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

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

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Contributions by Michael Jackson, Jenn Blancard, Sidney-Rae Flumerfelt (Pender Harbour Ocean Discovery Station); Pam Mackenzie and Richard Grace (SGS Axys); Xiangjun Liao and Andrew Ross (Fisheries and Oceans Canada).

Financial support from the estate of Mrs. Mary Gordon. Special thanks to Mark Tindle for assistance with funding.

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.

Table of Contents

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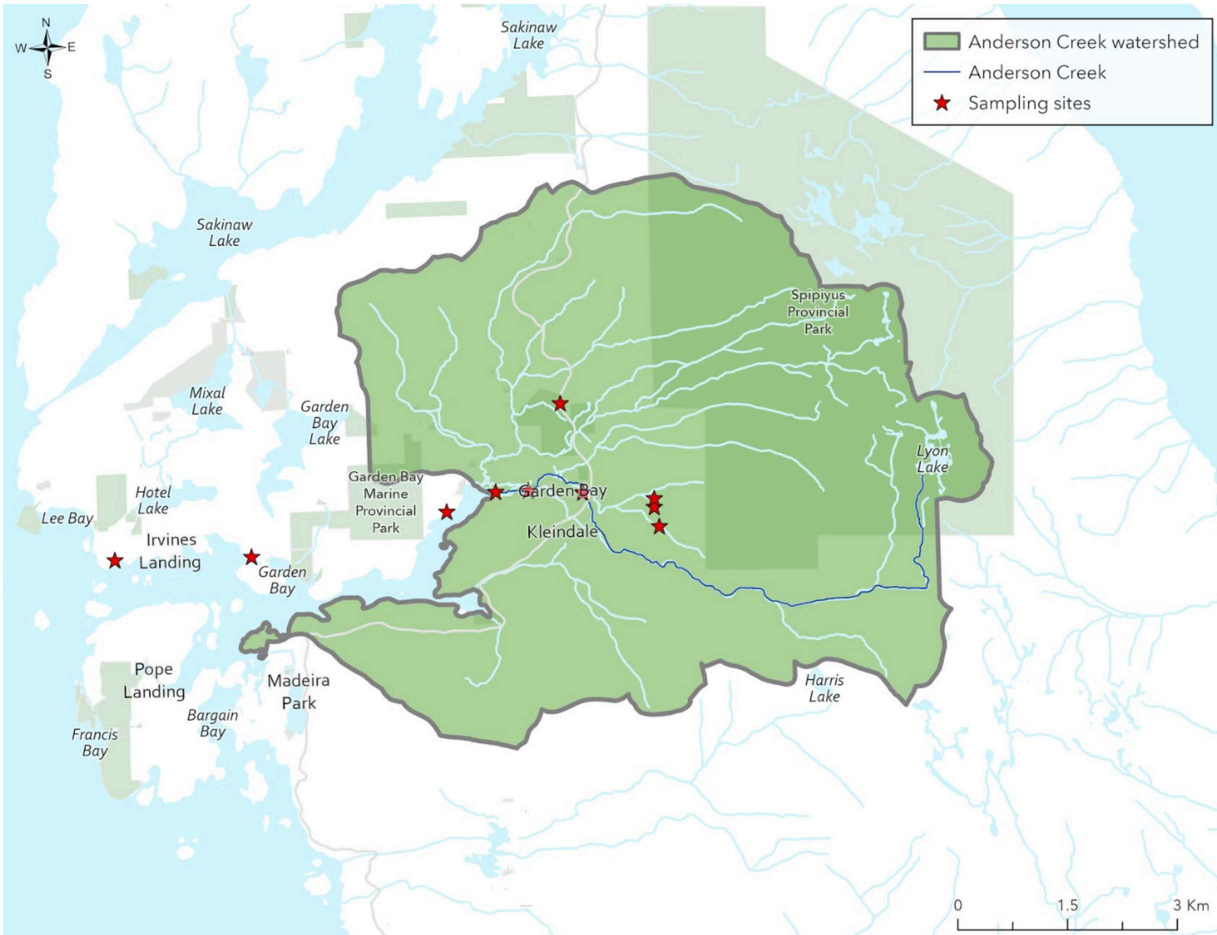
Executive summary

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 first in the dry season (summer), and the second being in the wet season (winter). This report highlights results from the first wet (winter) season sampling carried out with the support and participation of the Pender Harbour Ocean Discovery Station (PODS). Briefly, the Healthy Waters team collected water samples on January 16, 2024, from five water categories, including source water (3 samples), river water (3 samples), road runoff (3 samples), tap water (10 samples) and marine water (3 samples). Samples were then pooled by water category and analysed for coliform, metals, nutrients and physical parameters at ALS Environmental, and analysed for pesticides, polycyclic aromatic hydrocarbons (PAHs), pharmaceuticals and personal care products (PPCPs), polychlorinated biphenyls (PCBs), alkylphenol ethoxylates, bisphenols, per- and poly-fluoroalkyl substances (PFAS), and sucralose at SGS Axys Analytical and for 6PPD Quinone at DFO's Institute of Ocean Science. Overall, the Anderson Creek watershed had **relatively good** water quality in the wet season, but additional sampling and analysis will provide further insight into contamination impacts from forest fires, domestic wastewater, industrial chemicals and road runoff on the health of this valued watershed.

Key findings

- This preliminary assessment of water quality in the Anderson Creek watershed reflects the first of several site visits; our understanding of water quality in these watersheds will grow with additional sampling over the coming two years (2024-26).
- We collected and analysed water in the Anderson Creek watershed during the wet season (January 16, 2024).
- Road runoff was the most contaminated water category in the wet season; it had the highest concentrations of nutrients, per- and poly-fluoroalkyl substances, sucralose, and 6PPD-quinone.
- The stream and river sample had the highest concentrations of coliform, polycyclic aromatic hydrocarbons (PAHs), and alkylphenol ethoxylates.
- The marine water sample had the highest concentrations of metals, pesticides, and polychlorinated biphenyls (PCBs).
- Source water was the least contaminated water category in the wet season.
- Overall, the Anderson Creek watershed had **relatively good** water quality in the wet season:
    - There were no exceedances of Canadian Environmental Quality Guidelines.
    - There were no exceedances of Health Canada Drinking Water Quality Guidelines.

Figure 1: The Anderson Creek watershed



The Anderson Creek Watershed flows westward down from its source at Lyon Lake down into Pender Harbour, and covers an area of 49 km^2. Sampling sites were distributed throughout the watershed in order to capture a wide spatial range for our assessment of the health of fish habitat. The swiya of the shíshálh people lies between Queens Reach in lekw'emin (Jervis Inlet) and Howe Sound on the south coast of British Columbia. Historically there were four main settlements at kalpilin (Pender Harbour), ts'unay (Deserted Bay), xenichen (head of lekw'emin) and tewankw near alhtulich (Porpoise Bay) (Map by Brooke Gerle / Raincoast Conservation Foundation).

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Team

- Raincoast Healthy Waters: Peter S. Ross, Sam Scott, and Marie Noel
- Pender Harbour Ocean Discovery Station: Jenn Blancard and Sidney-Rae Flumerfelt

From left to right: Peter Ross and Sidney-Rae Flumerfelt. Photo by Sam Scott

https://doi.org/10.70766/126.498

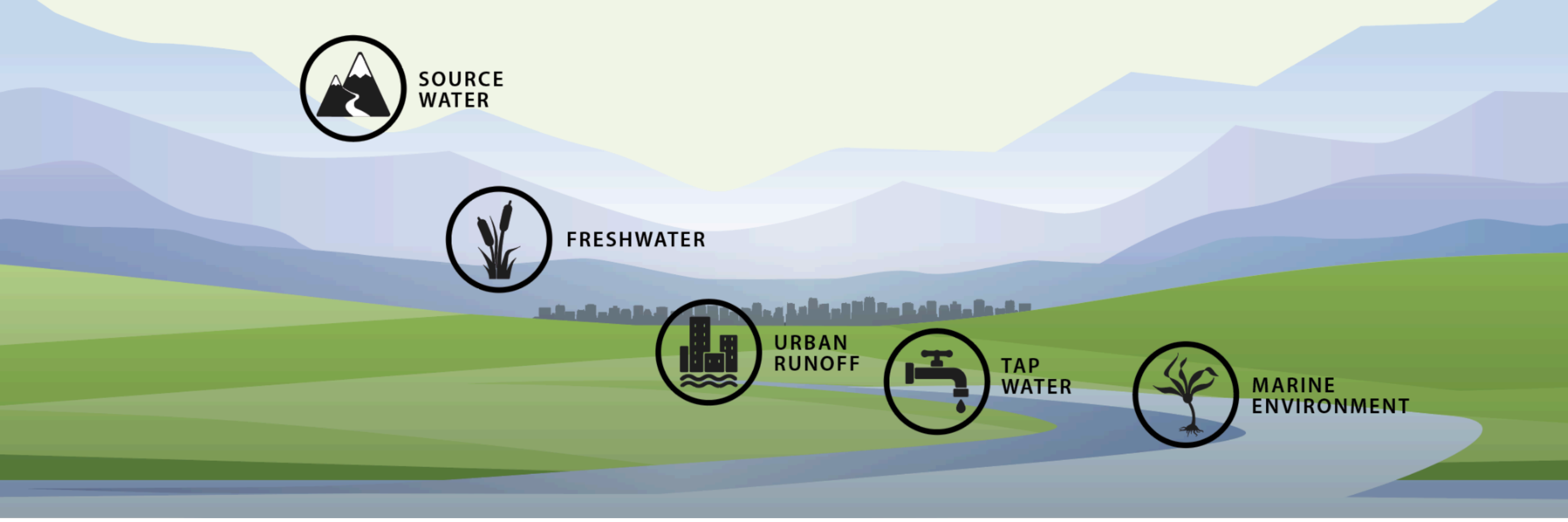
General introduction

Background

Raincoast's Healthy Waters Program (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 stewardship regarding both point and nonpoint source pollution.

Pender Harbour Ocean Discovery Station (PODS) is an initiative of the Loon Foundation. The Loon Foundation is a registered charity that was founded in 2002 (as the Ruby Lake Lagoon Nature Reserve Society). Their mission is to ignite connections between people and the natural world, encourage responsible stewardship of natural resources for future generations, and to provide facilities and programs for environmental education, arts and cultural exploration, scientific research, and ecological monitoring.

A watershed based approach to sampling



Healthy Waters

We collect samples from five different categories of water in each of our partner watersheds: from source water, upstream of human impacts, down to the marine environment.

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 6-PPD 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.

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 12 water samples were collected from field locations within the Anderson Creek watershed on January 16, 2024 by the Raincoast Healthy Waters team alongside representatives of the Pender Harbour Ocean Discovery Station. An additional 10 samples of tap water were obtained from homes and businesses in the surrounding community on the same day.

A portable water properties meter (YSI-ProDSS) was deployed to measure temperature, pH, conductivity, dissolved oxygen and turbidity. 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).

