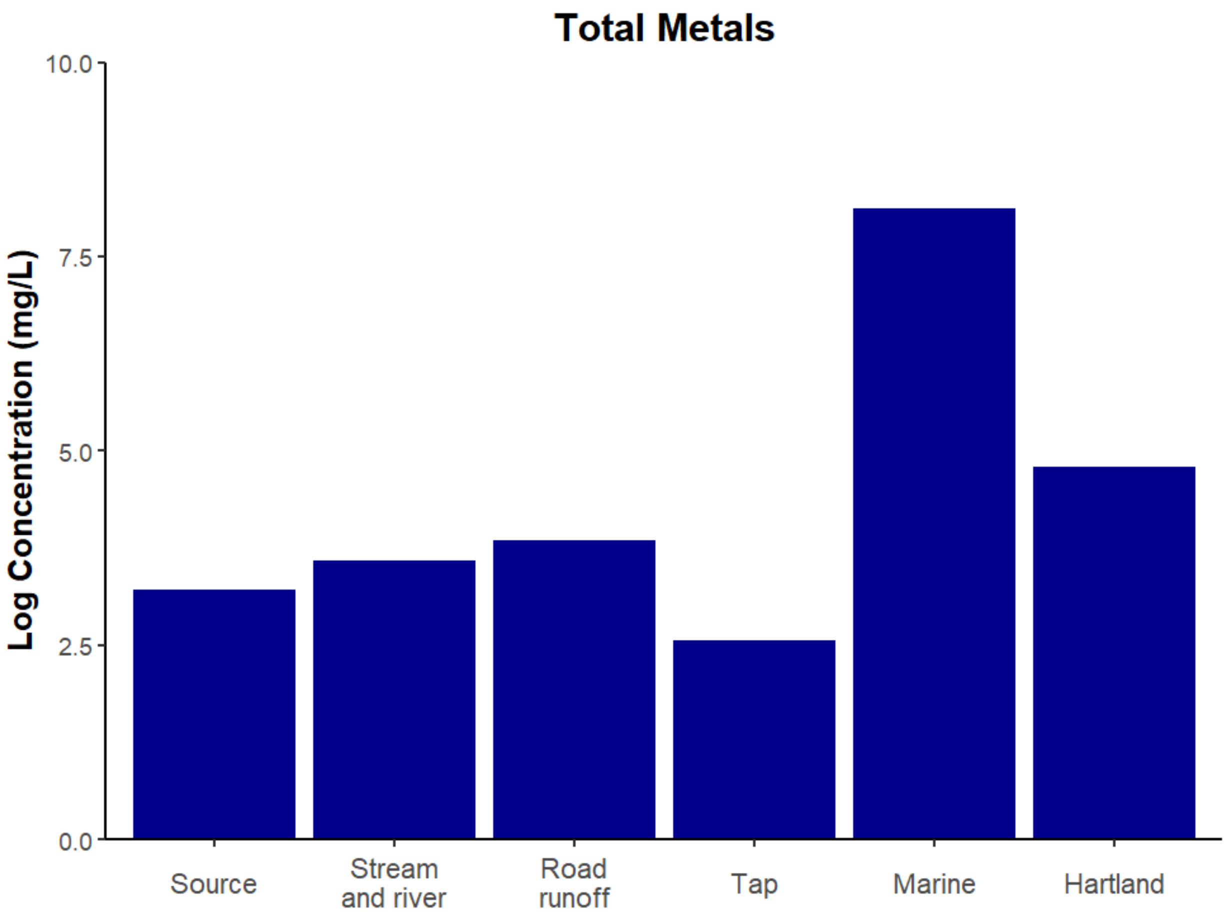
Cobalt, total	<0.00010	0.0001	0.00012	0.00031	<0.00100	0.00016
Copper, total	0.00108	0.00182	0.00329	0.0993	<0.00500	0.00363
Iron, total	0.251	0.159	0.162	0.029	0.165	0.148
Lead, total	0.000077	0.000122	0.000098	0.00031	<0.000500	0.000054
Lithium, total	<0.0010	<0.0010	<0.0010	<0.0010	0.0398	<0.0010
Magnesium, total	2.24	3.59	4.6	1.17	315	8.67
Manganese, total	0.017	0.0118	0.00719	0.00257	0.0113	0.0153
Mercury, total	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum, total	0.000211	0.000254	0.000224	0.00008	0.00279	0.00112
Nickel, total	<0.00050	0.00055	0.00056	0.00095	<0.00500	0.00093
Phosphorus, total	<0.050	<0.050	<0.050	<0.050	<0.500	<0.050
Potassium, total	0.45	1.02	1.19	0.144	98.7	1.03
Selenium, total	<0.000050	0.000072	0.00007	<0.000050	<0.000500	0.000272
Silicon, total	3.11	4.07	5.64	2.3	4.3	7.81
Silver, total	<0.000010	<0.000010	<0.000010	<0.000010	<0.000100	<0.000010
Sodium, total	8.14	7.56	9.98	3.89	2620	9.58
Strontium, total	0.0354	0.0528	0.0741	0.0186	1.82	0.173
Sulfur, total	1.43	3.61	3.75	<0.50	232	30
Thallium, total	<0.000010	<0.000010	<0.000010	<0.000010	<0.000100	<0.000010
Tin, total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00100	<0.00010
Titanium, total	0.0031	0.00419	0.0083	<0.00030	0.00608	0.00458
Uranium, total	<0.000010	0.000018	0.000024	<0.000010	0.000715	0.000044
Vanadium, total	0.00055	0.00081	0.00115	<0.00050	<0.00500	0.00254
Zinc, total	<0.0030	<0.0030	0.012	0.0092	<0.0300	0.0031
Zirconium, total	<0.00020	<0.00020	<0.00020	<0.00020	<0.00200	<0.00020
Total Metals	*25.0*	*35.7*	*47.4*	*12.9*	*3370*	*9570*

***Bold** indicates a concentration that is at or exceeds Environmental Quality Guidelines. Tap water did not exceed the Health Canada Drinking Water Quality Guideline.

Figure 4: Total metal concentrations (mg/L) in six water categories in the Tod Creek watersheds (WET Season)



Total metal concentrations are shown with a logarithmic transformation to allow for visualization of the data. The marine sample - as expected - had the highest concentration of total metals among all samples, while the Hartland sample had the highest concentration of total metals among the non-marine categories.

Table 11: Concentrations (mg/L) of lead detected in all six water categories in the Tod Creek watersheds (WET Season)

Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
Lead (mg/L)	0.000077	0.000122	0.000098	0.00031	0	0.000054

Lead can be a concern when found in drinking water. No water samples exceeded DWGs or EQGs available for lead.

Conclusions

- Total metal concentrations in the six water categories from highest to lowest are as follows: marine > Hartland > road runoff > stream and river > source > tap.
- The aluminum concentrations in all surface water samples were above the CCME Long Term Guideline for the protection of aquatic life (0.1 mg/L), possibly due to naturally-occurring levels of this metal.
- Lead was detected in all of the water samples apart from the marine water sample. There were no lead exceedances of EQGs or DWQGs.

Polycyclic Aromatic Hydrocarbons (PAHs)

Capsule

Low levels of polycyclic aromatic hydrocarbons (PAHs) were detected in all six water samples, with the highest concentrations observed in the tap water sample, and the lowest in the stream and river sample. Naphthalene was consistently detected at the highest concentrations in all samples. PAH profiles suggested that the combustion of wood and/or plant material contributed to the contamination of all samples, possibly a reflection of wildfire smoke. WQGs are only available for 10 PAHs, but no exceedances were observed for any samples. Finally, the tap water sample did not exceed the one PAH guideline (BaP) available for drinking water.

Introduction

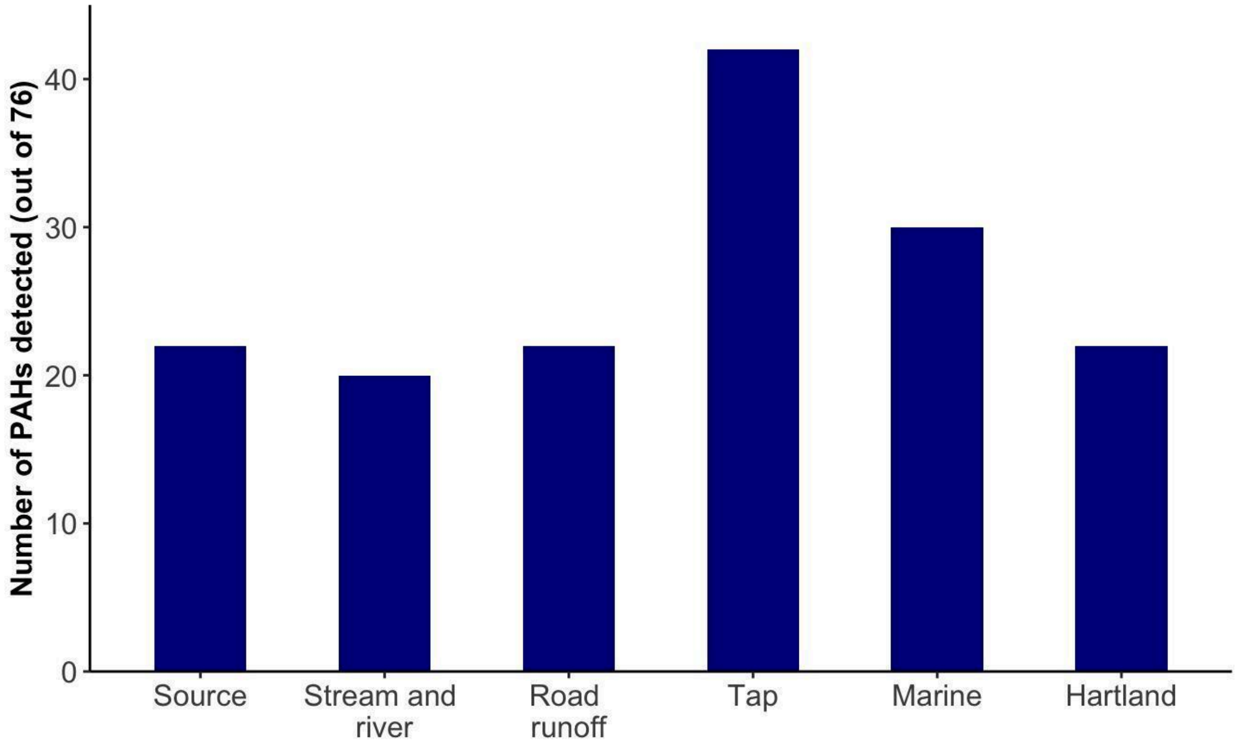
Polycyclic aromatic hydrocarbons (PAHs) are a complex group of compounds found in coal, petroleum and plant materials. They can enter waterways in the form of liquid petroleum products (gasoline, diesel, oil) or via the incomplete combustion of coal, oil, gas, wood garbage or other organic substances. They can occur naturally or as a result of human activities (anthropogenic). In Canada, forest fires are the single most important natural source of PAHs, while anthropogenic sources include residential wood heating, aluminum smelters, creosote-treated products, spills of petroleum products and metallurgical and coking plants, and household activities (Government of Canada, ECCC and Health Canada, 1994; Marvin et al., 2021).

Hydrocarbons can enter aquatic ecosystems either directly through oil spills or discharges from vessels (Morales-Caselles et al., 2017) or indirectly through atmospheric deposition, runoff and discharge from wastewater treatment plants. Depending on their molecular size, PAHs vary in toxicity and have been classified as toxic under the Canadian Environmental Protection Act (CEPA).

Results

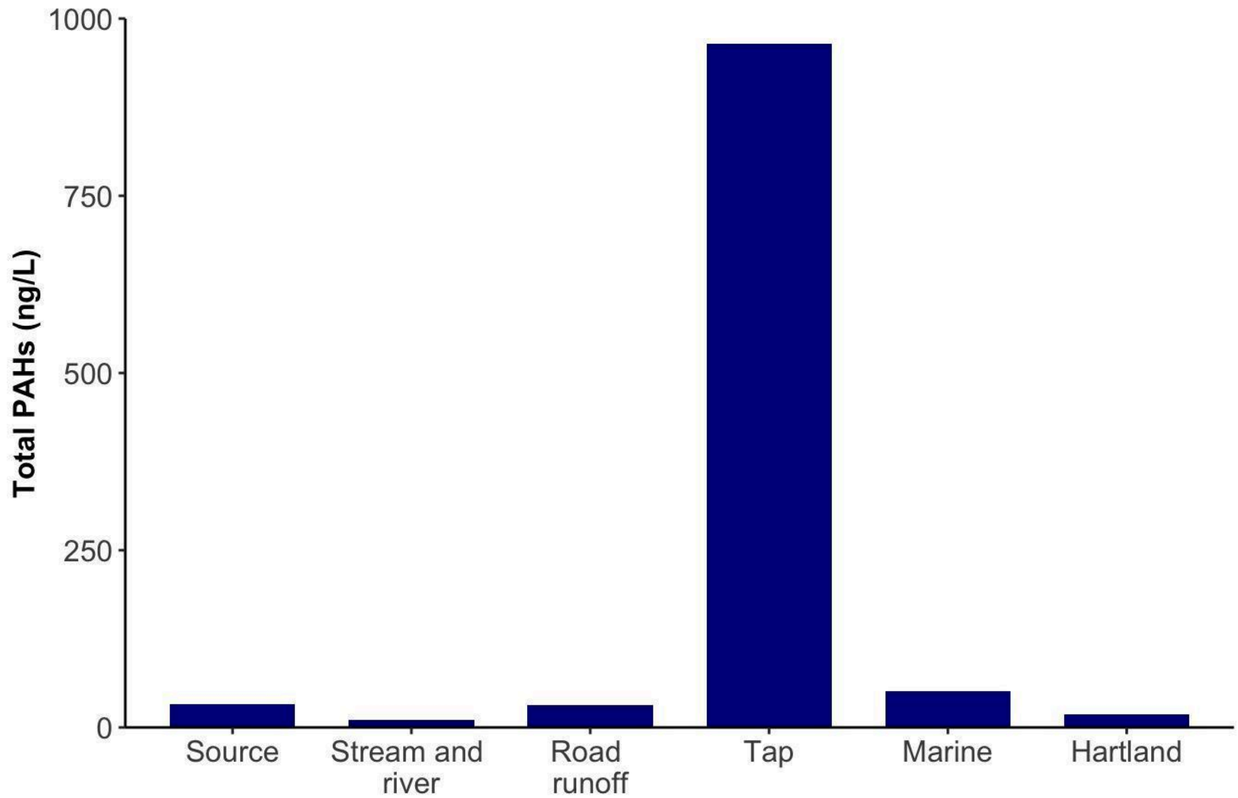
We measured 76 different parent and alkylated PAHs in the six water samples collected in the Tod Creek watersheds during the wet season.

Figure 5: Number of PAHs detected in water samples from the Tod Creek watershed (WET Season)



PAHs were detected in all six water categories. The number of PAHs detected ranged from 20 (stream and river) to 42 (tap) with an average of 26.3 ± 3.4.

Figure 6: Total PAH concentrations in water samples from the Tod Creek watershed (WET Season)



Total PAH levels ranged between 11.2 (stream and river) and 963.9 ng/L (tap) with an average across all water categories of 185 ± 156 ng/L.

The top 6 PAHs with the highest concentrations contributed between 60% (landfill) and 85% (Road runoff) of total PAH concentrations (Table 12). The PAH composition for these top 6 was variable across water categories with only naphthalene being consistently detected with the highest concentrations in all samples. C2-Biphenyls were present in the top 6 of all samples except stream and river water and tap.

Table 12: Top 6 PAHs with the highest concentrations in each water sample from the Tod Creek watersheds (WET Season)

Source	Stream and river	Road runoff	Tap	Marine	Hartland
C2-Biphenyls (15.4)	Naphthalene (2.6)	C2-Biphenyls (18)	Naphthalene (244.9)	C2-Biphenyls (11)	C2-Biphenyls (4.5)

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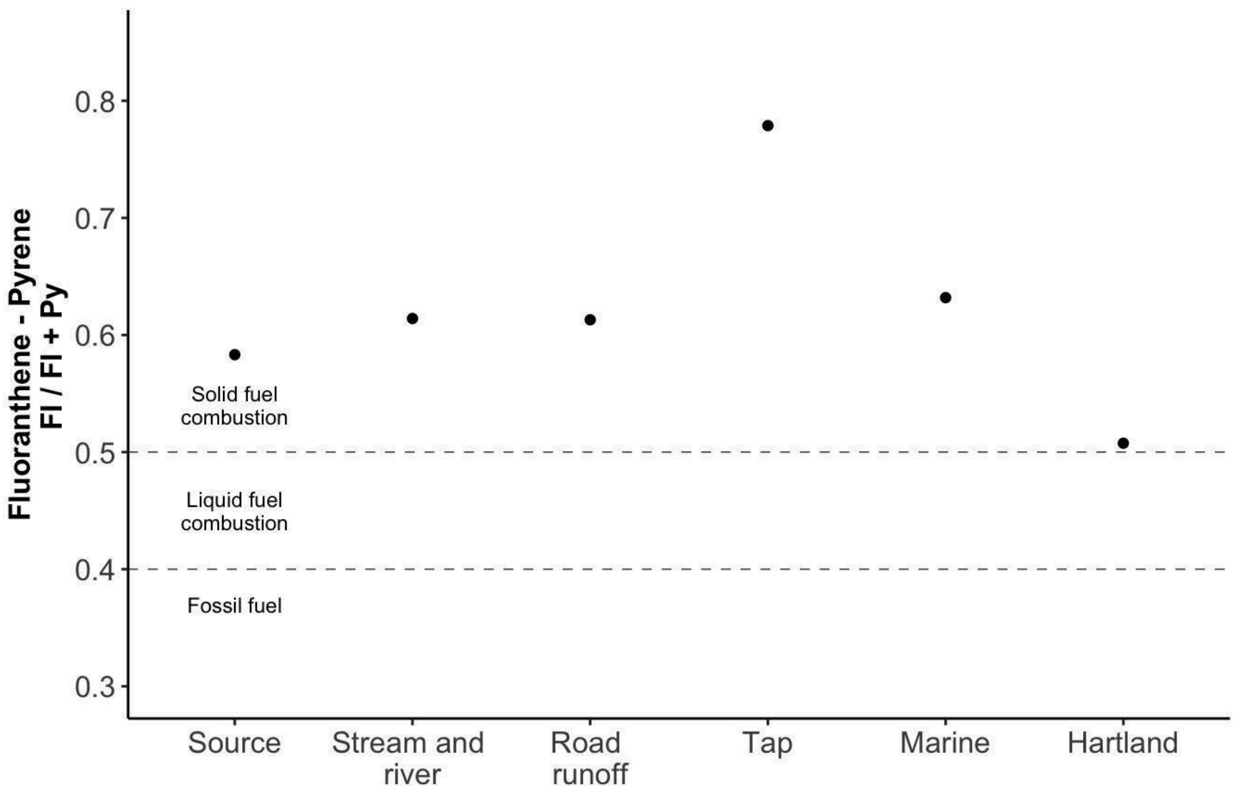
	C1-Biphenyls (2.9)	Phenanthrene (1.2)	C1-Biphenyls (3.2)	Phenanthrene (205.3)	Naphthalene (6.1)	Naphthalene (1.7)
	Naphthalene (2.3)	C1-Naphthalene (0.98)	Naphthalene (2.7)	Acenaphthene (96.6)	C1-Naphthalenes (5.3)	C4-Phenanthrenes (1.6)
	Retene (2.2)	Acenaphthene (0.90)	C2-Dibenzothiophenes (1.1)	C1-Naphthalenes (85.6)	2-Methylnaphthalene (3.3)	Acenaphthene (1.2)
	C4-Phenanthrenes (1.6)	1-Methylnaphthalene (0.63)	C1-Naphthalenes (1.1)	2-Methylnaphthalene (52.2)	Phenanthrene (3.1)	C2-Naphthalenes (1.0)
	Phenanthrene (1.4)	Retene (0.63)	Phenanthrene (0.64)	Fluoranthene (44.5)	C2-Naphthalenes (2.8)	C1-Biphenyls (1.0)
Total concentrations of top 6 (% of total PAHs)	25.9 (78%)	6.9 (62%)	26.7 (85%)	727.9 (75%)	31.6 (61%)	10.9 (60%)

Ratios of certain PAHs can be used to evaluate sources. Given that only a limited number of PAHs were detected in the water samples, the Fluoranthene - Pyrene ratio was the only one that could be calculated reliably for all samples.

Figure 7: PAH profiles from wood combustion and fuels in water samples from the Tod Creek watershed (WET Season)



All samples had Fl/Py ratios higher than 0.5, suggesting the contribution of combustion of solid fuel such as wood, plant material or coal as the source of PAHs.

Conclusions

- PAH concentrations were ranked as follows from highest to lowest: tap > marine > source > road runoff > Hartland > stream and river.

- Total PAH concentrations in Tod Creek watershed water samples ranged from 11.2 to 963.9 ng/L.

- Fluoranthene - Pyrene ratios revealed that PAHs in all samples originated primarily from the combustion of solid fuel such as wood or plant material. This is consistent with wood burning for heating homes, and wildfires, as being major sources of PAHs in Canada (Berthiaume et al., 2021). In addition, biomass burning in Asia has been shown to deliver PAHs to Canada through air masses traveling across the Pacific Ocean (Berthiaume et al., 2021).

- All the water samples were well below the BC WQGs available for individual PAHs (naphthalene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, chrysene, benzo-a-pyrene and benzo-a-anthracene).

- The only DWQG for PAHs was for benzo-a-pyrene (40 ng/L); BaP was not detected in the tap water sample.

- Background PAH concentrations were higher than those measured in the Hartland samples.

Pesticides

Capsule

A limited number of pesticides were detected in all six water samples, with the highest concentrations in the stream and river water sample, and the lowest in the tap water sample. All the pesticides detected are banned in Canada. Alpha- endosulfan, hexachlorobenzene and chlorpyriphos were detected in the majority of samples. Out of the pesticides detected in environmental samples, WQGs were only available for endosulfan and chlorpyriphos, but no exceedances for these pesticides were observed. There were no DWGs for hexachlorobenzene and alpha-HCH, the two pesticides detected in tap water.

Introduction

Pesticides have been developed to control, destroy or inhibit the activities of pests. They have a wide range of applications in agriculture such as insecticide to prevent crop damage and fungicides to prevent plant disease but also in forestry, industry as well as in our own backyards for lawn care or weed and insect control. In Canada, all pesticides used, sold or imported are regulated by Health Canada's Pest Management Agency (PMRA) (Health Canada, 2007).

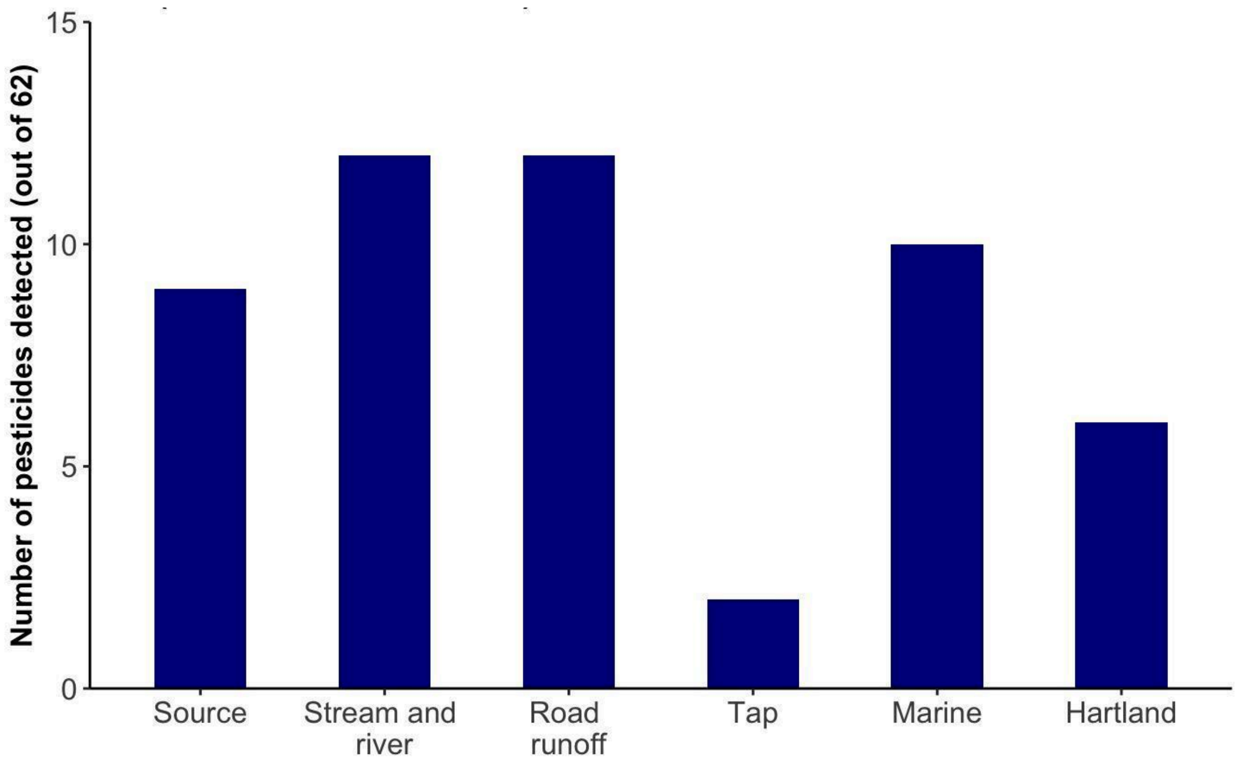
While pesticides are mostly applied on terrestrial habitats, they can reach aquatic environments through overspray or drift during application, surface runoff, and through long range atmospheric transport and deposition. It is estimated that 10% of pesticides applied to soil reach non-target areas, leading to their widespread presence in surface waters worldwide (Schulz, 2004; Anderson et al., 2022).

Organochlorine pesticides (OCP) were heavily used from the 1940s to the 1980s, but have been restricted due to their persistence, toxicity and potential for bioaccumulation. Current-use pesticides (CUPs) were subsequently favoured as an alternative to OCPs, and have been widely applied in recent decades (Ding et al., 2023). These tend to be more water-soluble and may be more mobile in fish habitat (Harris et al., 2008).