Table 1: Sampling sites in the Anderson Creek watershed

Site Number	Water Category	Site Name	Lat/Long
1	Source	Source 1	N 49.634620, W 123.953619
2	Source	Source 2	N 49.636993, W 123.954480
3	Source	Source 3	N 49.638061, W 123.954431
4	River	Sunshine Coast Hwy Ditch	N 49.637192, W 123.967910
5	River	Ditch Across from Golf Course	N 49.650067, W 123.971707
6	River	Garden Bay Road Ditch	N 49.638824, W 123.971730
7	Runoff	Anderson Ck @ PODS Property	N 49.639021, W 123.967946
8	Runoff	Anderson Ck @ John Daly Park	N 49.639437, W 123.978186
9	Runoff	Anderson Ck @ KR Bridge	N 49.6380901, W 123.983343
10	Marine	Oyster Bay Rd (Martin's)	N 49.637130, W 123.993736
11	Marine	Hospital Bay Gov't Dock	N 49.632264, W 124.030898
12	Marine	PODS Dock @ Irvine's Landing	N 49.632305, W 124.056749
13	Tap	Tap samples from 10 homes	various

Water quality analyses

Table 2: List of analytes, analysis locations, analytical methods, instruments, and number of samples submitted to service labs

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)	colorimetry	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 Nitrogen	ALS Environmental	Chinchilla Scientific Nitrate Method, 2011	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
6PPD-quinone	DFO Institute of Ocean Science		LCMS	5
Tier 3				
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
Multiresidue Pesticides	SGS Axys Analytical	EPA 1699 (mod)	HRMS	5
Per and Poly-fluoroalkyl substances (PFAS)	SGS Axys Analytical	EPA 1633 Draft	LC-MS/MS	5
Pharmaceuticals and Personal Care Products (PPCPs)	SGS Axys Analytical	EPA 1694	HPLC/MS/MS	5
Polychlorinated biphenyls (PCBs)	SGS Axys Analytical	SGS AXYS METHOD MLA-210 Rev 01	GC-MS/MS	5
Polycyclic Aromatic Hydrocarbons (PAHs)	SGS Axys Analytical	EPA 8270/ EPA 1625	GC-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 also 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 some contaminants. These levels 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 1.

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 health 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 the 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.

International Guidelines and emerging PFAS concerns

Since it takes many years to finalize guidelines and in light of increasing concerns over PFAS as a contaminant of concern has led to toxicity, Health Canada has also established screening values for nine PFAS (Appendix 4). These screening values provide guidance where there is a need for quick response. In addition, more recently, a 'proposed objective' of 30 ng/L for total PFAS was developed which set out a goal for a maximum level of PFAS in drinking water. This proposed objective is based on the sum of specific individual PFAS (29 individual PFAS that are quantified by US EPA methods 533 and 537.1). This objective, when finalized, will replace the two existing drinking water guidelines and nine screening values (Health Canada, 2023).

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. These are considered as approved guidelines for drinking water quality, they 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 for this contaminant class (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 Anderson Creek watershed. Source water sites were found to have the lowest temperature, and the highest dissolved oxygen (% and mg/L) among the non-marine sites. Road Runoff sites were found to have the lowest dissolved oxygen (% and mg/L), and the highest conductivity among non-marine samples.

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 (La, 2011), a particular concern for sensitive cold-water species such as salmonids. Conductivity and turbidity measurements can act as proxies for total dissolved solids (TDS) (Rusydi, 2018) and total suspended solids (TSS) respectively (Rügner, *et al,* 2013). These parameters can be relevant as increased TDS and TSS in a body of water can indicate contamination from road salt, nutrients, or flushing of disturbed sediments into the waterway. Unusual conductivity measurements suggest the need for more in-depth analysis for contaminants (Ribeiro de Sousa, 2014).

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.

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Results

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

Analyte	**Source** (n=3)	**Stream and river** (n=3)	**Road runoff** (n=3)	**Marine** (n=3)
Temperature (℃)	5.7 ± 0.05 (5.5-5.9)	1.9 ± 0.12 (1.3-2.1)	3.6 ± 0.19 (3.0-4.3)	6.8 ± 0.06 (6.5-7.0)
DO %	94.2 ± 0.11 (93.7-94.5)	95.3 ± 0.240 (94.3-96.7)	56.6 ± 3.15 (43.6-67.6)	81.2 ± 0.60 (78.7-84.2)
DO (mg/L)	11.8 ± 0.019 (11.8-11.9)	13.3 ± 0.094 (13.0-13.9)	7.46 ± 0.411 (5.84-8.96)	8.23 ± 0.063 (7.99-8.64)
pH	7.6 ± 0.06 (7.3-7.8)	7.1 ± 0.03 (7.0-7.3)	6.7 ± 0.13 (6.4-7.4)	7.4 ± 0.03 (7.32-7.49)
Conductivity (uS/cm)	65.6 ± 4.25 (49-75)	36.5 ± 2.73 (26.0-43.5)	149 ± 28.2 (45.4-240)	43200 ± 254 (42200-43900)
Turbidity (FNU)	2.0 ± 0.35 (0.69-3.3)	1.0 ± 0.12 (0.61-1.4)	2.2 ± 0.45 (0.46-3.6)	0.64 ± 0.07 (0.45-0.97)
Water Velocity (m/s)	-	0.27 ± 0.02 (0.20-0.42)	-	-

Data presented above represent 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 were unable to take water property measurements of the pooled tap water sample due to logistical reasons.

Conclusions

- Water temperature, pH, and dissolved oxygen were all within EQGs ranges for protection of aquatic life.

Coliform bacteria

Capsule

Coliform bacteria in water represent a potentially serious threat to human health. The highest counts of total and fecal coliform were measured in the road runoff sample. The highest counts of E. coli were measured in the stream and river sample. There were no coliform bacteria detected in the tap water sample.

Introduction

Coliform bacteria have historically been used to gauge water quality with respect to implications for human recreational use and drinking water consumption (van Elsas, et al., 2013). 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 (Li, 2021). 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.

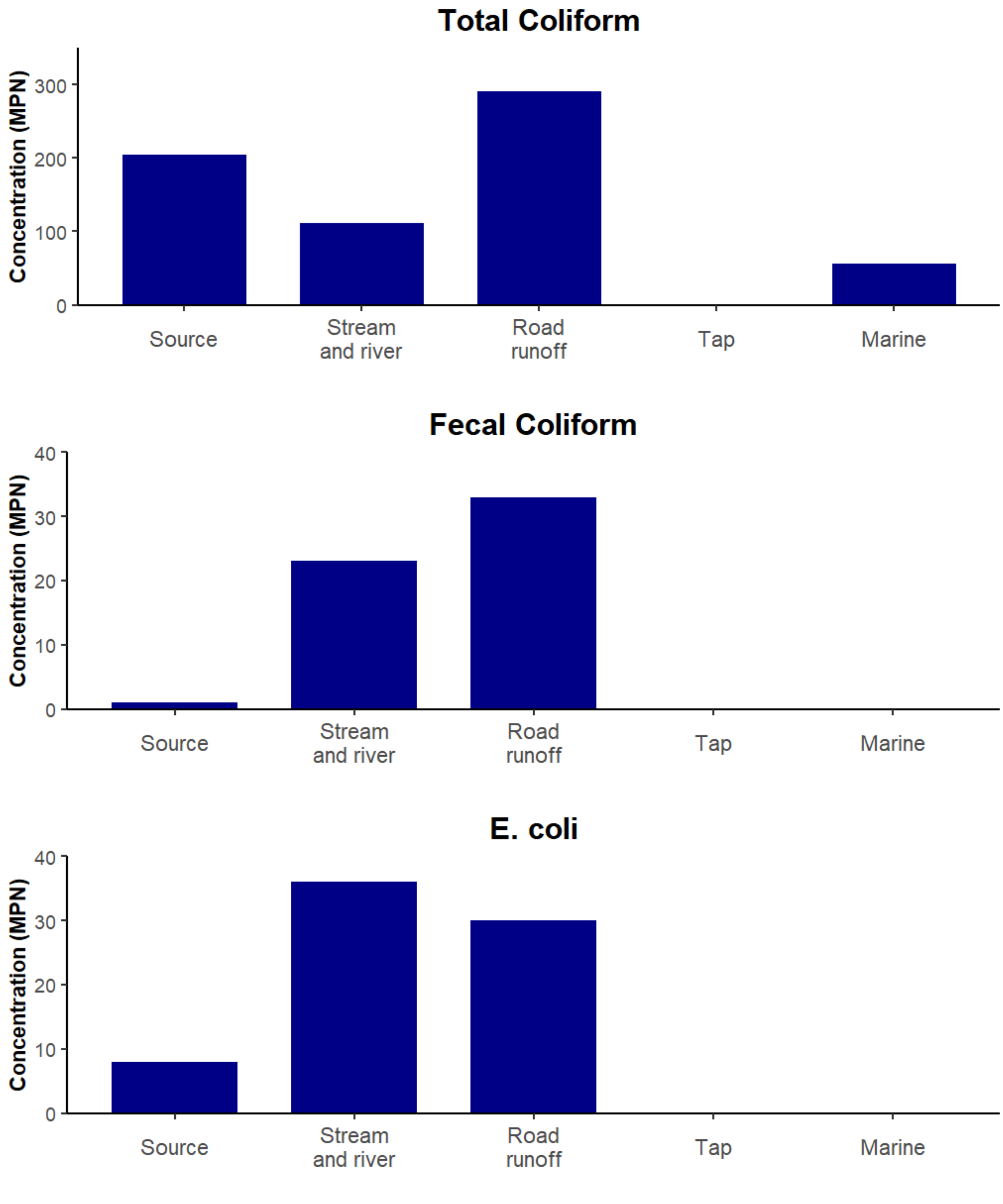
Results

Table 7: Mean counts (MPN/100ml) of coliform bacteria in five water categories in the Anderson Creek watershed (WET Season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)
Total coliform	205	111	291	0	56
Fecal Coliform	1	23	33	0	0
E. coli	8	36	30	0	0

https://doi.org/10.70766/126.498

Figure 2: Coliform counts (MPN) in five water categories in the Anderson Creek watershed (WET Season)



The road runoff sample had the highest coliform counts of total and fecal coliforms. The stream and river sample had the highest counts of E. coli. It is unusual, but not impossible to find more E.coli than fecal coliform in a sample, due to sample heterogeneity. No coliform were detected in the Tap water sample.

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Conclusions

- E. coli concentrations in each of the five water categories from highest to lowest area were as follows: stream and river > road runoff > source > marine = tap.
- There are currently no EQGs available for coliform bacteria for the protection of aquatic life.
- We did not detect any coliform bacteria counts that exceeded recommended levels for recreational use.
- Source water samples were within Health Canada guidelines for raw drinking water sources (<10 MPN/100ml), with this DWQG assuming that municipal, reserve or domestic disinfection processes destroy all coliform prior to drinking.
- Tap water samples did not contain any coliform bacteria.

Nutrients and Physical parameters

Capsule

Nutrients can readily degrade fish habitat by increasing plant and algal growth and causing a reduction in Dissolved Oxygen. Nitrate was the most commonly detected nutrient in the Anderson Creek watershed, and was found in four out of five water samples. The highest concentration of nitrate was detected in the road runoff sample.

Introduction

Nutrients such as nitrogen and phosphorus compounds can be naturally occurring, and are critical for the health and growth of plants and animals (CCME, 2016). 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 (Putt, et al. 2019). 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 (Davis, 1975).

In addition, some nutrients such as total ammonia are considered to be acutely toxic to freshwater fish species at concentrations that vary by pH and temperature of the water (CCME, 2010).