Results

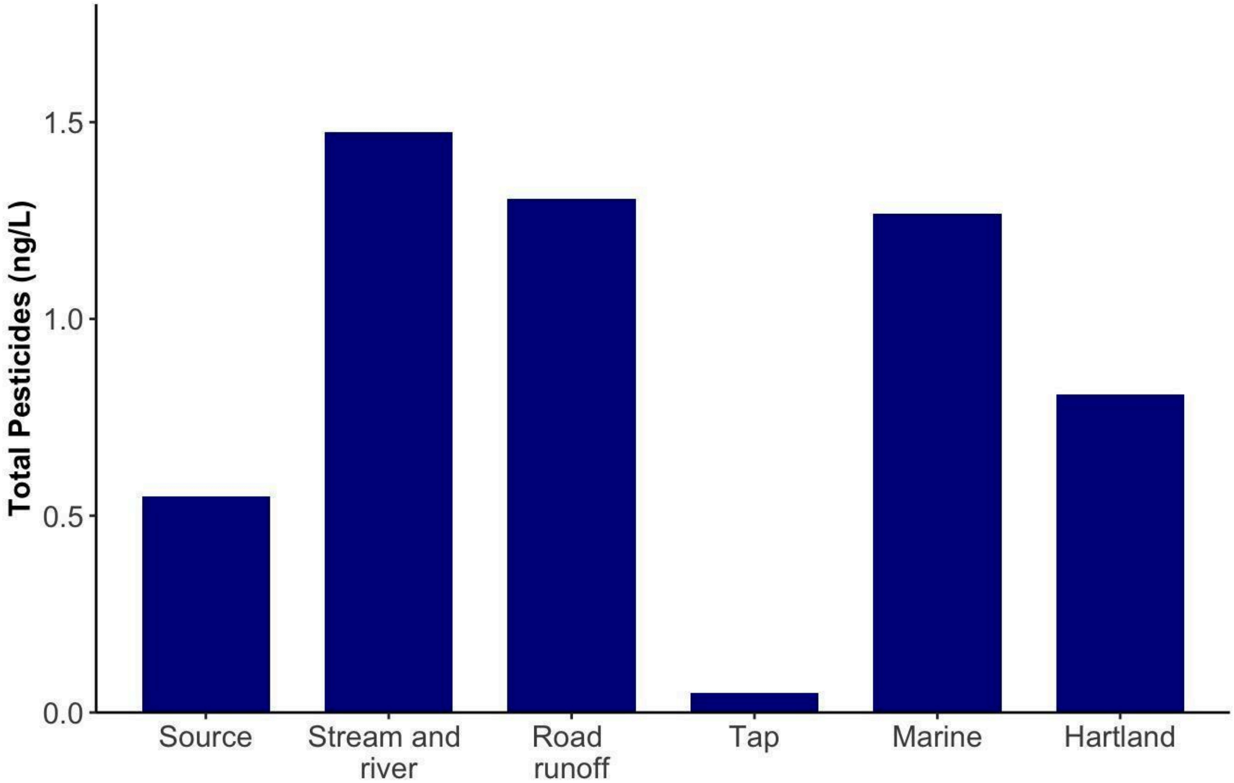
We measured 62 different pesticides, including both legacy and CUPs in the six water samples collected within the Tod Creek watershed during the wet season. Stream and river, and road runoff had the highest number of detected pesticides as well as the highest total concentrations.

Figure 8: Number of pesticides detected in water sampled in the Tod Creek watershed (WET Season)



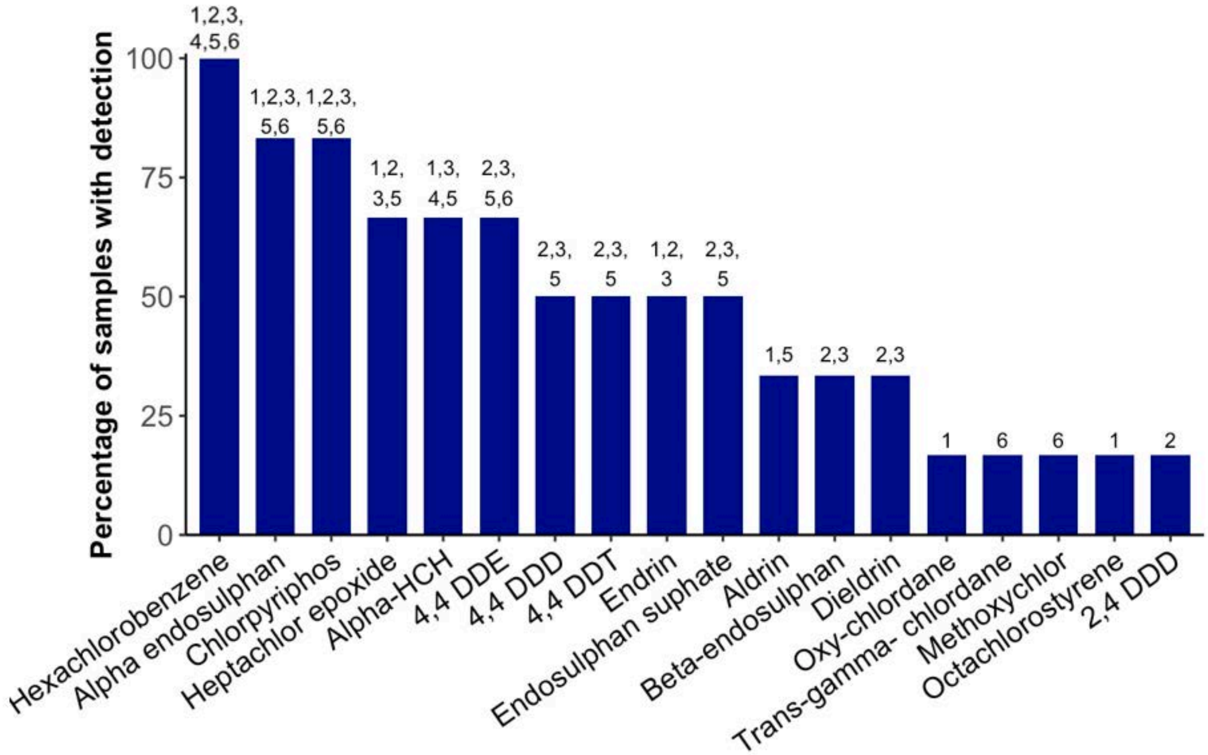
The number of pesticides detected ranged from 2 (tap) to 12 (stream and river and road runoff) with an average of 8.5 ± 1.6.

Figure 9: Total pesticide concentrations in water sampled in the Tod Creek watersheds (WET Season).



Total pesticide levels ranged from 0.05 (tap) to 1.5 ng/L (stream and river), with an average across all water categories of 0.91 ± 0.22 ng/L.

Figure 10: Most frequently detected pesticides in water categories sampled in the Tod Creek watershed (WET Season)



Numbers refer to water categories (1: Source; 2: Stream and river, 3: Road runoff, 4: Tap; 5: Marine; 6: Hartland). For example, the Hartland landfill water sample had detectable concentrations of Alpha-endosulfan, hexachlorobenzene, chlorpyriphos, 4,4′ DDE, methoxychlor and trans-gamma-chlordane. Tap water had detectable levels of hexachlorobenzene and alpha-HCH.

All the pesticides detected were legacy chemicals that were no longer in use at the time of sampling. Hexachlorobenzene (100% of samples), alpha- endosulfan (83% of samples) and chlorpyriphos (83% of samples) were detected in the majority of samples.

Hexachlorobenzene is a fungicide to treat seeds of food crops. While it is banned in Canada and most other countries, it can be produced unintentionally as a by-product of the manufacture of certain industrial chemicals (Government of Canada, 2017).

Endosulfan is a restricted-use insecticide and acaracide used to control a broad range of insect and arthropod pests on a wide variety of food, feed and ornamental crops (Health Canada, 2011). The commercial mixture contains both alpha- and beta- endosulfan.

Endosulfan has been banned in Canada since 2016 and is banned or restricted in most other countries (ECCC, 2023).

Chlorpyrifos is an organophosphate insecticide used in agricultural and ornamental production, forestry and mosquito control. Any use of chlorpyrifos pesticides has been prohibited since December 2023 (Health Canada, 2023).

Conclusions

- Pesticide concentrations in the Tod Creek watershed were ranked as follows from highest to lowest: stream and river > road runoff > marine > Hartland > source > tap.
- Total pesticide concentrations ranged from 0.05 to 1.5 ng/L.
- All pesticides detected are no longer in use in Canada. Their detection likely reflects historical use nearby as well as deposition following long-range atmospheric transport. Interestingly, hexachlorobenzene and endosulfan were the most abundant pesticides detected in air samples collected from four mountains across British Columbia, including Grouse Mountain in North Vancouver (Ding et al., 2023).
- Endosulfan and chlorpyriphos were the only pesticides detected that had EQGs, and no samples exceeded these Guidelines.
- Hexachlorobenzene and alpha-HCH were the only pesticides detected in tap water and no DWGs were available for these pesticides.

Pharmaceuticals and Personal Care Products

Capsule

Pharmaceuticals and Personal Care Products (PPCPs) are a category of contaminants that can enter the environment via wastewater, and are typically not removed during treatment. DEET and cocaine were detected in all six water samples. Metformin, penicillin, benzoylecgonine and cotinine were detected in five out of six water samples. Caffeine and theophylline were detected in four out of five water samples. PPCP concentrations were relatively low throughout all samples.

Introduction

Pharmaceuticals and Personal Care Products (PPCPs) comprise a wide range of products and chemical formulations. The common link among these compounds is their use in human health, veterinary health and personal care. Many PPCPs are introduced into the environment via wastewater streams, and are not reliably removed during treatment at wastewater treatment plants (WWTPs).

DEET (N,N-diethyl-meta-toluamide) is a widely used insect repellent. Cocaine is a recreational drug, with its metabolic product benzoylecgonine. Metformin is a drug commonly prescribed for the treatment of diabetes and pre-diabetes, and functions to lower the blood glucose levels of users. Caffeine is a plant-derived stimulant found in widely-consumed beverages. Penicillin is a well-known antibiotic used to treat bacterial infections. Cotinine is the breakdown product of nicotine. Cotinine is the breakdown product of nicotine. Theophylline is an asthma/pulmonary medication. Onsite sewage treatment systems (septic) can also be a significant source.

Caffeine has been used as an indicator of human wastewater in the environment - as it is relatively stable and persistent in surface waters, but sucralose is increasingly used in its place.

Results

Table 13: PPCP concentrations (ng/L) for all analytes detected in each water category for the Tod Creek watershed (WET Season)

Analyte	Source	Stream and river	Road runoff	Tap	Marine	Hartland
2-Hydroxy-ibuprofen	0	5.47	0	0	0	0
Cefotaxime	6.76	0	0	0	0	0
Penicillin G	0	0	0	39.78	3.79	3.79
Caffeine	0	16.7	9.04	0	14.3	10.5
Carbamazepine	0	0.614	0	0	0.715	1.52
Sulfamethizole	1.24	0	0	0	0	0
Cotinine	0.464	1.58	0.677	0	1.06	0.4
Metformin	1.49	4.33	2.91	0	9.58	2.59
Benzoylecgonine	0	0.547	0.375	1.32	0.518	0.485
Cocaine	0.389	0.262	0.258	4.54	0.186	0.309
DEET	1.98	2.93	1.22	6.9	1.13	37.94
10-hydroxy-amitriptyline	0.227	0	0	0	0	0
Theophylline	7.65	14.6	7.6	0	11	0
Total PPCP Concentration	**20.2**	**47.0**	**22.1**	**52.5**	**42.3**	**57.5**
Total number of PPCPs detected	*8*	*9*	*7*	*4*	*9*	*8*

A total of thirteen different PPCPs were detected in water samples collected in the Tod Creek watershed. The highest concentration was detected in the Hartland water sample. The greatest number of different PPCPs were detected in the stream and river, and marine samples.

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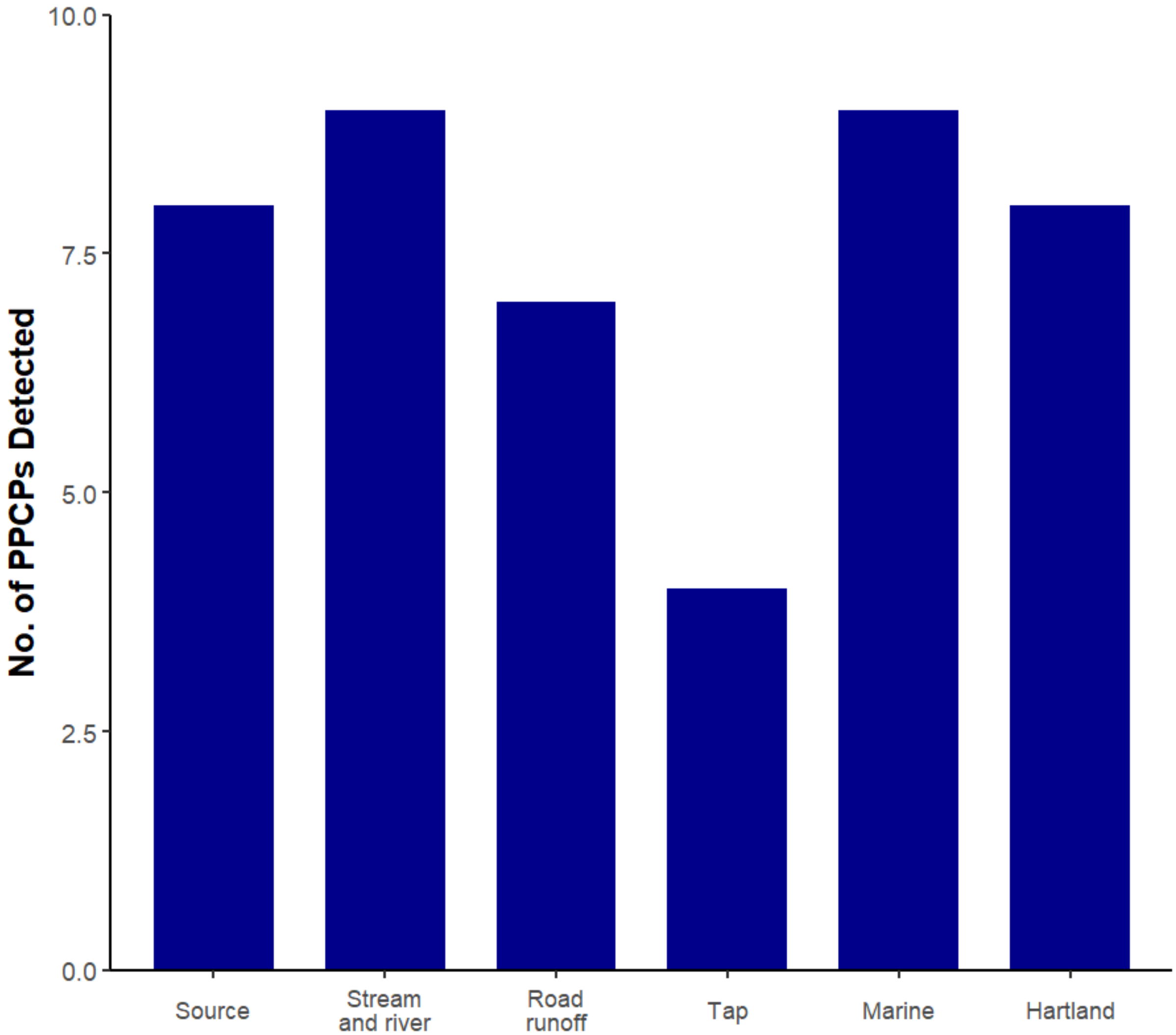
Figure 11: The number of PPCPs detected in each of six water samples from the Tod Creek watershed (WET Season)



Stream and river, and marine samples had the greatest number of PPCPs detected among water categories. The tap sample had the lowest number of compounds detected, but highest concentrations.

Conclusions

- Relatively low levels of PPCPs were detected in water samples in the Tod Creek watershed.
- PPCP concentrations in water samples ranged from highest to lowest as follows: Hartland > tap > stream and river > marine > road runoff > source.
- There are no EQGs available in Canada for any of the PPCPs we detected in water samples for the Tod Creek watershed.
- The only PPCP for which there is an Environmental Quality Guideline is Ethinylestradiol (EE), which is used widely as one of the hormonal components of birth control - as it has been shown to negatively impact both reproductive and immune function in some fish species. We did not detect EE in any of the samples collected from the Tod Creek watershed.
- Future sampling will complement findings here and contribute to a better understanding of the modest number of PPCPs detected in the various water categories in Tod Creek.

Per- and poly-fluoroalkyl substances (PFAS)

Capsule

Per- and poly-fluoroalkyl substances (PFAS) were detected in all Tod Creek watershed samples, with the highest concentrations observed in the Hartland drainage sample and the lowest in tap water. Perfluorooctanesulfonic acid (PFOS) and Perfluorooctanoic Acid (PFOA) were detected in all samples except tap water, reflecting legacy use as these chemicals were banned in Canada in 2009 and 2016, respectively. Perfluoro-octanesulfonamide (PFOSA) was the only PFAS detected in tap water. None of the samples exceeded the few environmental quality guidelines available (PFOS) or Canadian and international guidelines or other regulatory values for drinking water. New guidelines for PFAS are in development, such that this interpretation may change for this class of contaminant.

Introduction

Per- and poly-fluoroalkyl substances (PFAS) are large group (~15,000 compounds) of human-made substances that are widely used in a variety of products such as food packaging, non-stick cookware, clothing, cosmetics but also firefighting foams, lubricants and oil/water repellents. They are extremely stable and therefore persistent in the environment, which has led to the use of the term "forever chemicals".

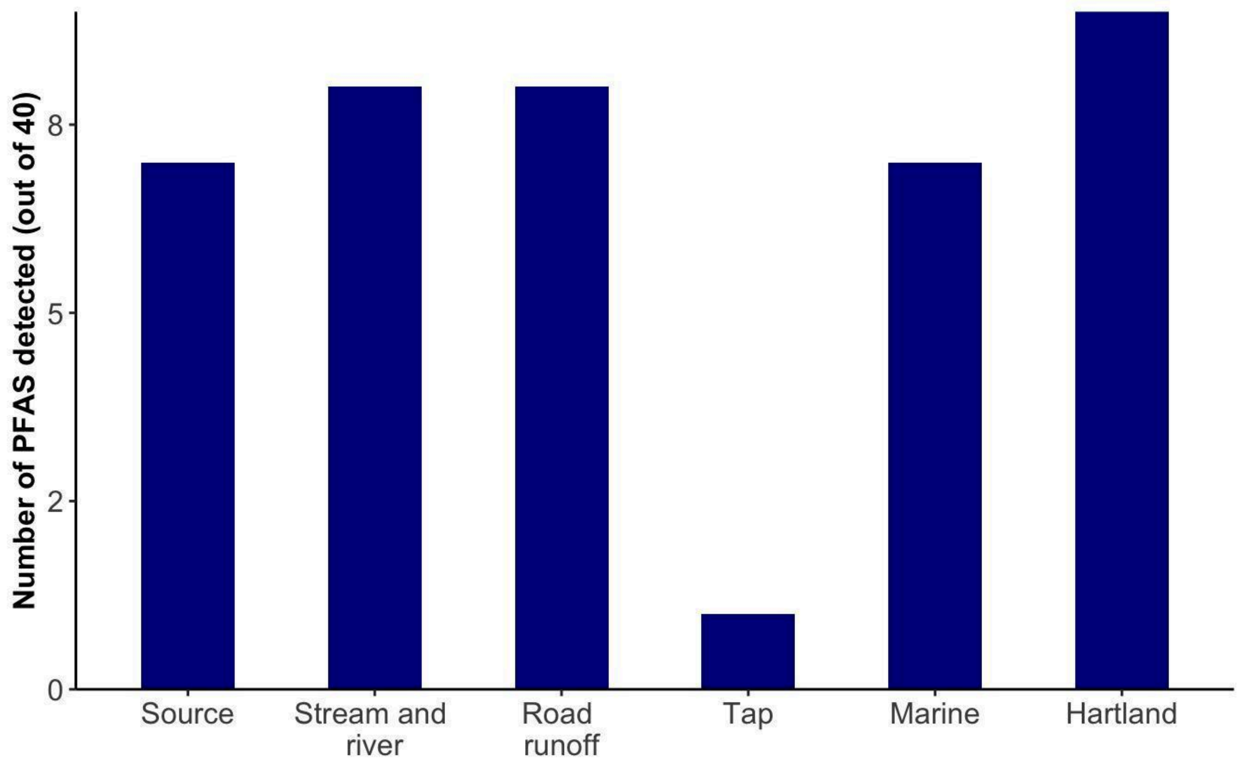
PFAS can be released in the environment at point sources such as manufacturing plants, or where firefighting foams have been used such as airports and military installations. PFAS can also be released through consumer use and disposal of PFAS-containing products. PFAS has been found in all environmental compartments (ECCC and Health Canada, 2023).

Evidence of adverse effects on the environment and human health has led Canada to prohibit the manufacture, use, sale, offer for sale and import of a limited number of PFAS including perfluorooctanesulfonic acid (PFOS), perfluorooctanoic Acid (PFOA), long-chain perfluorocarboxylic acids and their salts and precursors under the *Prohibition of Certain Toxic Substances Regulations* and the *Canadian Environmental Protection Act* (CEPA) (ECCC and Health Canada, 2023b).

Results

We analysed up to 40 different PFAS in the six water samples collected within the Tod Creek watershed during the wet season.

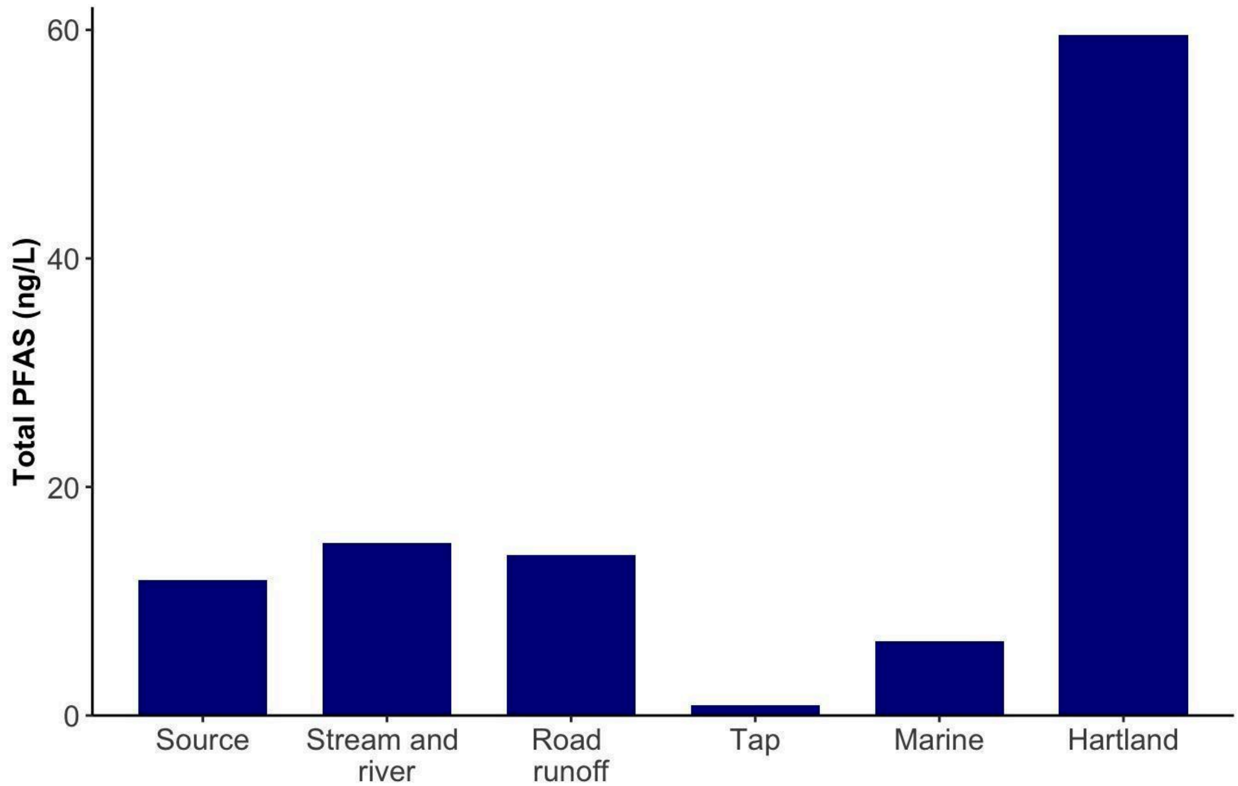
Figure 12: Number of PFAS substances detected in water samples from the Tod Creek watershed (WET Season)



PFAS were detected in all six water categories. The number of PFAS detected ranged from 1 (tap) to 9 (Hartland) with an average of 6.7 ± 1.2.