Results

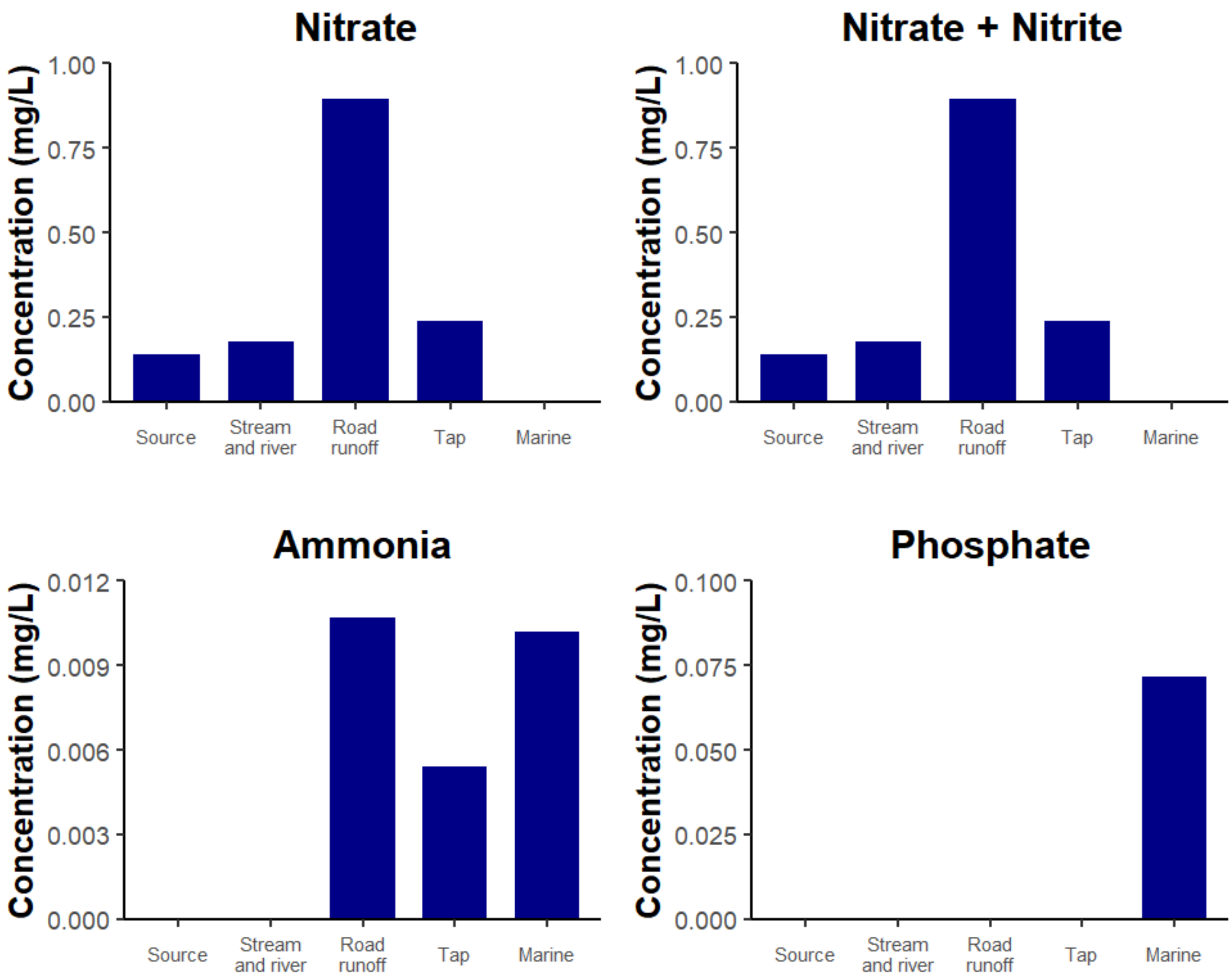
Table 8: Concentrations (mg/L) of physical and chemical properties in each water category for the Anderson Creek watershed (WET Season)

Analyte	Source (n=1)	Stream and river (n=1)	Runoff (n=1)	Tap (n=1)	Marine (n=1)
Hardness (as CaCO3)	19	12.6	25.4	21.2	5920
Solids, total dissolved [TDS]	51	41	97	74	28200
Solids, total suspended [TSS]	0	0	0	0	0
Carbon, total organic [TOC]	1.25	2.44	2.73	2.6	1.1
Biochemical oxygen demand [BOD]	0	0	0	0	0
Chemical oxygen demand [COD]	0	0	23	0	478

Table 9: Nutrient concentrations (mg/L) in each water category for the Anderson Creek watershed (WET Season)

Analyte	Source (n=1)	Stream and river (n=1)	Runoff (n=1)	Tap (n=1)	Marine (n=1)
Nitrogen, total	0.202	0.231	0.955	0.339	0.15
Nitrate (as N)	0.141	0.179	0.894	0.24	0
Nitrate + Nitrite (as N)	0.141	0.179	0.895	0.24	0
Ammonia, total (as N)	0	0	0.0107	0.0054	0.0102
Nitrite (as N)	0	0	0.0011	0	0
Phosphate, ortho-, dissolved (as P)	0	0	0	0	0.0717

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



Nitrate (NO3-) was the most commonly detected nutrient in water samples from the Anderson Creek watershed. The highest concentration (mg/L) was detected in Road Runoff samples (n=6).

Conclusions

- Nitrate concentrations in the five water categories were ranked from highest to lowest as follows: road runoff > tap > stream and river > source > marine.
- Nitrate was the most frequently detected nutrient in samples across the Anderson Creek watershed.
- Road runoff was found to have the highest concentration of ammonia (0.0107 mg/L), which was well below the BC MOE acute exposure guideline value for the protection of freshwater aquatic life (23.0 mg/L) and the BC MOE long-term exposure guideline value for the protection of freshwater aquatic life (1.94 mg/L). Ammonia guideline values are determined based on water temperature and pH measurements taken at the time of water sampling.
- Phosphate was only detected in the marine water sample.
- No nutrient values exceeded available EQGs for the protection of aquatic life.

Metals

Capsule

Metals can be present in water due to both natural and anthropogenic inputs. Nine metals were detected in all of the water samples submitted to the laboratory for analysis. Lead was detected in the pooled tap water sample, and did not exceed the current Health Canada guideline for drinking 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 (Jadaa, et al., 2023). 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 (Giardina, et al., 2009) and copper (Malholtra, et al., 2020).

Results

Table 10: Concentrations (mg/L) of metals that were detected in each water category in the Anderson Creek watershed (WET Season)

Analyte	Source	Stream and river	Road runoff	Tap	Marine
Aluminum, total	0.0682	0.0847	0.085	0.0294	<0.150
Antimony, total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00500
Arsenic, total	0.00011	0.00023	0.00051	0.00032	<0.00500
Barium, total	0.00265	0.00313	0.0114	0.0044	0.00893
Beryllium, total	<0.000020	<0.000020	<0.000020	<0.000020	<0.00100
Bismuth, total	<0.000050	<0.000050	<0.000050	<0.000050	<0.00250
Boron, total	<0.010	<0.010	0.071	0.015	3.68
Cadmium, total	0.0000052	0.0000137	0.0000175	0.0000193	<0.000250
Calcium, total	5.70	3.66	7.42	6.39	342
Chromium, total	<0.00050	<0.00050	<0.00050	<0.00050	<0.0250
Cobalt, total	<0.00010	<0.00010	<0.00010	<0.00010	<0.00500
Copper, total	0.00117	0.00222	0.00242	0.415	<0.0250

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Iron, total	0.052	0.044	0.055	0.052	<0.500
Lead, total	<0.000050	<0.000050	0.000071	0.0015	<0.00250
Lithium, total	<0.0010	<0.0010	<0.0010	<0.0010	0.151
Magnesium, total	1.17	0.842	1.68	1.28	1230
Manganese, total	0.00194	0.00206	0.0136	0.00271	<0.00500
Mercury, total	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
Molybdenum, total	0.000471	0.00054	0.000665	0.00278	0.00964
Nickel, total	<0.00050	<0.00050	<0.00050	0.0016	<0.0250
Phosphorus, total	<0.050	<0.050	<0.050	<0.050	<2.50
Potassium, total	0.717	0.435	1.27	0.973	377
Selenium, total	<0.000050	<0.000050	<0.000050	0.000051	<0.00250
Silicon, total	8.42	5.78	7.46	6.17	<5.00
Silver, total	<0.000010	<0.000010	<0.000010	0.000012	<0.000500
Sodium, total	2.35	2.28	19.0	10.8	9910
Strontium, total	0.028	0.0189	0.0557	0.034	6.81
Sulfur, total	<0.50	0.52	1.23	0.90	919
Thallium, total	<0.000010	<0.000010	<0.000010	<0.000010	<0.000500
Tin, total	<0.00010	<0.00010	<0.00010	0.00011	<0.00500
Titanium, total	0.002	0.0005	0.00131	0.00039	<0.0150
Uranium, total	0.000061	0.000031	0.000036	0.000151	0.00273
Vanadium, total	0.00098	0.00055	<0.00050	<0.00050	<0.0250
Zinc, total	<0.0030	0.0041	0.0093	0.269	<0.150
Zirconium, total	<0.00020	<0.00020	<0.00020	<0.00020	<0.0100
Total Metals	*18.5*	*13.7*	*38.4*	*27.3*	*12800*

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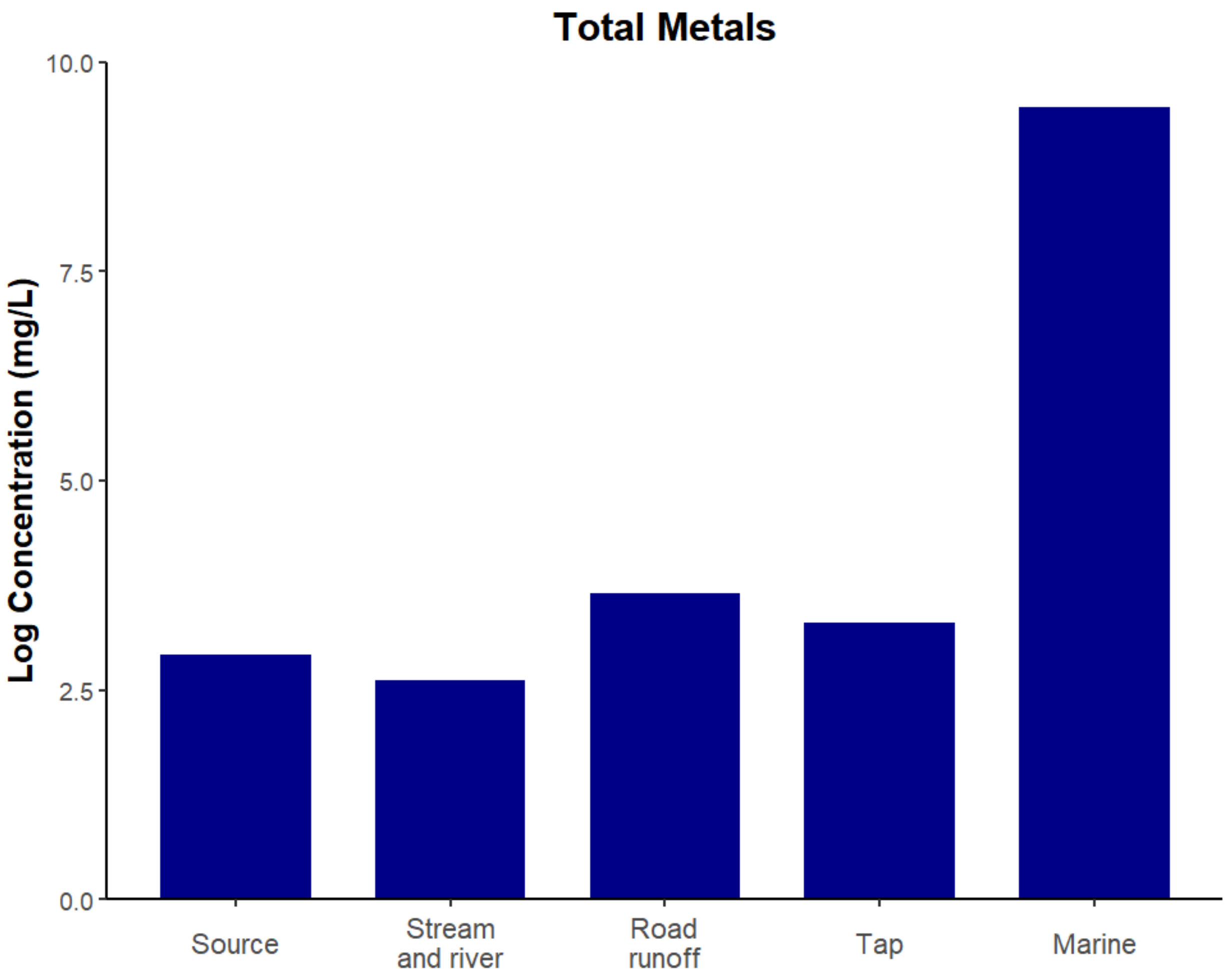
Figure 4: Total metal concentrations (mg/L) in five water categories in the Anderson Creek watershed (WET Season)



Total metal concentrations are shown with a logarithmic transformation to allow for visualization of the data - as the Marine water sample had considerably higher concentrations of metals than the four non-marine samples.

Table 11: Concentrations (mg/L) of lead detected in all five water categories in the Anderson Creek watershed (WET Season)

Analyte	Source (n=1)	Fresh (n=1)	Runoff (n=1)	Tap (n=1)	Marine (n=1)
Lead (mg/L)	0	0	0.000071	0.0015	0

https://doi.org/10.70766/126.498

Conclusions

- Total metal concentration for the five water categories was ranked from highest to lowest as follows: marine > road runoff > tap > source > stream and river.
- Lead was only detected in the pooled tap water sample (0.0015 mg/L), and was present at a concentration lower than the limit set by Health Canada for safe drinking water of 0.005 mg/L.
- No other analytes exceeded Health Canada drinking water quality guidelines.

Polycyclic Aromatic Hydrocarbons (PAHs)

Capsule

Polycyclic aromatic hydrocarbons (PAHs) were detected in all five water samples, with the highest concentrations observed in the stream and river water sample and the lowest in the tap sample. The common PAHs present at the highest concentrations were the C2-naphthalenes, C3-naphthalenes and naphthalene. WQGs were only available for a few PAHs, but no exceedances were observed for any of our samples. Finally, the tap water sample did not exceed the one PAH guideline available for drinking water.

Introduction

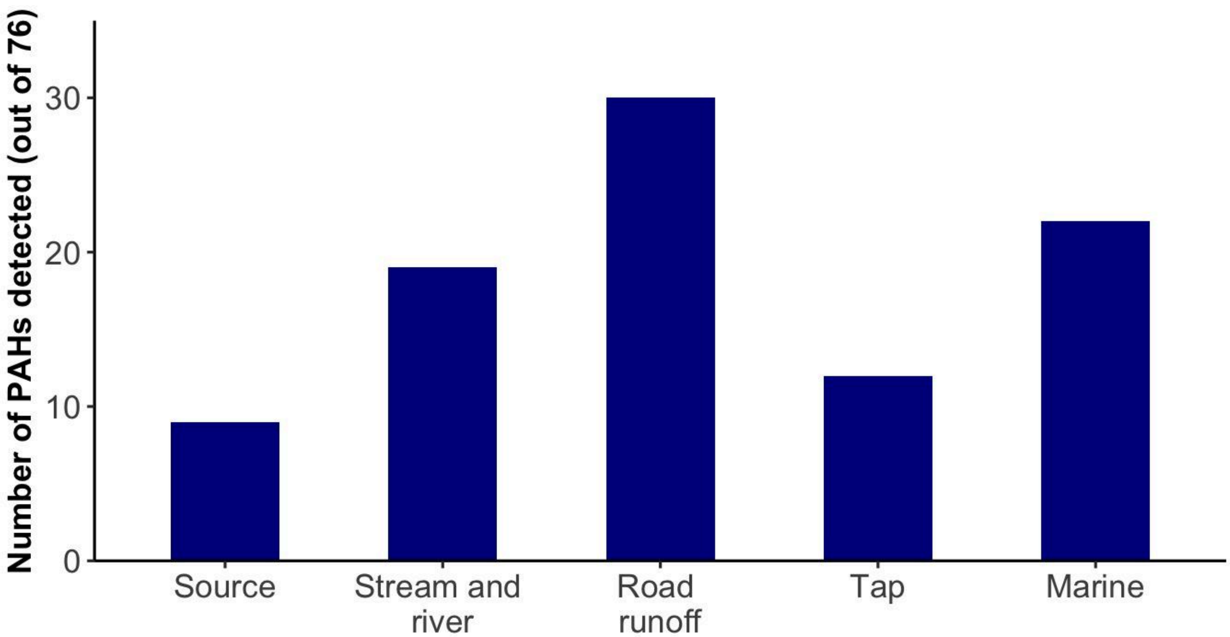
Polycyclic aromatic hydrocarbons (PAHs) are a complex group of compounds found in coal, petroleum and plant materials. They can enter waterways in the form of liquid petroleum products (gasoline, diesel, oil) or via the incomplete combustion of coal, oil, gas, wood garbage or other organic substances. 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 (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 five water samples collected within the Anderson Creek watershed during the wet season.

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



PAHs were detected in all five water categories. The number of PAHs detected ranged from 9 (source) to 30 (road runoff) with an average of 18.4 ± 3.7.

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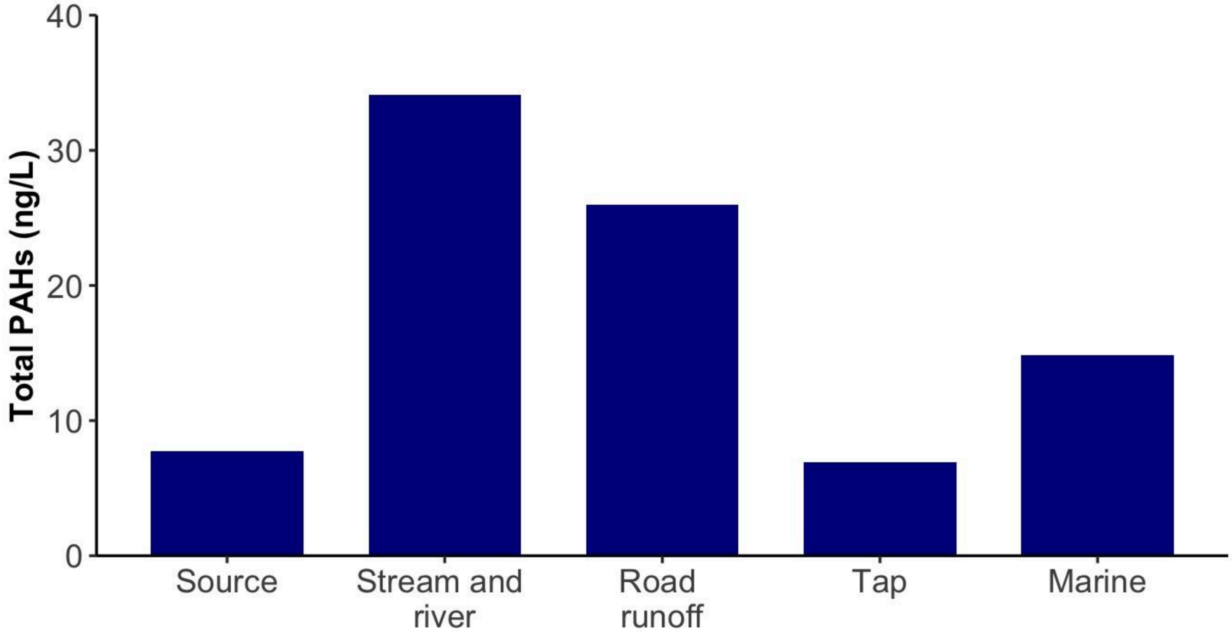
Figure 6: Total PAH concentrations in water samples from the Anderson Creek watershed (WET Season)



Total PAH levels ranged between 6.9 (tap) and 34.1 ng/L (stream and river) with an average across all sample types of 17.9 ± 5.3 ng/L.

The top 6 PAHs with the highest concentrations contributed between 55% (road Runoff) and 93% (source) of total PAH concentrations (Table X). C2-Naphthalenes, C3-Naphthalenes (except road runoff) and naphthalene were present in all samples. C1-Naphthalenes were present in stream and river, road runoff and marine samples. Finally, retene was only detected in the source sample.

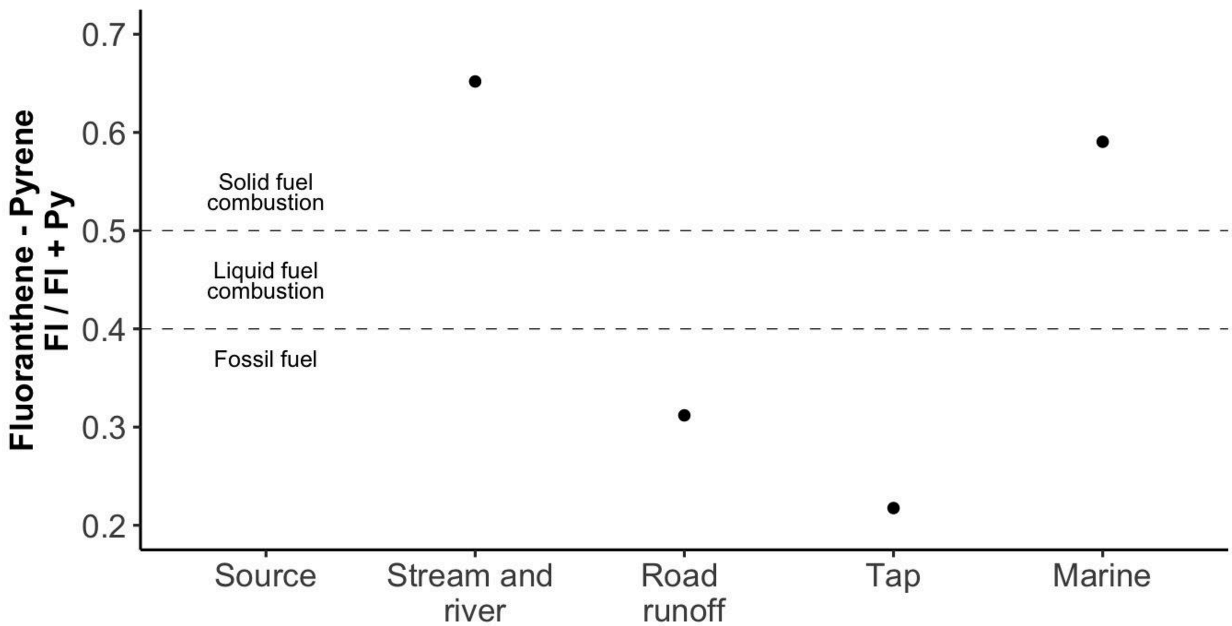
Table 12: Top 6 PAHs with the highest concentration in each water sample from the Anderson Creek watershed and their respective concentrations in brackets (WET Season).

Source	Freshwater	Road Runoff	Tap	Marine
C2-Naphthalenes (3.8)	Naphthalene (12.6)	C2-Naphthalenes (3.5)	C2-Naphthalenes (1.9)	C2-Naphthalenes (4.1)
Naphthalene (1.5)	C2-Naphthalenes (5.2)	Naphthalene (3.5)	C3-Naphthalenes (1.5)	Naphthalene (1.9)

	C2-Biphenyls (0.59)	C1-Naphthalenes (3.9)	C3-Phenanthrenes, Anthracenes (3.3)	Naphthalene (1.1)	Phenanthrene (1.2)
	C3-Naphthalenes (0.58)	1 Methyl-naphthalenes (2.1)	C4-Phenanthrenes, Anthracenes (1.5)	C1-Fluoranthenes, Pyrenes (0.69)	C1 Naphthalenes (1.1)
	C4-Phenanthrenes, Anthracenes (0.56)	2 Methyl-naphthalene (1.9)	C4-Naphthalenes (1.4)	Phenanthrene (0.58)	C3 Naphthalenes (0.94)
	Retene (0.29)	C3-Naphthalenes (1.4)	C1-Naphthalenes (1.0)	2 Methyl-naphthalene (0.38)	Acenaphthene (0.94)
Total concentrations of top 6 (% contribution to total PAHs)	7.2 (93%)	27.2 (80%)	14.3 (55%)	6.1 (88%)	10.1 (68%)

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 water categories except source water.

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



The marine (0.59) and stream and river (0.65) water samples had Fl/(Fl+Pyr) ratios higher than 0.5, suggesting a contribution of combustion of solid fuel such as wood, plant material or coal as the source of PAHs. The ratios from the road runoff (0.31) and tap (0.22) samples were lower than 0.4 suggesting the contribution of liquid fossil fuels.