https://doi.org/10.70766/76.9001

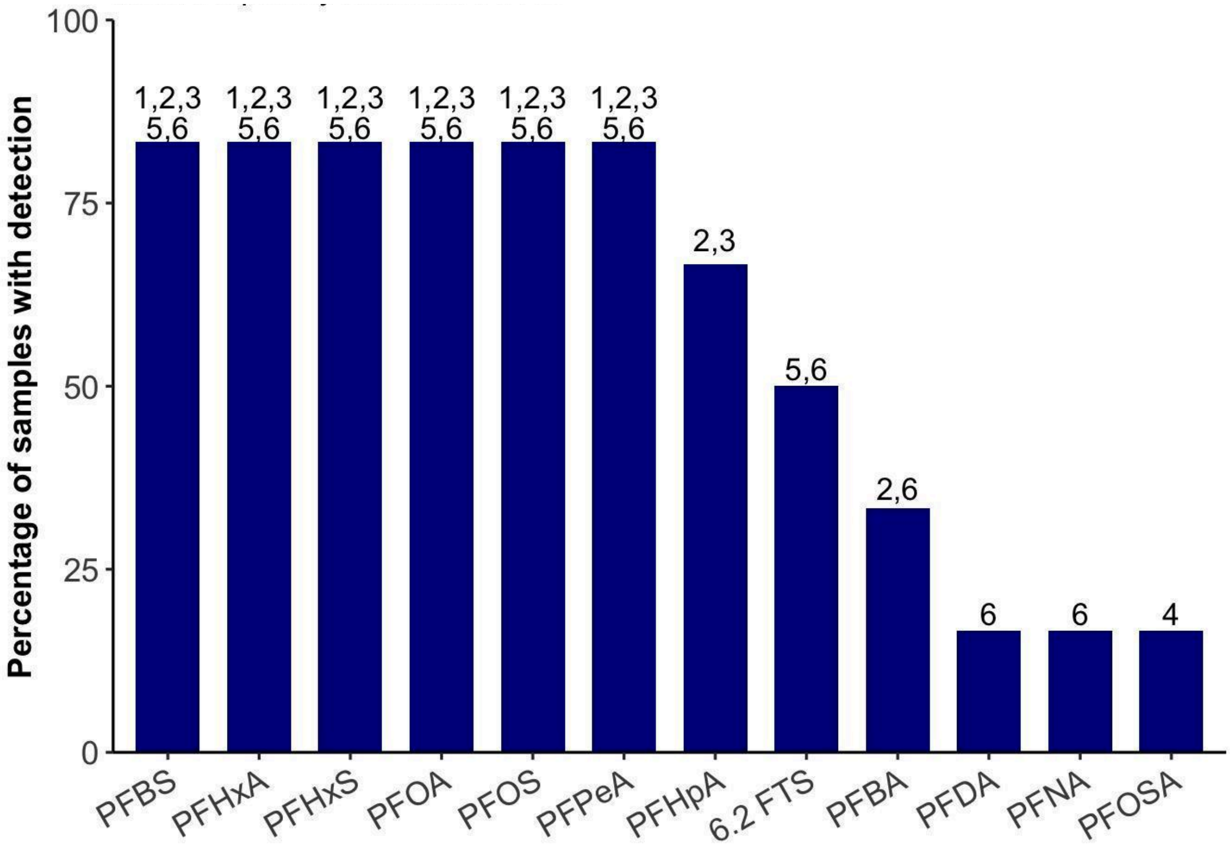
Figure 13: Total PFAS concentrations in water sampled in the Tod Creek watershed (WET Season)



Total PFAS levels ranged between 0.94 (tap) and 59.5 ng/L (Hartland), with an average across all sample categories of 18.0 ± 8.6 ng/L.

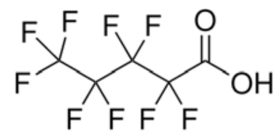
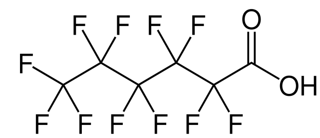
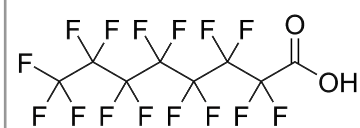
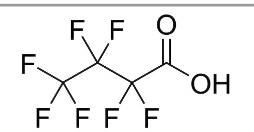
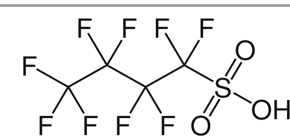
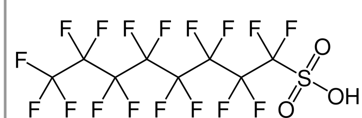
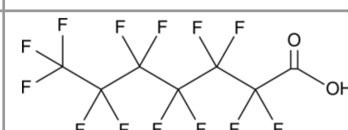
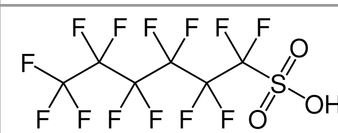
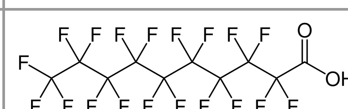
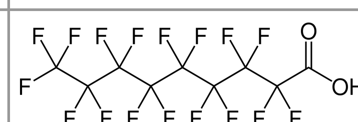
https://doi.org/10.70766/76.9001

Figure 14: Most frequently detected PFAS in water sampled in the Tod Creek watershed (WET Season)



Numbers refer to the water category (1: Source, 2: Stream and river, 3: Road runoff, 4: Tap, 5: Marine, 6: Hartland). While Perfluorobutanesulfonic acid (PFBS), Perfluorohexanoic Acid (PFHxA), Perfluorohexanesulfonic acid (PFHxS), Perfluorooctanoic Acid (PFOA), Perfluorooctanesulfonic acid (PFOS) and Perfluoropentanoic acid (PFPeA) were detected in all samples except tap water, Perfluorooctanesulfonamide (PFOSA) was the only PFAS detected in tap water.

Table 14: Individual PFAS compounds detected in the Hartland water sample and their concentrations (from highest to lowest) during the WET Season

Individual PFAS	Concentrations (ng/L)	Notes	Structure
PFPeA	12.5	Used as stain- and grease-proof coatings on food packaging and household products. Also a breakdown product of larger PFAS.	
PFHxA	11.6	Used as stain- and grease-proof coatings on food packaging and household products. Also a breakdown product of larger PFAS.	
PFOA	10.5	Used in industrial and household applications. Was banned in Canada in 2012 and added to the *List of Toxic Substances* in 2013. (Health Canada, 2012) Also a breakdown product of larger PFAS.	
PFBA	8.28	Used in stain- and grease-proof coatings on food packaging and household products, and photographic film. (US EPA, 2022)	
PFBS	5.12	Introduced as a replacement for PFOS after PFOS was voluntarily phased out in 2002.	
PFOS	4.96	Used primarily as a dirt-, oil-, water-repellant in papers and fabrics, as well as in fire fighting foams. Voluntarily phased-out globally in 2000. Added to the *List of Toxic Substances* in 2006.	
PFHpA	2.88	Breakdown product - Short-chain alternative to legacy PFAS compounds following their phase-out.	
PFHxS	2.4	Initially used as a replacement for PFOS after its use was restricted following the Stockholm Convention in 2004. Also a by-product during the production of PFOS.	
PFDA	0.67		
PFNA	0.605	Suspected to be a breakdown product of longer-chain PFAS compounds. No guidelines available.	

https://doi.org/10.70766/76.9001

Perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA) and perfluorooctanoic acid (PFOA) were the top three PFAS compounds detected in the Hartland water sample.

Conclusions

- PFAS concentrations for the wet season were ranked as follows from highest to lowest: Hartland > stream and river > road runoff > source > marine > tap.
- Total PFAS levels in all water samples collected from the Tod Creek watershed ranged from 0.94 to 59.5 ng/L.
- PFAS concentrations were in the lower range of PFAS levels (0 - 138 ng/L) reported for 29 ambient surface freshwater sites across Canada between 2013 and 2020 (ECCC and Health Canada, 2023).
- Not surprisingly, the Hartland water sample had relatively low concentrations of PFAS (59.5 ng/L) when compared to total PFAS (320 - 9,400 ng/L) measured elsewhere in leachate (which may be expected to be relatively high) at 12 large landfills across Canada between 2009 and 2011 (Gewurtz et al., 2013, Government of Canada, 2013).
- All water samples were below the available EQGs (PFOS: Federal Environmental Quality Guideline (FEQG) = 6.8 ug/L; BC Working Water Quality Guideline (WWGG) = 3.4 ug/L).
- PFOSA was the only PFAS detected in tap water; there is no Canadian drinking water guideline for this compound.
- The total PFAS concentration in the drinking water sample was:
    - below the Health Canada ‘proposed objective’ for drinking water (30 ng/L).
    - below The European Union Water Directive drinking water quality guideline (500 ng/L) and the limit of 100 ng/L for the sum of 20 individual PFAS.
    - below the new US maximum contaminant level - the highest level allowed in drinking water (4 ng/L).

Polychlorinated Biphenyls (PCBs)

Capsule

Despite having been banned in Canada in 1977, industrial PCBs continue to be found in the environment, reflecting their stability and persistence. PCBs were detected in all six water samples, with the highest concentration observed in the composite Hartland sample and the lowest in the composite source sample. The tap water sample had the 'lightest' PCB signature with the 'heaviest' reported for the marine and Hartland samples. One sample (landfill) exceeded the Water Quality Guideline (WQG) for the protection of aquatic life for total PCBs.

Introduction

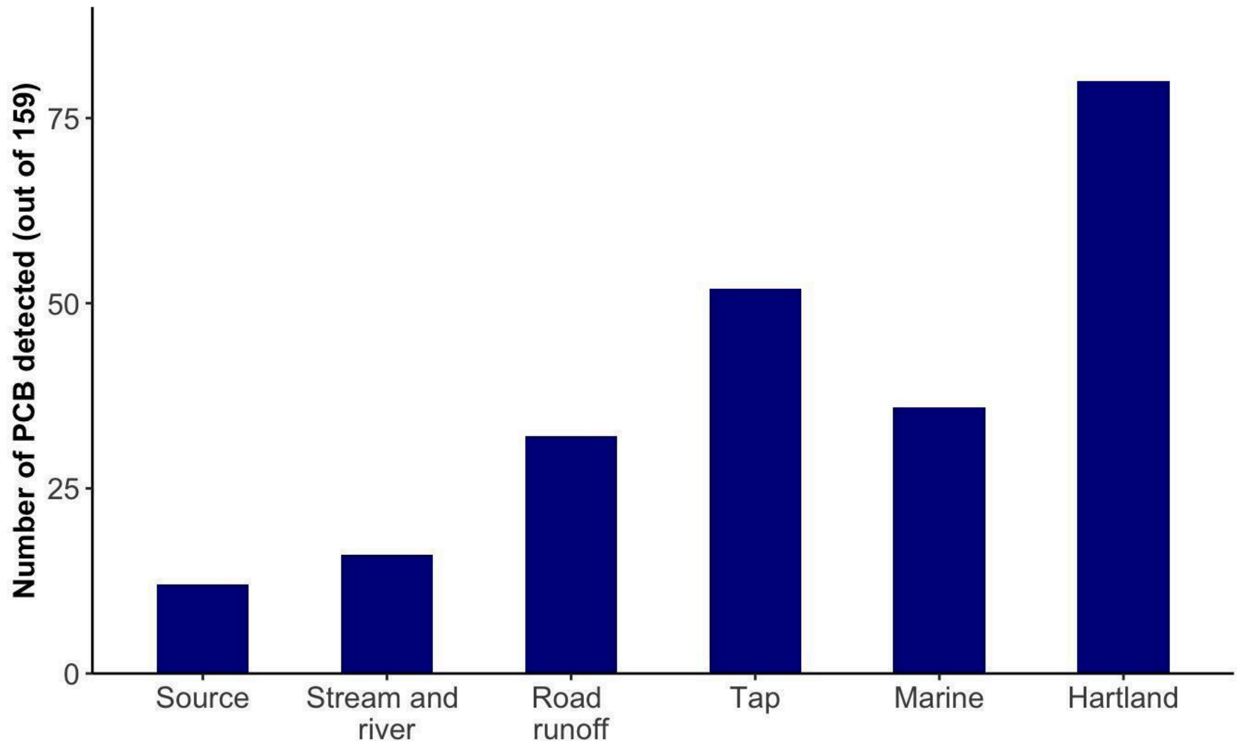
Polychlorinated biphenyls (PCBs) comprise 209 congeners that are structurally related but have differing degrees of chlorination. The commercial production of PCBs began in 1929, after which they were heavily used in electrical and hydraulic equipment, as well as in paint additives, sealing and caulking compounds and inks. Due to their adverse health effects, the production of PCBs was banned in the late 1970s (Othman et al., 2022). PCBs are among the first 12 Persistent Organic Pollutants (POPs) - often referred to as the "dirty dozen" - defined by the Stockholm Convention, an international treaty aimed at eliminating or restricting the production and use of POPs.

PCBs were never produced in Canada, and are currently specified on the List of Toxic Substances under the Canadian Environmental Protection Act (Health Canada, 2010). Despite their ban, PCBs continue to pose a threat due to their persistence in the environment and their release from products that were manufactured before the ban and/or were improperly disposed of (Othman et al., 2022). In British Columbia (BC), PCBs remain the number one contaminant of concern in marine food webs with the iconic killer whales being among some of the most-PCB contaminated marine mammals in the world (Ross et al., 2000).