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Conclusions

- PAH concentrations were ranked as follows from highest to lowest: stream and river > road runoff > marine > source > tap.
- Total PAH concentrations ranged between 6.9 and 34.1 ng/L in Anderson Creek water samples collected during the wet season.
- PAHs in marine and stream and river water likely originated from the combustion of solid fuel such as wood or plant material. This is consistent with wood burning for heating homes and wildfires 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).
- PAHs likely originated from fossil fuel in the road runoff and tap samples.
- All the environmental water samples were well below the WQGs available for individual PAHs (naphthalene, acenaphthene, fluorene, anthracene, phenanthrene, fluoranthene, pyrene, chrysene, benzo-a-pyrene and benzo-a-anthracene).
- DWQG was only available for benzo-a-pyrene (40 ng/L) which was not detected in the tap water sample.

Pesticides

Capsule

A limited number of pesticides were detected in all five water samples, with the highest concentrations in the marine water sample, and the lowest in the source water sample. Alpha- endosulfan (100% of samples), hexachlorobenzene (100% of samples) and endrin (80% of samples) were detected in the majority of samples. Endosulfan and simazine were the only pesticides detected that had EQGs but no exceedances for these pesticides were observed for any of the water samples. Canadian drinking water guidelines were only available for six pesticides that were not detected in the tap water sample.

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).

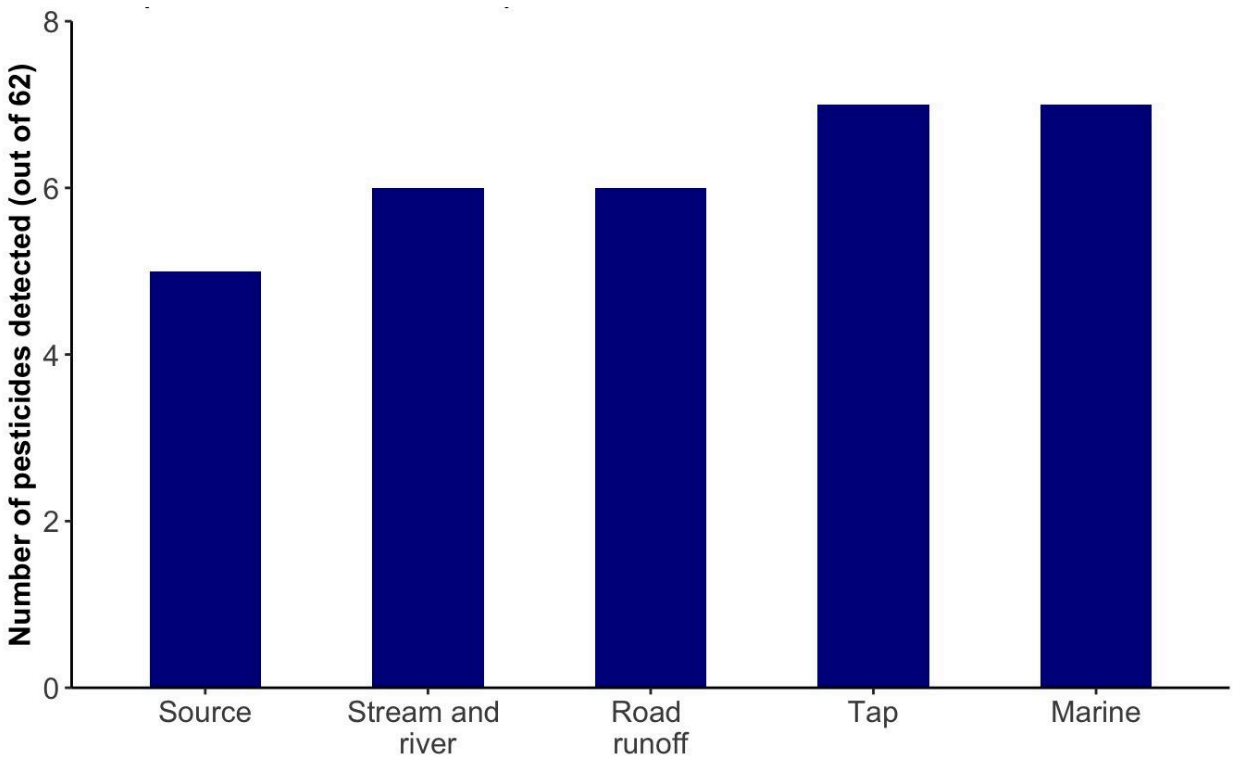
While pesticides are mostly applied on terrestrial habitats, they can reach aquatic environments through overspray or drift during application, surface runoff, and through long range atmospheric transport and deposition. It is estimated that 10% of pesticides applied to soil reach non-target areas, leading 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 five water samples collected within the Anderson Creek watershed during the wet season.

Figure 8: Number of pesticide detections in water sampled in the Anderson Creek watershed (WET Season)



The number of pesticides detected ranged from 5 (source) to 7 (tap and marine) with an average of 6.2 ± 0.4.

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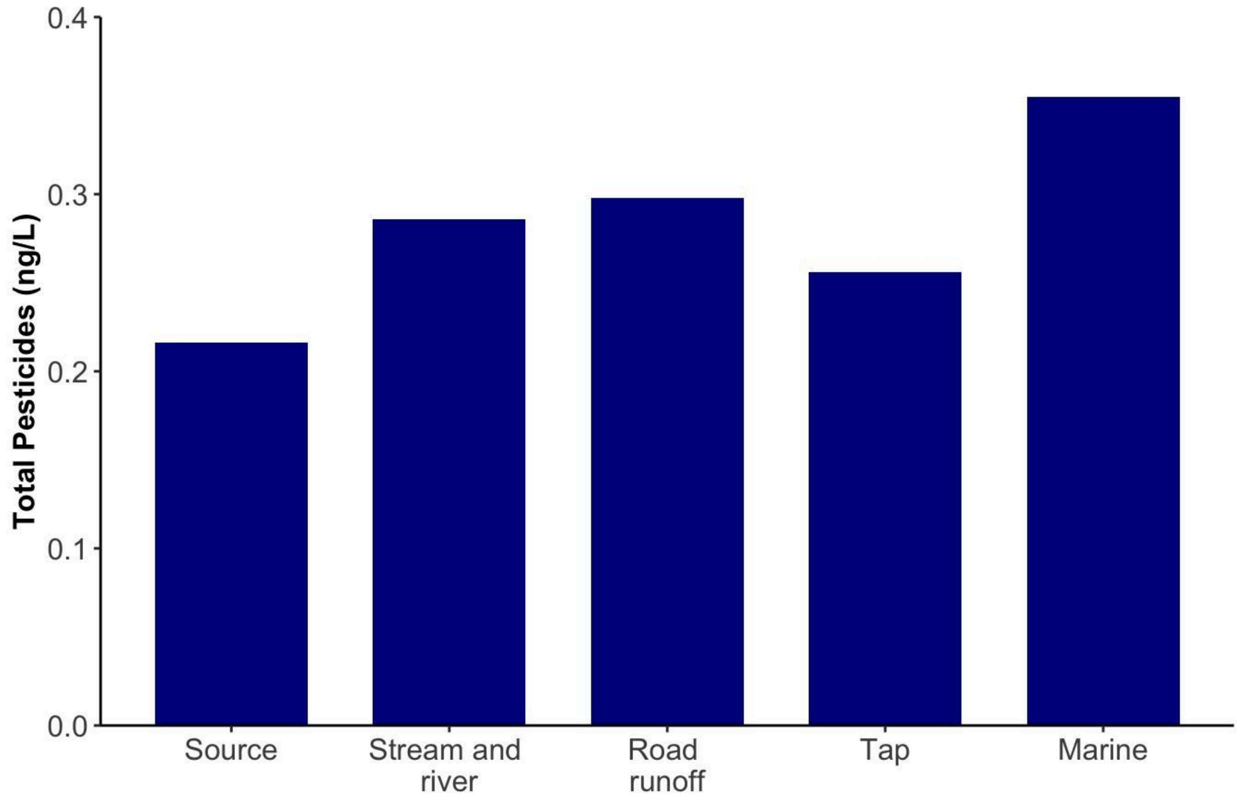
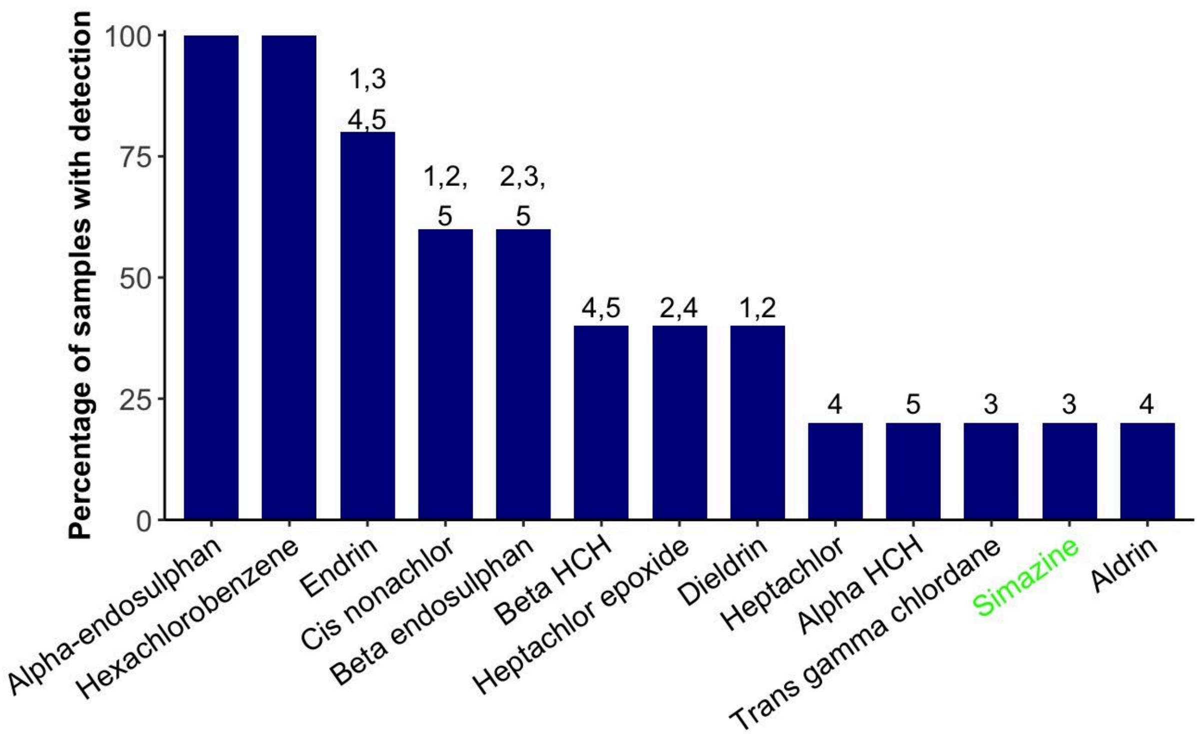
Figure 9: Total pesticide concentrations in water sampled in the Anderson Creek watershed (WET Season)



Total pesticide levels ranged from 0.22 (source) to 0.36 ng/L (marine), with an average across all water categories of 0.28 ± 0.02 ng/L.

https://doi.org/10.70766/126.498

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



Numbers refer to water categories (1: Source; 2: Stream and river, 3: Road runoff, 4: Tap; 5: Marine). For example, the tap water sample had detectable concentrations of Alpha-endosulfan, hexachlorobenzene, endrin, beta-HCH, heptachlor epoxide, heptachlor and endrin.

Alpha- endosulfan (100% of samples), hexachlorobenzene (100% of samples) and endrin (80% of samples) were detected in the majority of samples.