Results

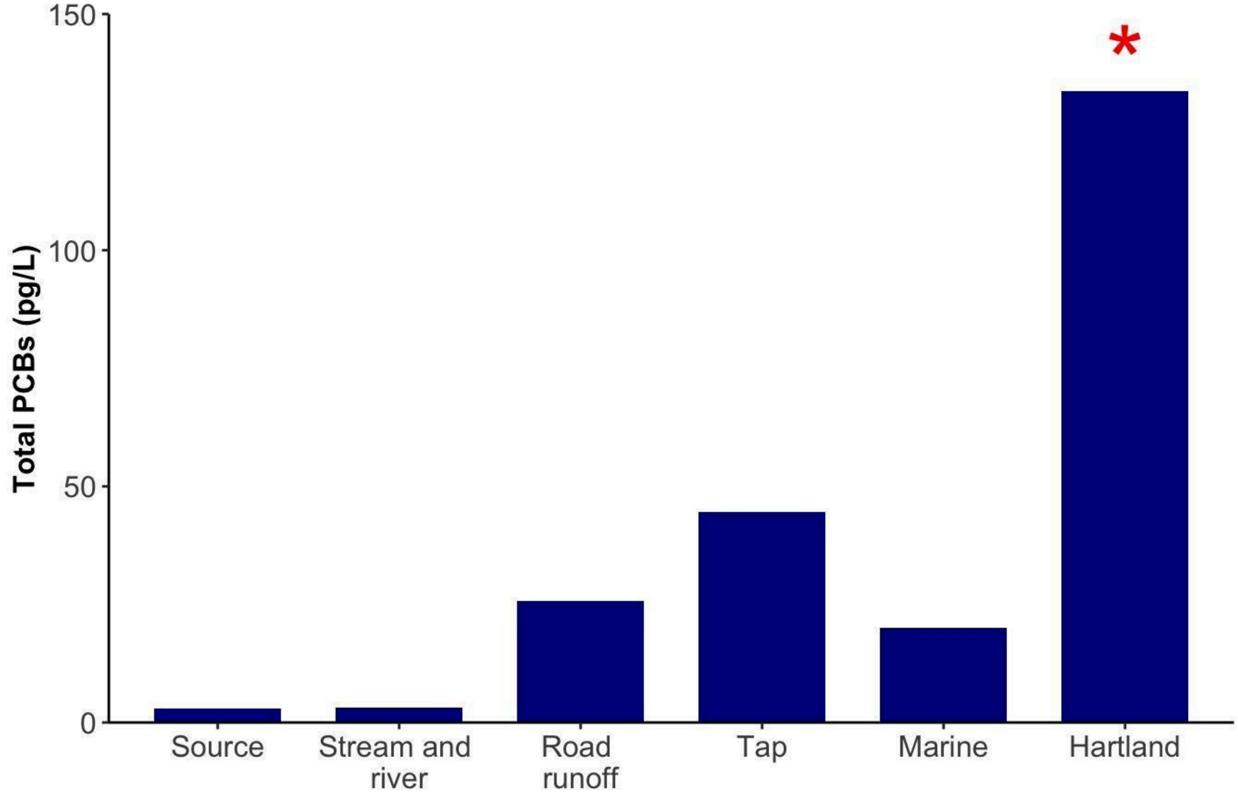
We measured 159 out of a total 209 PCB congeners in the six water samples collected within the Tod Creek watershed during the wet season. Concentrations of the top six PCBs detected in the six water samples collected from the Tod Creek watershed can be found in Appendix 5.

Figure 15: Number of PCB detections in water sampled from the Tod Creek watershed (WET Season)



PCBs were detected in all six water categories. The number of PCBs detected ranged from 12 (source) to 80 (landfill) with an average of 38.0 ± 10.3.

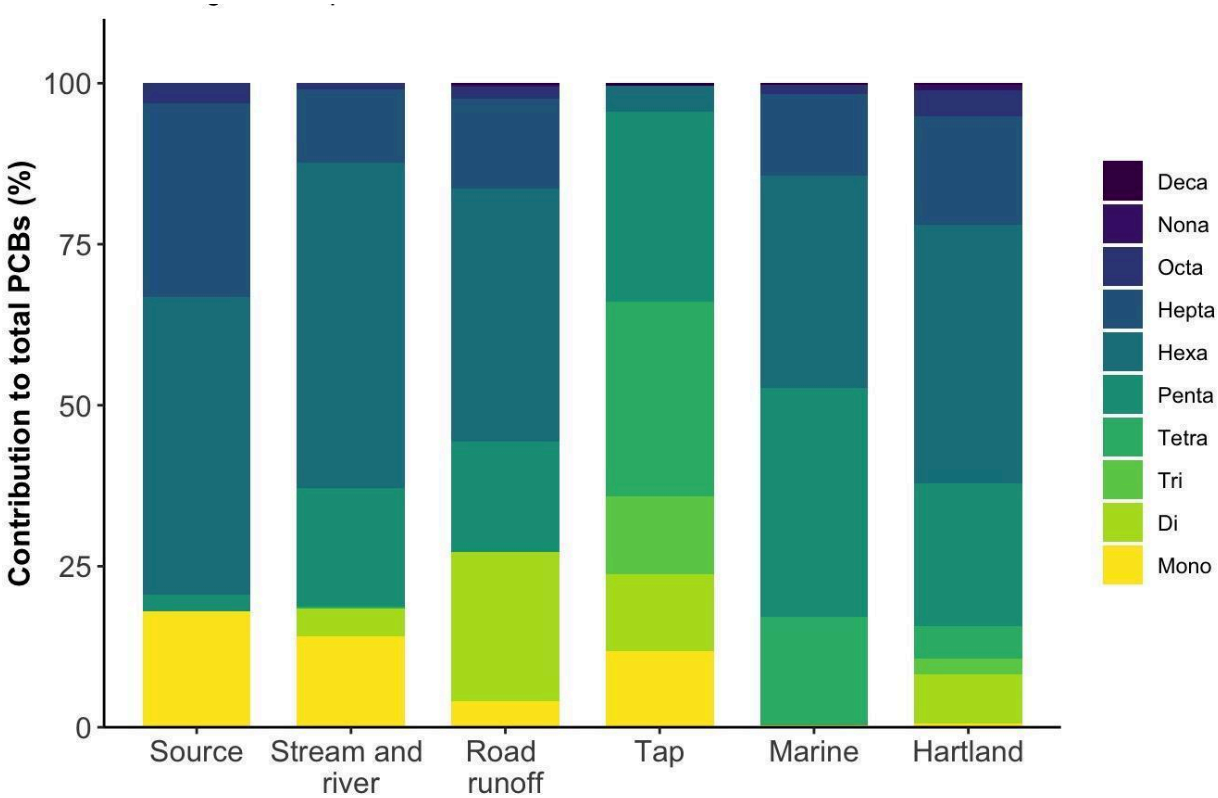
Figure 16: Total PCB concentrations in water sampled from the Tod Creek watershed (WET Season)



Total PCB levels ranged from 3.1 (source) to 133.7 pg/L (Hartland), with an average across all water categories of 38.4 ± 20.1 pg/L. (* indicates that the landfill sample exceeded the BC WQG of 100 pg/L).

The 209 individual PCBs have different degrees of chlorination, with each individual PCB containing between 1 and 10 chlorine atoms in their structure. PCBs can be categorized by their degree of chlorination into homologue groups. For example, all PCBs with one chlorine will fall into the mono-chlorinated homologue group and all PCBs with five chlorines will fall into the penta-chlorinated PCBs. In general, the more chlorines bound to a biphenyl ring, the 'heavier' the PCB molecule is. Heavier PCBs tend to not travel far from their sources, whereas lighter PCBs are more volatile and can undergo long-range transport. PCBs are strongly lipophilic - fat-soluble - such that they have a tendency to bind to organic particles and fatty tissues, rather than dissolve in water.

Figure 17: Homologue group contribution to total PCBs in water sampled from the Tod Creek watershed (WET Season)



The lighter colours represent 'lighter' PCB homologue groups, such that the tap water sample had the 'lightest' PCB signature while the marine and Hartland samples had the 'heaviest' PCB signatures. The source, stream and river and road runoff samples had similar homologue group signatures.

Conclusions

- PCB concentrations were ranked as follows from highest to lowest: Hartland > tap > road runoff > marine > stream and river > source.
- PCB concentrations ranged from 3.1 to 133.7 pg/L. In a recent study of urban-influenced and background stream and rivers samples collected in the northwestern part of Lake Ontario, Zhang et al. (2020) identified PCBs as the dominant compound class measured with levels ranging from 10 pg/L in remote areas to 4,100 pg/L in urban areas.

- The PCB levels reported here were in the range reported northwest of Lake Ontario. In their study of air samples in coastal British Columbia, Noël et al. (2004) also observed uniform background levels for this legacy compound.
- Water Quality Guidelines were available for four individual PCBs (PCB-77, -105, -126 and -169), as well as total PCBs.
    - There were no exceedances for any of the individual PCBs.
    - The Hartland water sample exceeded the WQG for the protection of stream and rivers aquatic life for total PCBs (100 pg/L).
- There are no guidelines for PCBs in drinking water in Canada. The US Environmental Protection Agency's enforceable Maximum Contaminant Level (MCL) for PCBs in public water systems is 500,000 pg/L (EPA, 2001), well above the 44.6 pg/L reported in the current tap water sample.

Alkylphenol Ethoxylates

Capsule

Alkylphenol ethoxylates (APEs) are industrial grade surfactants that have been found in wastewater and industrial discharges. APEs were detected in all six of the Tod Creek water samples. Further sampling will confirm this initial detection of APEs in tap water (146.9 ng/L) and stream and river water (13.1 ng/L).

Introduction

Alkylphenol ethoxylates are non-ionic surfactants used in industrial and consumer applications. APEs and their breakdown products are considered estrogenic and can disrupt reproductive development in fish.

Results

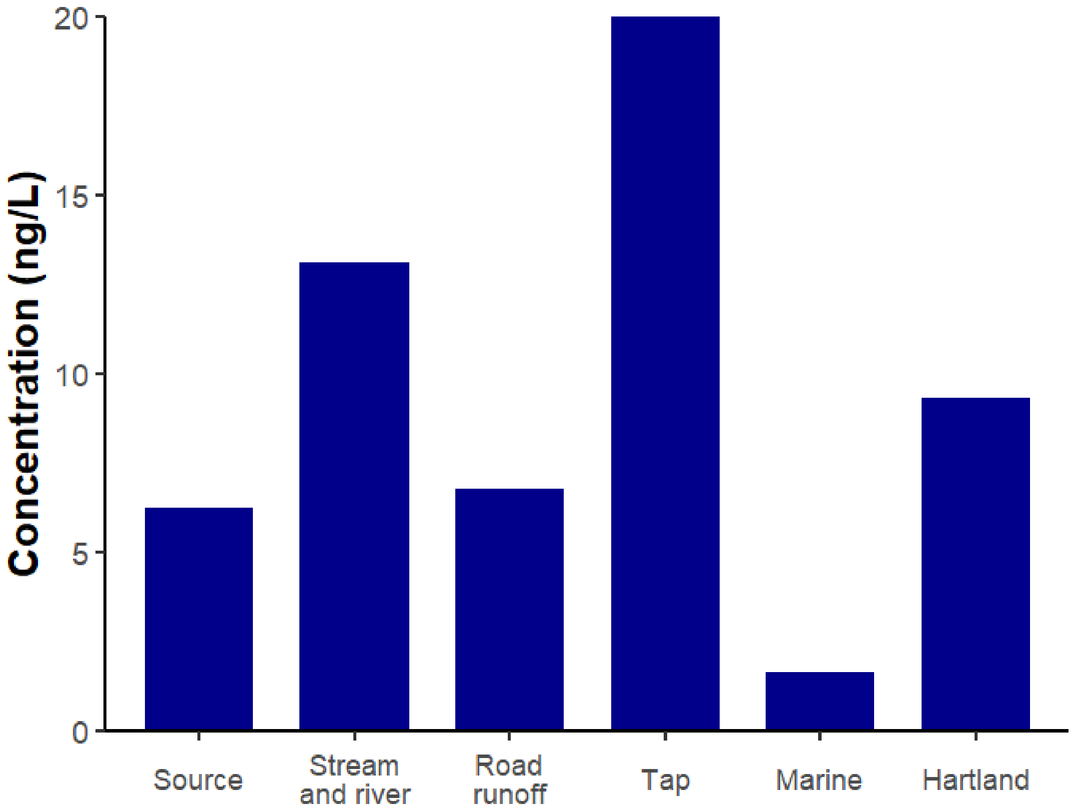
Table 15: Alkylphenol concentration (ng/L) for six water samples from the Tod Creek watershed (WET Season)

Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
4-Nonylphenols	6.25	13.1	6.76	145.6	1.66	9.32
4-Nonylphenol monoethoxylates	0	0	0	0	0	0
4-Nonylphenol diethoxylates	0	0	0	0	0	0
4-n-Octylphenol	0.735	0	0	1.32	0	0
Total Alkylphenols	6.99	13.1	6.76	146.9	1.66	9.32

4-Nonylphenols were detected in all water samples. 4-n-Octylphenol was detected in the Source and tap water samples. Tap water had the highest total concentration of APEs, dominated by 4-Nonylphenols.