- 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).
- 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) .
- Endrin is an organochlorine pesticide that was used to treat a variety of insect pests until 1991 when registration and use of endrin was discontinued in Canada (CCME, 1999).

Simazine was the only pesticide detected that is still currently in use in Canada. Siazine is an herbicide used to control weeds in various crops, at airports, and along shelterbelts and rights-of-way, as well as being used in aquatic weed control in ditches, farm ponds, fish hatcheries, aquaria, and fountains (Health Canada, 2016) .

Conclusions

- Pesticide concentrations were ranked as follows from highest to lowest: marine > road runoff > stream and river > tap > source.
- Total pesticide concentrations ranged from 0.22 to 0.36 ng/L.
- The majority of pesticides detected, except simazine, were no longer in use in Canada at the time of sampling. Their detection likely reflects historical use nearby as well as deposition following long-range atmospheric transport. Interestingly, hexachlorobenzene, endosulfan and simazine 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 simazine were the only pesticides detected that had EQGs (Appendix X), and their concentrations did not exceed these.
- Canadian drinking water guidelines were only available for six pesticides (atrazine, chlorpyrifos, dimethoate, metribuzin, malathion and simazine; Appendix X), none of which were detected in the tap water sample.

Pharmaceuticals and Personal Care Products

Capsule

Pharmaceuticals and Personal Care Products (PPCPs) are a wide category of contaminants that enter the environment via wastewater streams, and are typically not removed during treatment of municipal wastewater. DEET was the most frequently detected PPCP in our samples, and was detected in all five samples. The tap and marine water samples contained the greatest number of different PPCP compounds (n=6), the source and stream and river samples contained the least number of different PPCP compounds (n=1).

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).

Pharmaceuticals may enter the environment by way of WWTP effluent, land-applied biosolids and/or septic tank failures (Metcalfe et al 2004). Monitoring of source water is deemed an important means of assuring the safety of drinking water, especially First Nations (Schwartz et al., 2021). However, the lack of Environmental Quality Guidelines and Drinking Water Quality Guidelines in Canada for PPCPs and internationally constrains a fulsome risk-based evaluation of environmental concentrations (Lee and Choi, 2019).

DEET (N,N-diethyl-meta-toluamide) is a widely used insect repellent. 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. Diatrizoic acid is used as a dye in medical imaging as an alternative to barium. Cocaine is a recreational drug, and co-occurs with its metabolic product benzoylecgonine

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 Anderson Creek watershed (WET season)

Analyte	Source	Stream and river	Road runoff	Tap	Marine
Penicillin G	0	0	0	20.1	0.130
Caffeine	0	0	0	75.5	6.94
Diatrizoic acid	0	0	31.8	0	0
Cotinine	0	0	0	0.365	0.441
Metformin	0	0	1.54	0	15.9
Benzoylecgonine	0	0	0	0.185	0.402
Cocaine	0	0	0.193	0.587	0
DEET	0.990	0.630	0.360	2.49	0.620
Total PPCP concentration	**0.990**	**0.630**	**33.9**	**99.3**	**24.4**
Total number of PPCPs detected	*1*	*1*	*4*	*6*	*6*

The greatest total concentration of PPCP compounds was detected in the tap water sample (99.3 ng/L), largely dominated by caffeine. The lowest total concentration of PPCP compounds was detected in the stream and river sample (0.630 ng/L).

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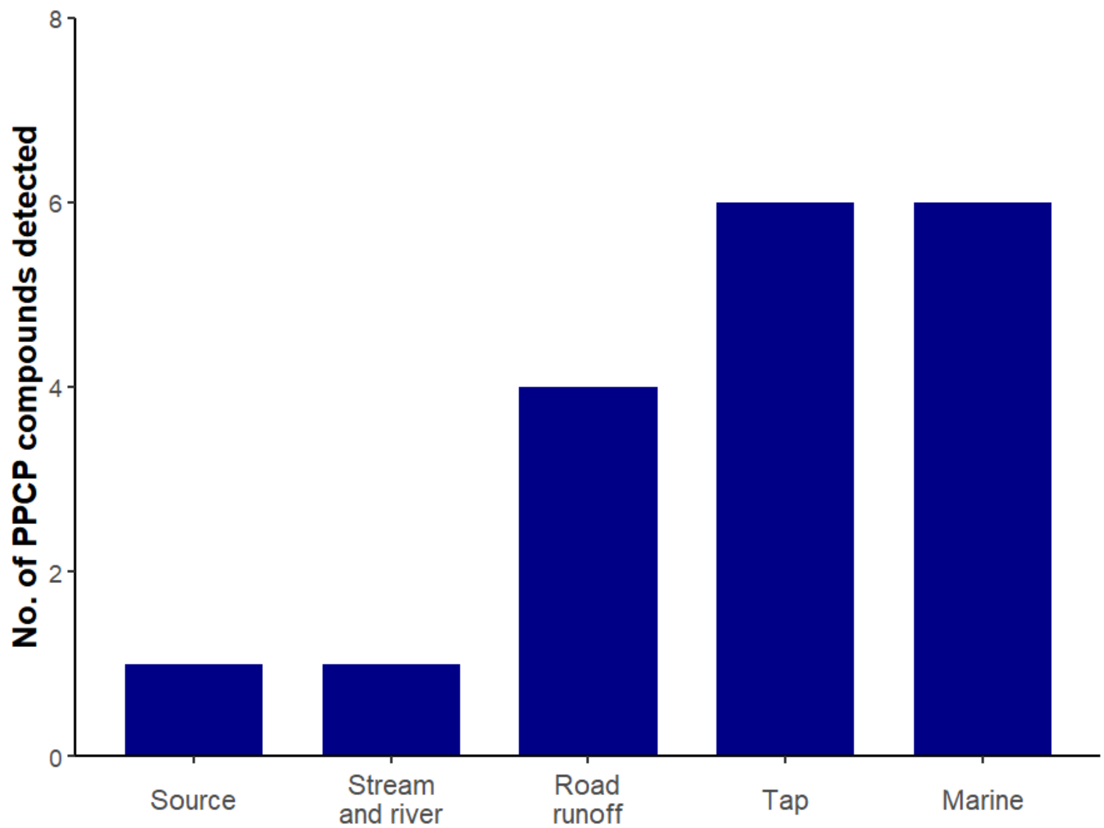
Figure 11: PPCP counts for analytes detected in each of five water samples from the Anderson Creek watershed (WET Season)



The tap and marine samples had the greatest number of PPCPs detected among water categories (n=6). The source and stream and river samples had the lowest number of compounds detected (n=1).

Conclusions

- PPCP concentrations in water samples from highest to lowest were as follows: tap > road runoff > marine > source > stream and river
- There are no EQGs available in Canada for any of the PPCPs we detected.
- 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. EE was not detected in any sample.
- High levels of caffeine in tap water merit a follow up investigation.

Per- and poly-fluoroalkyl substances (PFAS)

Capsule

Per- and poly-fluoroalkyl substances (PFAS) were detected in road runoff and tap water samples with the highest levels being in road runoff. Perfluorooctanesulfonamide (PFOSA) was the only PFAS detected in tap water. Perfluorooctanoic Acid (PFOA) and perfluorooctanesulfonic acid (PFOS) were detected in road runoff. None of the samples exceeded the environmental quality guidelines available (PFOS) or drinking water guidelines (PFOS and PFOA).

Introduction

Per- and poly-fluoroalkyl substances (PFAS) are large group (~15,000 compounds) of human-made substances used in a wide variety of products such as food packaging, non-stick cookware, clothing, and cosmetics, but also lubricants, oil/water repellents, and notably - aqueous firefighting foams (AAAF; Barzen-Hanson et al., 2017). They are extremely stable and therefore persistent in the environment, which has led to the use of the term “forever chemicals” for this category of chemical.

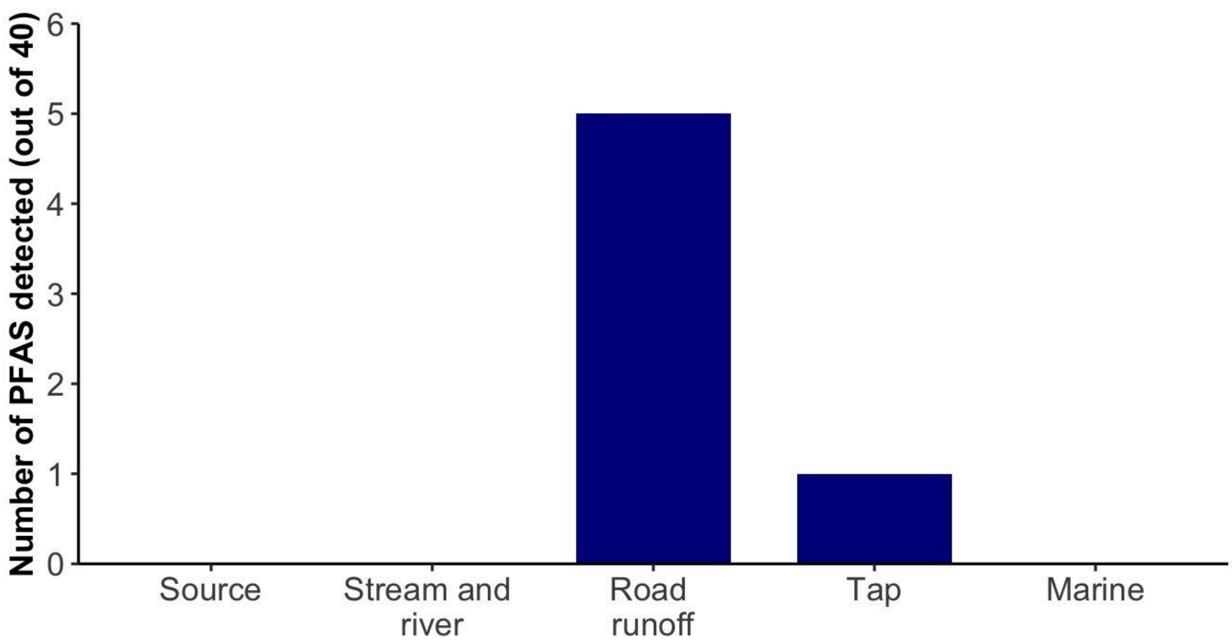
PFAS can be released into the environment from point sources such as manufacturing plants, or sites where firefighting foams have been used. PFAS can also be released through consumer use and disposal of PFAS-containing products. PFAS has been found in all environmental compartments (Moller et al., 2010; ECCC and Health Canada, 2023).

Evidence of adverse effects on the environment and on 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). Advancing regulatory aspects pertaining to rapidly emerging concerns about the many PFAS being detected in the environment is a current priority in Canada (Longpre et al., 2020).

Results

We measured 40 different PFAS in the five water samples collected within the Anderson Creek watershed during the wet season.