https://doi.org/10.70766/76.9001

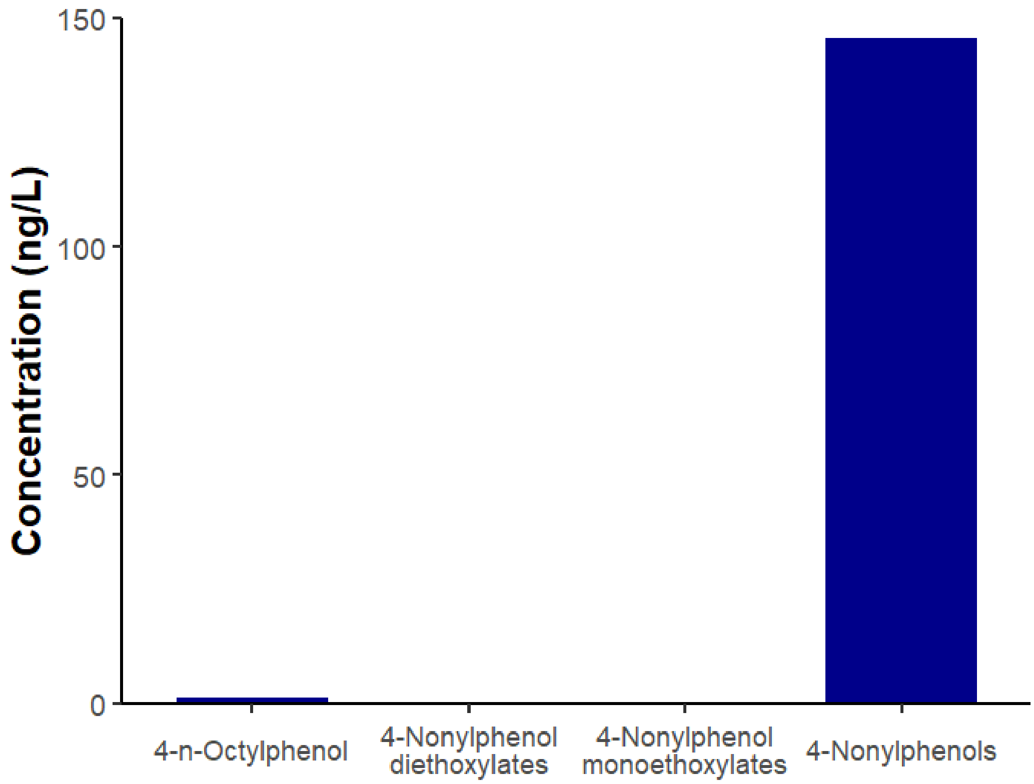
Figure 18: Alkylphenol concentrations (ng/L) for six water samples from the Tod Creek watershed (WET Season)



APEs were detected in all of the six water samples that were analyzed. The highest concentration was detected in the tap sample, the second highest concentration was detected in the stream and river sample. The lowest concentration was detected in the marine water sample.

https://doi.org/10.70766/76.9001

Figure 19: Total alkylphenol concentrations (ng/L) by analyte for samples from the Tod Creek watershed (WET Season)



4-Nonylphenol was the most abundant APE detected in the Tod Creek water samples. There was also a small amount of 4-n-Octylphenol detected.

Conclusions

- Total APE concentration for the six water samples in the Tod Creek watershed was ranked from highest to lowest as follows: tap > stream and river > Hartland > source > road runoff > marine.
- APEs were detected in all water samples.
- The concentrations are well below the long-term CCME guideline for the protection of freshwater aquatic life for nonylphenol and its ethoxylates of 1,000 ng/L.
- There are no Health Canada Drinking Water Guidelines for APEs.
- The concentration of APEs in the tap water sample (146.9 ng/L) is well below the State of Minnesota guidance value of 20,000 ng/L for NPs.

Bisphenols

Capsule

Bisphenols are plastic additives with widely reported estrogenic (endocrine disrupting) properties. We did not detect any of the bisphenol compounds that were analyzed in water samples from the Tod Creek watershed in the Wet (winter) season.

Introduction

Bisphenols are used widely in the manufacturing sector, and are primarily used in the production of plastics and resins. Both single and multi-use plastic containers are frequently produced using bisphenol compounds, the most popular of which is Bisphenol A (BPA). Bisphenols are endocrine-disrupting chemicals that have been found to negatively impact reproductive systems in fish, amphibians, and mammals including humans (Marlatt, *et al.* (2022)).

BPA has come under intense regulatory scrutiny in recent years. The widespread use of these chemicals in food packaging, beverage containers, and in water delivery systems has caused widespread low-level exposure among the general population.

Results

Table 16: Concentration (ng/L) of bisphenols in six water samples from the Tod Creek watershed (WET Season)

Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
Bisphenol E (BPE)	0	0	0	0	0	0
Bisphenol F (BPF)	0	0	0	0	0	0
Bisphenol A (BPA)	0	0	0	0	0	0
Bisphenol AF (BPAF)	0	0	0	0	0	0
Bisphenol B (BPB)	0	0	0	0	0	0
Bisphenol S (BPS)	0	0	0	0	0	0
Total bisphenols	0	0	0	0	0	0

Conclusions

- We did not detect any of the six bisphenol compounds that were analyzed for in the six samples collected from the Tod Creek watershed.

https://doi.org/10.70766/76.9001

Sucralose

Capsule

Sucralose is a popular artificial sweetener (trade name '*Splenda*') used in foods and beverages. Because it survives the wastewater treatment process, sucralose has become a useful tracer of domestic wastewater. Sucralose was detected in five out of six water samples collected within the Tod Creek watershed, indicating a possible influx of human wastewater from septic or sewage networks. It was detected at the highest concentration in the road runoff sample, followed by the stream and river sample.

Introduction

Sucralose (*Splenda*) is an artificial sweetener used in the production of sugar-free food and beverage products. Its popularity and its resistance to breakdown during the wastewater treatment process have led to its adoption as a useful tracer of human wastewater infiltration.

Sucralose is not fully metabolized by the human body following consumption, and is not removed during the wastewater treatment process. Therefore, its detection in environmental samples indicates the presence of treated or untreated sewage.

Results

Table 17: Sucralose concentration (ng/L) in six categories of water from the Tod Creek watershed

Analyte	Source	Stream and river	Road runoff	Tap	Marine	Hartland
Sucralose (ng/L)	23.3	180	477	0	96.4	38.3

Sucralose was detected in the highest concentration in the road runoff sample. The second highest concentration was detected in the stream and river sample.

Conclusions

- Sucralose concentrations in water samples from highest to lowest are as follows: road runoff > stream and river > marine > Hartland > source > tap.
- The highest concentration of the artificial sweetener sucralose was detected in the road runoff sample, possibly indicative of residential septic seepage or failures in the area.

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- There was no sucralose detected in the tap water sample.
- There are no current Canadian Environmental Quality Guidelines available for sucralose.
- There are no current Health Canada Drinking Water Guidelines available for sucralose.

6PPD-quinone

Capsule

The breakdown product of a UV-stabilizing chemical in vehicle tires (6PPD-quinone) has been associated with significant and repeated instances of coho salmon mortality events in Washington State and in British Columbia. 6PPD-quinone was detected in all water samples that were collected in the Tod Creek watershed.

Introduction

6PPD is an anti-ozonant chemical that is added to automotive tire rubber during the manufacturing process in order to extend the life of tires. When 6PPD comes into contact with air, it oxidizes and becomes 6PPD-quinone - a transformation product that in recent years was discovered to be lethal to Coho salmon (*Onchorhynchus kitsutch*) at low concentrations (Tian et al., 2021). It is the causative agent of what has been deemed Urban Runoff Mortality Syndrome (URMS) - which has seen mortality rates of up to 90 percent. Research is being conducted to assess the risk to other fish species.

Results

Table 18: 6PPD- quinone concentration (ng/L) in six categories of water from the Tod Creek watersheds

Analyte	**Source** (n=1)	**Stream and river** (n=1)	**Road runoff** (n=1)	**Tap** (n=1)	**Marine** (n=1)	**Hartland** (n=1)
6PPDq (ng/L)	0.04	0.11	0.10	0.19	0.13	0.30

Low levels of 6PPD-quinone were detected in water samples from the Tod Creek watershed.

Conclusions

- Total 6PPD-q concentrations for the six water samples was ranked from highest to lowest as follows: Hartland > tap > marine > stream and river > road runoff > source.
- The concentrations of 6PPD-q were low in all samples, but are understood to increase during rainfall-associated runoff events.

- The 0.30 ng/L concentration of 6PPD- detected in the road runoff sample is much lower than the Lethal Concentration at which 50% of individuals die (LC50) for Coho salmon of 41 ng/L (Lo et al., 2023).
- There are no current Canadian Environmental Quality Guidelines available for 6PPD quinone.
- There are no current Health Canada Drinking Water Guidelines available for 6PPD quinone.

Wet season water quality summary

This report encapsulates a single wet season water sampling event comprising pooled samples in six water categories: source water, stream & river water, road runoff, tap water, marine water and Hartland drainage water. **These initial r**esults suggest that Tod Creek waters are in relatively good condition, but follow-up study is warranted to confirm or correct initial observations of some contaminants of concern in the watershed (summary data in Appendix 6). Findings herein will be built upon by additional seasonal water sampling in 2024 and 2025, and an analysis of sediment and biosolid matrices. Collectively, these findings will provide an integrated evaluation of the contaminants, activities and sectors that are influencing water quality in the Tod Creek watershed. This may, in turn, provide guidance on mitigation, stewardship and restoration initiatives that protect and restore fish habitat throughout Tod Creek.

List of acronyms

Abbreviation	Meaning
APE	Alkylphenol ethoxylates
BC EMA	British Columbia Environmental Management Act
CCME	Canadian Council of Ministers of the Environment
CEC	Contaminants of Emerging Concern
CEPA	Canadian Environmental Protection Act
CUP	Current-use pesticide
DO	Dissolved oxygen
DRIPA	Declaration on the Rights of Indigenous Peoples Act
ECCC	Environment and Climate Change Canada
MOE	Ministry of Environment
MST	Microbial Source Tracking
NP	Nonylphenol
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PFAS	Polyfluoroalkyl substances
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
POP	Persistent organic pollutant
PPCP	Pharmaceutical and personal care products
PVC	Polyvinyl chloride

TDS	Total dissolved solids
TOC	Total organic carbon
TSS	Total suspended solids
TWP	Tire wear particle
WQGs	Water Quality Guidelines
WQI	Water Quality Index
WWTP	Wastewater treatment plant

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Appendix

Appendix 1: Healthy Waters - Standard Operating Procedure (SOP) for water sample collection

Healthy Waters – Standard Operating Procedure (SOP) for water sample collection

Purpose: The collection of water samples for lab analysis is an important step in assessing the potential impacts to water quality in our partner watersheds. This Standard Operating Procedure (SOP) outlines the steps to collect water samples for lab submission and analyses in support of the Raincoast Healthy Waters program. This SOP should follow in situ measurements of water quality properties using a YSI ProDSS (detailed in *Healthy Waters – SOP for in situ determination of water properties*).

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Required Equipment

- Clean sampling wand
- Sampling bottles (suitably cleaned in advance and typically provided by service lab for a specific analysis)
- Labels with sample ID, date, sample custodian
- Large containers for pooling of samples (cleaning methodology detailed in *Healthy Waters – Bottle cleaning procedure*)
- Coolers
- Ice packs (frozen)
- Nitrile gloves
- Data sheets
- Pencils

Step 1: Record site details

Upon arrival at a sampling site, record the following on your Data Sheet:

Data Sheet Healthy Waters			
Date:			
Watershed:			
Weather:			
Air Temperature:			
Name (recorder):			
Name (YSI):			
Name (others):			
Site Name:		**Dominant vegetation (circle):**	**Riparian Zone (circle):**
Time Sampled:		conifers	natural
GPS Location:		hardwood trees	disturbed - agriculture
Water Source Type:	source streams/rivers road runoff marine tap	shrubs/grasses	disturbed- forestry
Width (Stream/River):		agricultural	disturbed - roadway
Depth:		other:	other:

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Step 2: Describe riparian zone

Circle the site characteristics for the surrounding vegetation and riparian zone under "Dominant Vegetation" and "Riparian Zone". If none of the labels apply, circle "other" and describe the conditions.

Step 3: Record sample IDs

Record the sample ID for each on the datasheet in the space provided, using the following format:

XXX-MMDD-##(a)

XXX - a three-letter code specific to the watershed.

MMDD- record the four digit month and year.

- Sample number (1-5 (5 buckets)) 01 = source water; 02 = freshwater; 03 = road runoff; 04 = tap; 05 = marine) - Where discrete samples are being submitted for each individual site, use a letter (e.g. a,b,c,d) to differentiate samples. Where necessary, additional water categories can be included by adding additional numbers.

Step 4: Collect the water samples

Using a sampling wand with attached 600ml cup, reach out towards the middle of the body of water to be sampled and fill the cup with a shallow scoop of water. Rinse twice in this way, without disturbing sediments. Continue by collecting water in approximately the same location until all sampling containers are full. The person responsible for opening and closing bottles should wear a pair of nitrile gloves. If sampling from inside a boat, sample as far away from the boat's engine as possible - turning it off when possible to reduce the risk of sample contamination.

For tap/well water

1. Turn the tap on and allow water to run for 3 seconds.
2. Fill a clean sample bottle with tap water till approximately ¼ full and stop filling.
3. Allow tap to run for an additional 3 seconds.

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4. Repeat until the sampling container is full.

For pooled samples

Use a 4L amber glass bottle to collect samples from each of the sites to be pooled (volume per site to depend on the number of sites being sampled) in most cases, fill each of four large pooling containers 1/3 at each of three sampling sites to ensure that there is enough total volume (minimum of 10L for all analytes) to subdivide into lab bottles.

Once sample collection is complete, pooled samples should be aliquoted into lab bottles for submission, carefully using nitrile gloves to avoid contamination of samples.

Samples should be placed into a cooler containing ice packs as quickly as possible - as many parameters require the sample to be kept at a temperature of 4°C prior to analysis.

Sample bottles must be returned to the correct partner lab within required holding times (see Lab holding times). Tier 2 analytes to be analyzed at ALS Environmental, Tier 3 analytes to be analyzed at SGS Axys Analytical Labs.