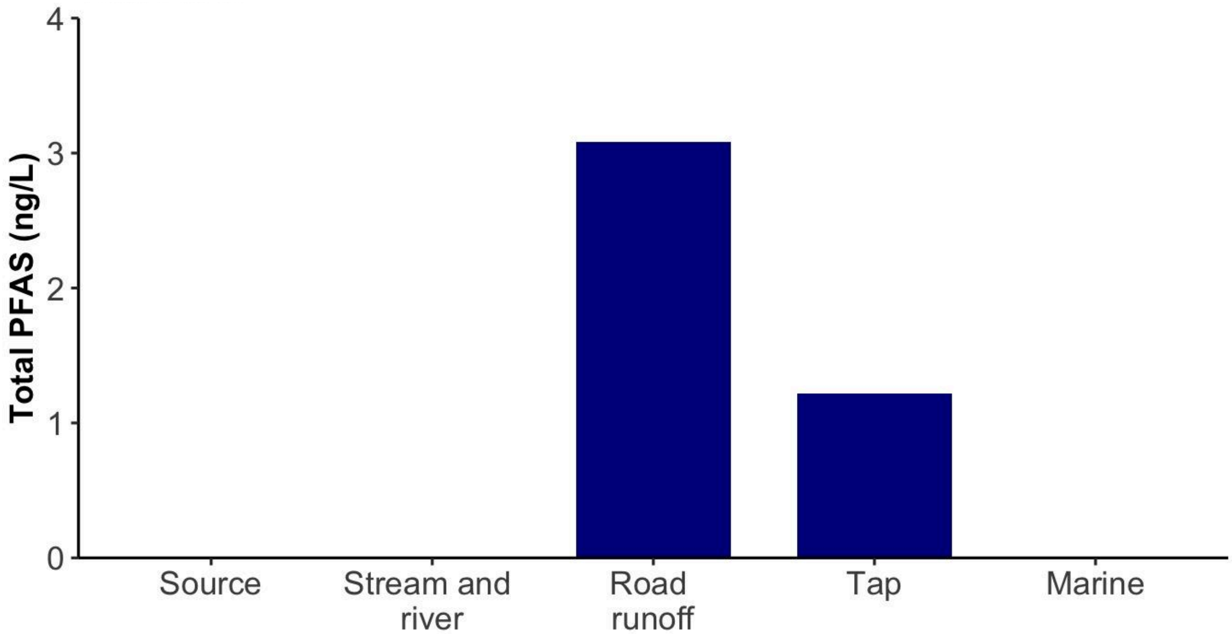
Figure 12: Number of PFAS substances detected in water samples from the Anderson Creek watershed (WET Season).



PFAS were only detected in the tap (1 individual PFAS) and road runoff (5 PFAS) samples. The average number of PFAS detected was 1.2 ± 0.9.

https://doi.org/10.70766/126.498

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



Total PFAS levels ranged between 0 (source, stream and river, marine) and 3.1 ng/L (road runoff) with an average across all water categories of 0.86± 0.60 ng/L.

While perfluorooctanesulfonamide (PFOSA) was the only PFAS detected in tap water, perfluorobutane sulfonic acid (PFBS), perfluorohexane Sulfonate (PFHxS), perfluorooctanesulfonic acid (PFOS), perfluorooctanoic Acid (PFOA) and perfluorohexanoic Acid (PFHxA) were the only PFAS detected in road runoff.

Conclusions

- PFAS concentrations were ranked as follows from highest to lowest: road runoff > tap > source, stream and river, marine.
- Total PFAS levels in water samples collected from the Anderson Creek watershed ranged from 0 to 3.1 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).

- All the environmental 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 and no Canadian drinking water guidelines were available.
- Total PFAS levels were below the European Union Water Directive drinking water quality guideline (500 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 five water samples, with the highest concentration observed in the marine water sample and the lowest in the stream and river sample. The stream and river, tap and marine water samples had the 'lightest' PCB signatures while the road runoff sample had the 'heaviest' PCB signature. None of the samples exceeded the water quality guidelines for individual PCB congeners (PCB-77, -105, -126 and -169) or total PCBs. No guidelines were available for drinking water.

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). Regulatory steps in the 1970s and since have led to declining PCB concentrations in aquatic animals in BC (Ross et al., 2013).

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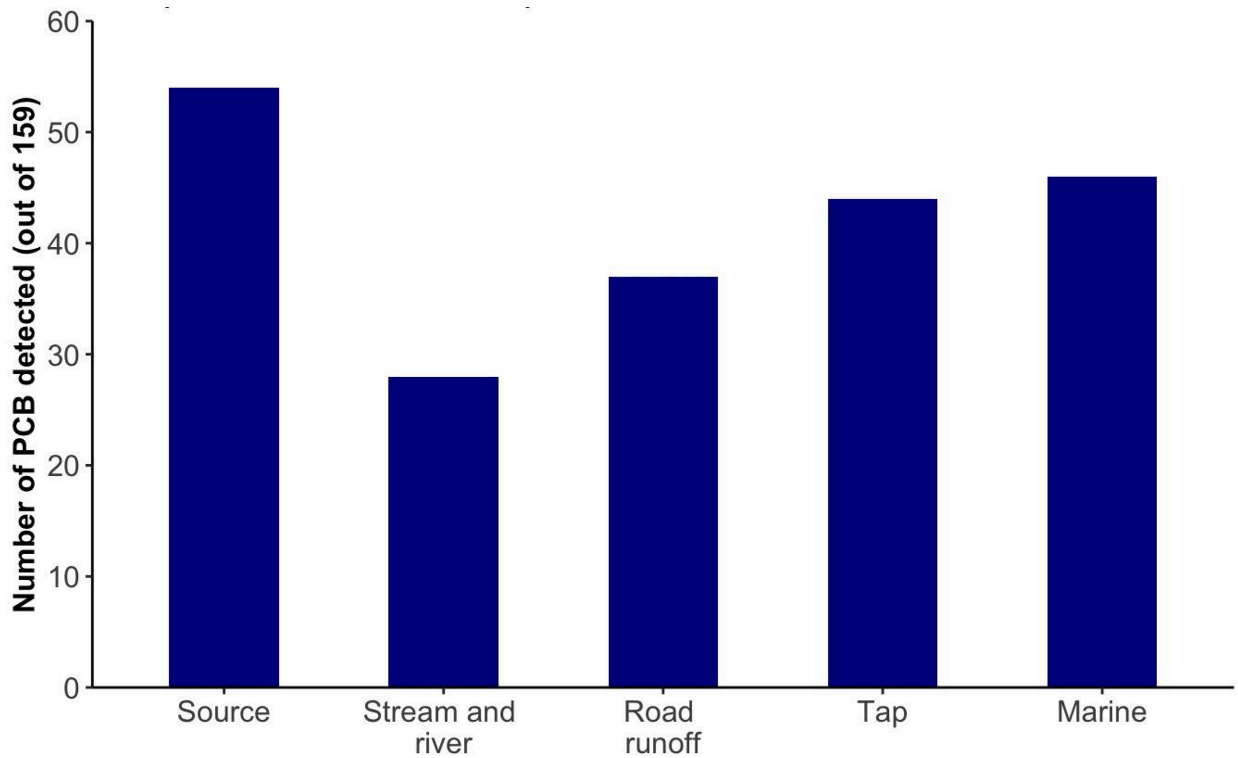
Results

Out of the 209 individual congeners, we measured 159 of them in the five water samples collected within the Anderson Creek watershed during the wet season.

Figure 14: Number of PCB detections in water sampled from the Anderson Creek watershed (WET Season)



PCBs were detected in all five water categories. The number of PCBs detected ranged from 28 (stream and river) to 54 (source) with an average of 38.0 ± 10.3.

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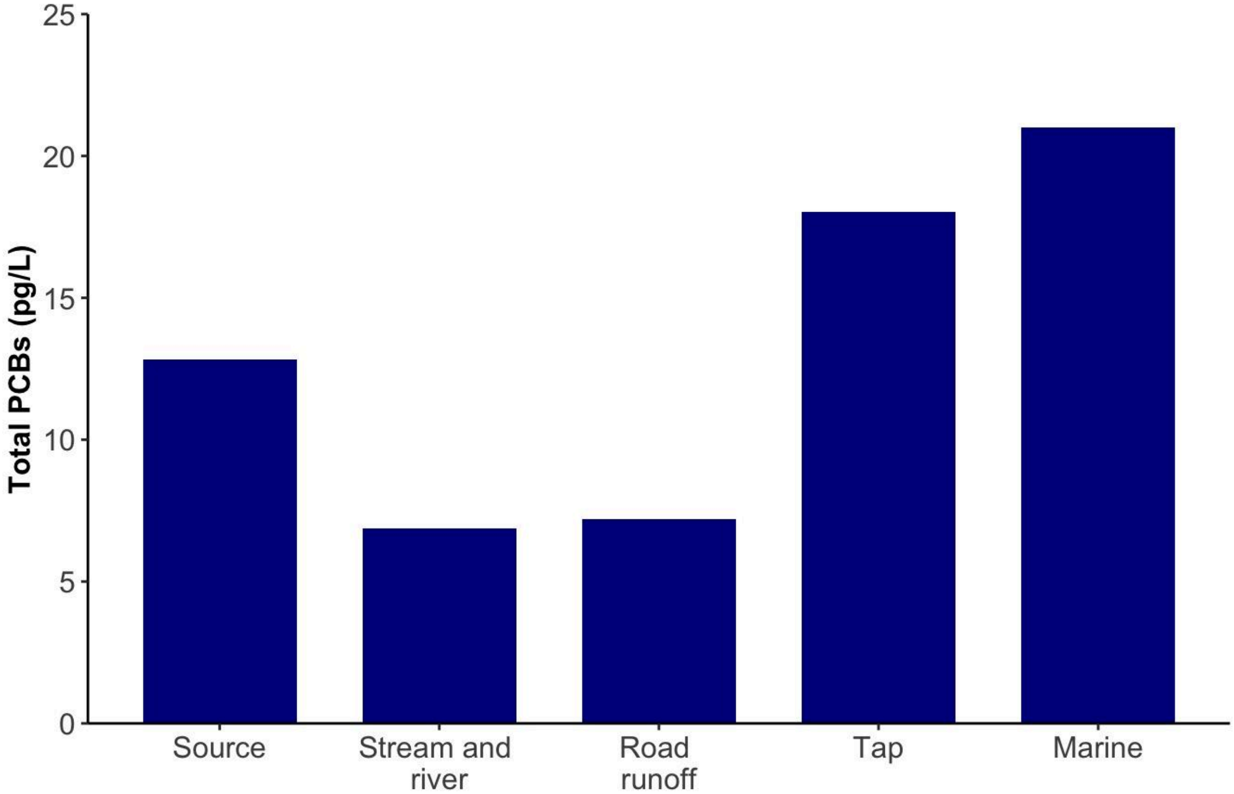
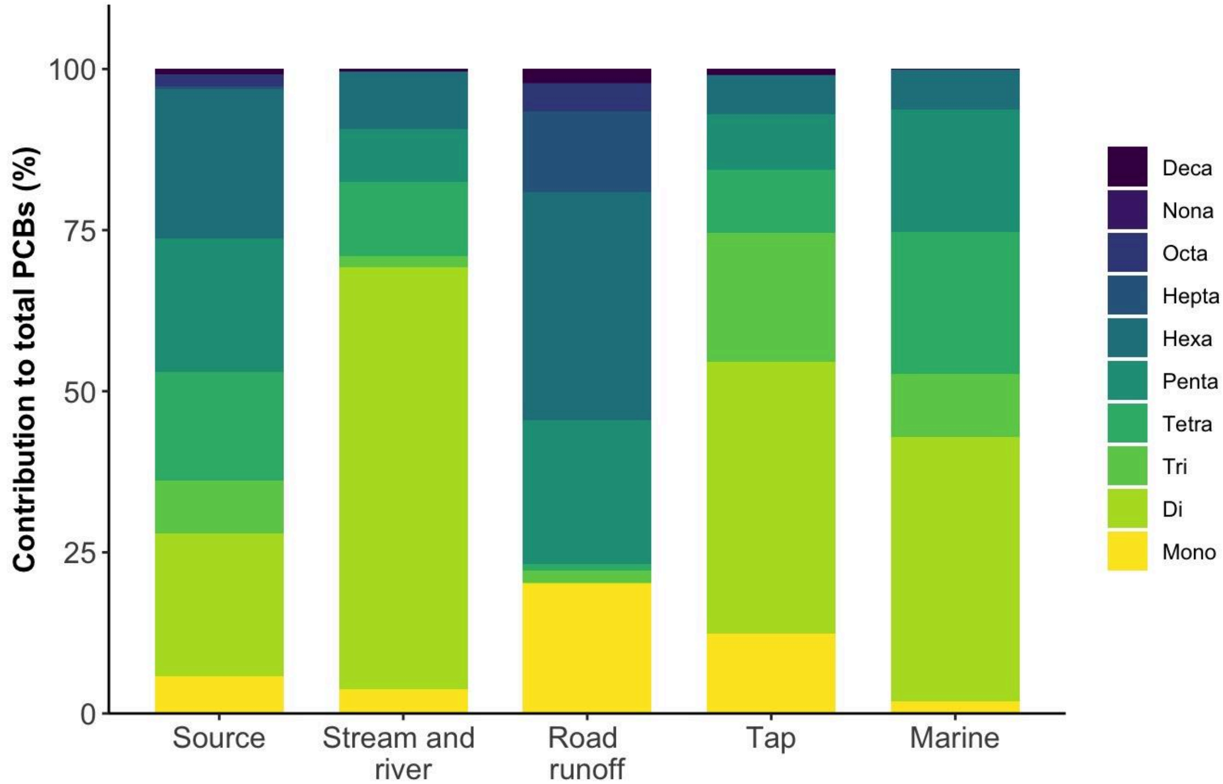
Figure 15: Total PCB concentrations in water sampled from the Anderson Creek watershed (WET season)



Total PCB levels ranged from 6.9 (stream and river) to 21.0 pg/L (marine), with an average across all water categories of 13.2 ± 2.8 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 16: Homologue group contribution to total PCBs in water sampled from the Anderson Creek watershed (WET Season)



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

Conclusions

- PCB concentrations were ranked as follows from highest to lowest: marine > tap > source > road runoff > stream and river.
- PCB concentrations ranged from 6.9 to 21.0 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.
- 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 samples collected from within the Anderson Creek watershed. The highest concentration was found in the stream and river sample, and the lowest concentration was found in the road runoff sample.