Completed datasheets

Confirm that field datasheets have been completed and make a backup copy using a phone camera or scanner. Upload completed datasheets to the Watershed partnership folder on the Raincoast Google Drive.

Lab-specific holding times (in water)

Tier 2 - ALS Environmental

Coliform: 24-30 hours

BOD/COD: 3 days

TSS/TDS: 7 days

Nutrients: 28 days

TOC: 28 days

Metals: 180 days

Tier 3 - SGS Axys Analytical

PAHs: 7 days (unpreserved - 14 days if preserved with sodium azide)

PPCPs (including sucralose and BPAs): 7 days

A/Ps: 14 days (unpreserved)

MRES Pesticides: not defined

PFAS: 90 days

PCBs: 1 year

References

Canadian Council of Ministers of the Environment (2011) procedures Manual for Water Quality Sampling in Canada
https://beta-static.fishersci.com/content/dam/fishersci/en_CA/documents/brochures-and-catalogs/catalogs/ccme-procedures-manual-water-quality-sampling.pdf

Government of the Northwest Territories. NWT-Wide Community-Based Water Quality Monitoring Program- procedures for Collecting Water Quality Samples.
https://nwtdiscoveryportal.enr.gov.nt.ca/geoportaldocuments/FINAL%20CBM%20procedures%20for%20Collecting%20Water%20Quality%20Samples.pdf

Appendix 2: Healthy Waters - Standard Operating Procedure for for in situ determination of basic water properties

RAINCOAST CONSERVATION FOUNDATION

Healthy Waters – Standard Operating Procedure (SOP) for in situ determination of basic water properties

Purpose: The use of handheld instruments to determine basic water properties is the first step to understanding fish habitat and the threats to its quality. This Standard Operating Procedure (SOP) outlines the steps to deploying a YSI ProDSS meter during water sampling events in support of the Raincoast Healthy Waters program. This SOP represents a necessary first step when one is collecting samples for later analysis in dedicated laboratories (detailed in ***Healthy Waters – Water sample collection SOP***).

*Calibrate the YSI ProDSS 24 hours prior to the sampling date

Required Equipment

- YSI ProDSS (or other water quality meter capable of measuring parameters)
- Nitrile gloves
- Clean bucket
- Data sheets
- Pencils

Step 1: Record site details

Upon arrival at a sampling site, record the following on your Data Sheet:

Data Sheet Healthy Waters			
Date:			
Watershed:			
Weather:			
Air Temperature:			
Name (recorder):			
Name (YSI):			
Name (others):			
Site Name:		**Dominant vegetation (circle):**	**Riparian Zone (circle):**
Time Sampled:		conifers	natural
GPS Location:		hardwood trees	disturbed - agriculture
Water Source Type:	source streams/rivers road runoff marine tap	shrubs/grasses	disturbed- forestry
Width (Stream/River):		agricultural	disturbed - roadway
Depth:		other:	other:

Step 2: Describe riparian zone

Circle the site characteristics for the surrounding vegetation and riparian zone under "Dominant Vegetation" and "Riparian Zone". If none of the labels apply, circle "other" and describe the conditions.

Step 3a: Measure Tier 1 water properties at the site

To take a measurement with the YSI ProDSS directly in a body of water (ie. stream, pond, ditch, river etc.) perform the following procedure:

1. Review instrument manual (YSI (Revision H) *ProDIGITAL User Manual*. Xylem, Inc.).

10. Confirm that all data have been recorded on the data sheet and then make a copy for safekeeping (take a picture with phone camera or scan).

11. Upload field data sheets to Watershed partner folder on Raincoast Google Drive.

Step 3b: Measure Tier 1 water properties ex situ

To take a measurement with the YSI ProDSS where the probe cannot be submerged in the water (ie. municipal manhole access, well-water, tap water, small stream etc.) perform the following procedure:

1. Take a water sample from the desired water source using a clean bucket (if bucket has been used for previous water samples rinse three times with water from a new site before taking YSI measurements)

   For Tap/Well Water:

   - Turn the tap on and allow water to run for 3 seconds.
   - Fill clean bucket with tap water till approximately ¼ full and stop filling.
   - Allow tap to run for an additional 3 seconds.
   - Repeat until the bucket is full.

2. Turn the YSI ProDSS on.

3. Remove the light blue – protective calibration cup from the device by unscrewing it. Make sure to leave the black probe guard covering the sensors ON while sampling.

4. Rinse the YSI ProDSS probes with a small amount of sample water.

5. Submerge the YSI probe guard in the collected sample water – ensuring that all probes are fully submerged.

6. Allow the parameters to stabilize for approximately 1 minute – parameters are considered "stable" when there is no change in each value for 30 seconds. Gently stir the probe continuously while the values stabilize to ensure an accurate DO reading.

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7. Once the parameters stabilize, record the following parameters in the Healthy Waters datasheet provided:

    - Temperature (°C)
    - pH
    - DO (both mg/L and %DO)
    - Turbidity (FNU)
    - Specific conductance (uS/cm)

8. Remove the probe from the water. Rinse probes and probe guard thoroughly with clean water, and replace the calibration cup. Always ensure that there is a small amount of clean water in the calibration cup to prevent the sensors from drying out.

9. Confirm that all data have been recorded on the data sheet and then make a copy for safekeeping (take a picture with phone camera or scan).

10. Upload field data sheets to Watershed partner folder on Raincoast Google Drive.

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Government of the Northwest Territories. NWT-Wide Community-Based Water Quality Monitoring Program- procedures for Collecting Water Quality Samples.
https://nwtdiscoveryportal.enr.gov.nt.ca/geoportaldocuments/FINAL%20CBM%20procedures%20for%20Collecting%20Water%20Quality%20Samples.pdf

Appendix 3: Environmental and Drinking water quality guidelines relevant for the present study. These guidelines were retrieved in May 2024.

Analyte Class	Federal EQGs[1]	BC WQGs		CCME EQGs[2]		Drinking WQGs
		Freshwater	Marine	Freshwater	Marine	
Basic Water Properties						
Temperature	-	19 (short-term)	+1°C per hour change from background	narrative	max change of +0.5°C per hour	-
pH	-	6.5-9.0	7.0-8.7	6.5-9.0	7.0-8.7	7.0-10.5
Dissolved oxygen	-	>8.0 (long-term) >5.0 (short-term)	-	6.5-9.5 mg/L	80 mg/L	-
Conductivity	-	-	-	-	-	-
Turbidity	-	-	-	narrative	narrative	≤ 1.0 NTU
Metals (mg/L)						
Aluminum	-	variable	-	0.005 if pH < 6.5	-	2.9
Lead	-	3 when ≤ 8 mg/L CaCO3 (short-term)	<140 ug/L	equation	-	0.005
Nutrients (mg/L)						
Nitrate (as N)	-	3.0 (long-term) 32.8 (short-term)	3.7 (long-term)	550	200 (long-term) 1500 (short-term)	10
Nitrite (as N)	-	table	0.02 when Cl- ≤ 2 (long-term) 0.06 when Cl- ≤ 2 - (short-term)	0.06	-	1.0
Ammonia (Total as N)	-	table	table	table	-	-
Phosphate	-	0.015 (long-term)	-	-	-	-
Coliform						
Total coliform	-	-	-	-	-	0
Fecal coliform	-	-	-	-	-	0
E. coli	-	-	-	-	-	0
PAHs (ug/L)						

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Naphthalene	-	1	-	1.1	1.4	-
Acenaphthene	-	6	6	5.8	-	-
Fluorene	-	12	12	3	-	-
Anthracene	-	4	-	0.012	-	-
Phenanthrene	-	0.3	-	4.4	-	-
Fluoranthene	-	4	-	0.04	-	-
Pyrene	-	0.02	-	0.025	-	-
Chrysene	-	-	0.1	-	-	-
Benzo-a-anthracene	-	0.1	-	0.018	-	-
Benzo-a-pyrene	-	0.01	-	0.015	-	0.04
PCBs (ng/L)						
Total PCBs	-	0.1	-	-	-	-
PCB-105	-	0.09	-	-	-	-
PCB-169	-	0.06	-	-	-	-
PCB-77	-	0.04	-	-	-	-
PCB126	-	0.00025	-	-	-	-
Bisphenols (ug/L)						
BPA	1.4	-	-	-	-	-
Alkylphenols (ug/L)						
4-Nonylphenols	-	1 (long-term)	-	-	-	-
PFAS (ug/L)						
Perfluorooctane Sulfonate (PFOS)	6.8 (fresh)	3.4	-	-	-	0.6
Perfluorooctanic acid (PFOA)	-	-	-	-	-	0.2
Pesticides (ug/L)						
Atrazine	-	1.8[3]	-	1.8	-	5
Chlorothalonil	-	-	-	0.18	-	-
Cyanazine	-	2	-	-	-	-
Chlorpyrifos	-	0.02	0.002	-	-	90
Diazinon	-	0.0043	-	-	-	-
Dimethoate	-	-	-	6.2	-	20
Endosulfan	-	0.0007 (active ingredient)	-	0.06 (short-term) 0.003 (long-term)	0.09 (short-term) 0.002 (long-term)	-
Malathion	-	0.1	-	-	-	290
Metribuzin	-	1[3]	-	1.0	-	80

Permethrin	-	0.004[3]	-	0.004	0.001	-
Picloram	-	29	-	-	-	-
Simazine	-	10[3]	-	10	-	10

[1] Federal EQGs apply to both fresh and marine waters unless otherwise stated. [2] CCME EQGs are reported for long-term effects unless otherwise stated. [3] Represents CCME guidelines that the BC government has adopted as working water guidelines

Appendix 4: Health Canada Screening values for nine different PFAS compounds

Compound Name	Acronym	Screening value (mg/L)	Screening value (ug/L)
perfluorobutanoate	PFBA	0.03	30
perfluorobutane sulfonate	PFBS	0.015	15
perfluorohexanesulfonate	PFHxS	0.0006	0.6
perfluoropentanoate	PFPeA	0.0002	0.2
perfluorohexanoate	PFHxA	0.0002	0.2
perfluoroheptanoate	PFHpA	0.0002	0.2
perfluorononanoate	PFNA	0.00002	0.02
6:2 fluorotelomer sulfonate	6:2 FTS	0.0002	0.2
8:2 fluorotelomer sulfonate	8:2 FTS	0.0002	0.2

Adapted from https://www.canada.ca/en/services/health/publications/healthy-living/water-talk-drinking-water-screening-values-perfluoroalkylated-substances.html

Appendix 5: The top 6 PCBs in each water category sampled in the Tod Creek watershed and their concentrations (WET Season)

	Source	Stream and river	Road runoff	Tap	Marine	Hartland
	PCB-180+193 (0.59)	PCB-129+138+160+163 (0.78)	PCB-7 (5.9)	PCB-61+70+74+76 (4.6)	PCB-118 (3.3)	PCB-153+168 (19.4)
	PCB-129+138+160+163 (0.58)	PCB-118 (0.50)	PCB-153+168 (4.1)	PCB-52 (3.6)	PCB-153+168 (2.8)	PCB-129+138+160+163 (15.2)
	PCB-3 (0.55)	PCB-3 (0.45)	PCB-129+138+160+163 (3.4)	PCB-110+115 (3.3)	PCB-129+138+160+163 (2.3)	PCB-118 (12.2)
	PCB-153+168 (0.47)	PCB-153+168 (0.40)	PCB-118 (2.3)	PCB-93+95+98+100+102 (2.4)	PCB-66 (1.6)	PCB-180+193 (10.5)
	PCB-141 (0.29)	PCB-141 (0.35)	PCB-180+193 (2.1)	PCB-1 (2.3)	PCB-61+70+74+76 (1.4)	PCB-4 (9.5)
	PCB-174 (0.17)	PCB-180+193 (0.19)	PCB-3 (0.9)	PCB-90+101+119 (2.3)	PCB-180+193 (1.2)	PCB-156+157 (4.0)
Total concentrations of top 6 (% contribution to total PCBs)	2.6 (85%)	2.7 (83%)	19.1 (74%)	18.4 (41%)	12.6 (63%)	70.7 (53%)

Appendix 6: Total analyte concentrations in water sampled in the Tod Creek watersheds (WET Season)

	Source	Stream and river	Road runoff	Tap	Marine	Hartland
E. coli (MPN)	1	**71**	12	0	23	19
Total NO^{-3} and PO_4^{3} (mg/L)	0.065	0.441	2.25	0.061	0.570	**11.9**
Metals (mg/L)	25	36	47	13	**3400**	120
Pesticides (ng/L)	0.55	**1.5**	1.3	0.05	1.3	0.81
PCBs (pg/L)	3.1	3.2	25.7	44.6	20.1	**133.7**
PAHs (ng/L)	32.9	11.2	31.3	**963.9**	51.4	18.1
PPCPs (ng/L)	3.60	107	268	197	**606**	73.4
PFAS (ng/L)	11.9	15.1	14.0	0.94	6.5	**59.5**
APEs (ng/L)	6.99	13.1	6.76	**146.9**	1.66	9.32
bisphenols (ng/L)	0	0	0	0	0	0
6-PPDq (ng/L)	0.04	0.11	0.10	0.19	0.13	**0.30**

Bold indicates the highest concentrations across water categories for each contaminant.

Tod Creek watershed: Water quality report for the 2023 wet season

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