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. These surfactants can be released into the environment via municipal and industrial discharges (Lalonde et al., 2021). Once released, APEs may reside in aquatic sediments and/or undergo some breakdown into shorter chain APEs; their half-life is estimated at over 60 years (Shang et al., 1999).

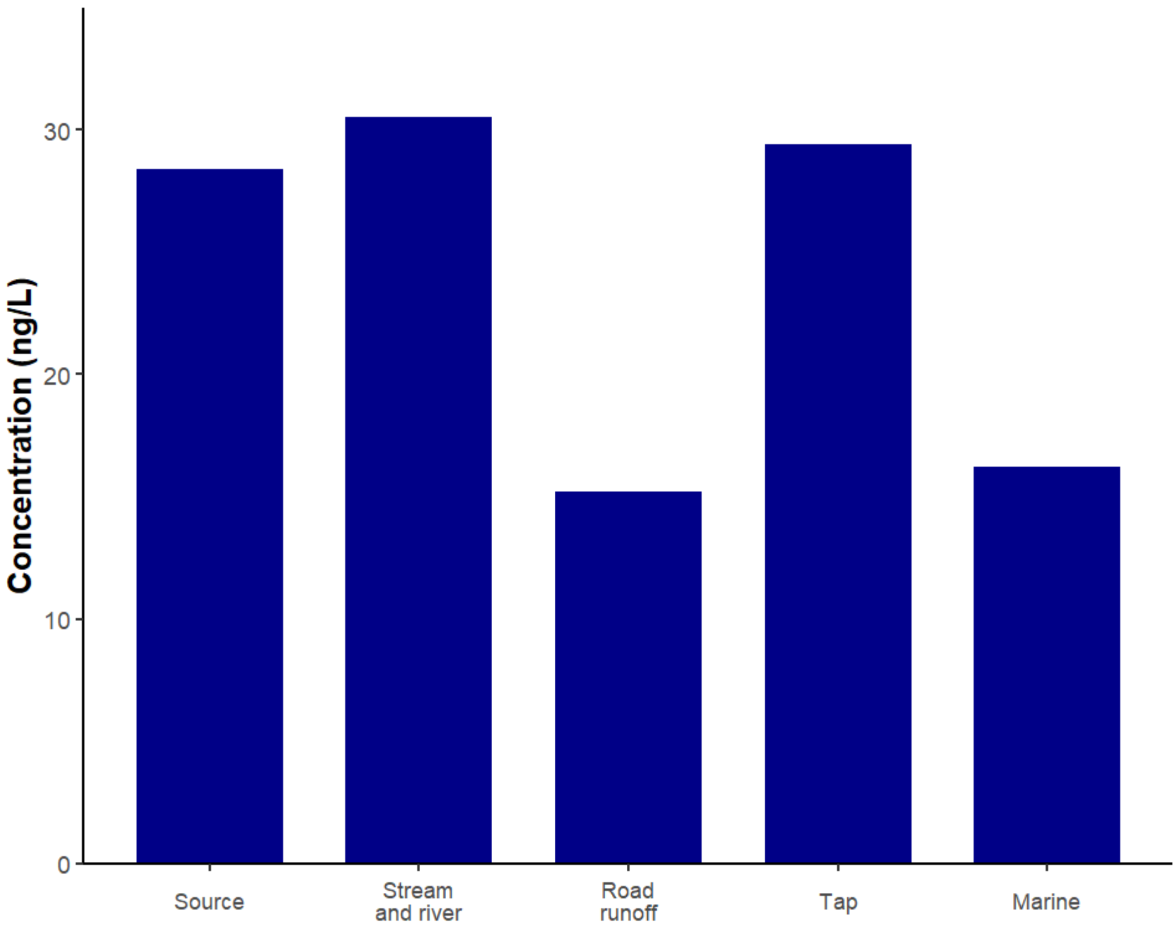
The endocrine-disrupting potential of APEs and their breakdown products in fish and wildlife has represented a concern in receiving waters around municipal wastewater treatment plants (La Guardia et al., 2001).

Results

Table 14: Alkylphenol concentration (ng/L) for six water samples from the Anderson Creek watershed (WET season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)
4-Nonylphenols	28.4	30.5	15.2	29.4	16.2
4-Nonylphenol monoethoxylates	0	0	0	0	0
4-Nonylphenol diethoxylates	0	0	0	0	0
4-n-Octylphenol	0	0	0.182	0.378	0.138
Total Alkylphenols	28.4	30.5	15.4	29.8	16.3

Figure 17: Concentrations (ng/L) of APEs detected in five water samples from the Anderson Creek watershed (WET Season)



Overall, low levels of APEs were detected in water samples from the Anderson Creek watershed. The highest concentration of APEs was found in the stream and river sample (30.5 ng/L). The second highest concentration was detected in the pooled tap water sample (29.8 ng/L). The lowest concentration was detected in the road runoff sample (15.4 ng/L).

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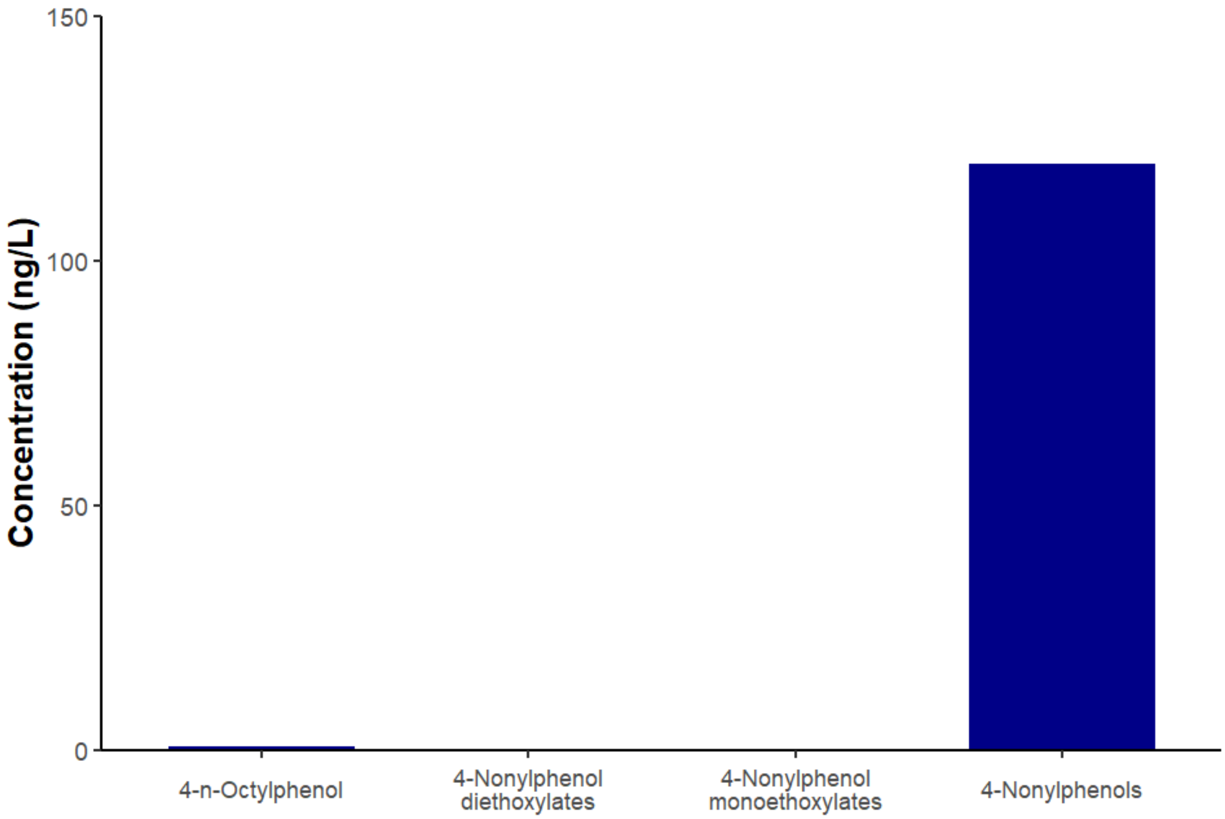
Figure 18: Concentrations (ng/L) of different APE compounds detected in five samples of water from the Anderson Creek watershed (WET Season)



4-Nonylphenol was the most commonly detected APE compound in the Anderson Creek watershed, followed by 4-n-Octylphenol.

Conclusions

- Total APE concentration for the five water samples was ranked from highest to lowest as follows: stream and river > tap > source > marine > road runoff.
- The detected concentrations in water samples from the Anderson Creek watershed in the WET season are well below the long-term CCME guideline for the protection of freshwater aquatic life for nonylphenol and its ethoxylates of 1000 ng/L.

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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 theAnderson 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 development in fish, amphibians, and mammals (Faheem and Bhandari, 2021; 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 led to exposure in the general population, and associations with adverse outcomes in humans (Rochester 2013).

Results

Table 15: Concentration (ng/L) of bisphenols in six water samples from the Anderson Creek watershed (WET season)

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

Conclusions

- As no bisphenols were measured above the analytical laboratories detection limits, we conclude that there do not appear to be discharges of these contaminants into the waterways sampled. Additional data from the dry season sampling will provide additional insight into bisphenols.

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 three out of five water samples collected within the Anderson Creek watershed. It was detected at the highest concentration in the road runoff sample, and at the lowest concentrations in the source and marine water samples.

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 (Oppenheimer et al., 2011). It is not generally considered to be toxic, such that its utility as a tracer provides an opportunity to better understand the source of other more harmful pollutants in a given body of water.

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 (van Stempvoort et al., 2020).

Results

Table 16: Sucralose concentration (ng/L) in five categories of water from the Anderson Creek watershed (WET season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)
Sucralose (ng/L)	0	17.2	250	30.1	0

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

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Conclusions

- Sucralose concentrations in water samples from highest to lowest are as follows: road runoff > tap > stream and river > source = marine.
- The highest concentration of the artificial sweetener sucralose was detected in the road runoff sample.
- There are no current Canadian Environmental Quality Guidelines available for sucralose.
- There are no current Health Canada Drinking Water Guidelines available for sucralose.

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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 three out of five water samples from the Anderson Creek watershed. Road Runoff had the highest concentration - over ten times higher than the concentration detected in the source water sample.

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 (Lo et al., 2023; Tian et al., 2021). 6PPD-quinone 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 17: 6PPD-quinone concentration (ng/L) in five categories of water from the Anderson Creek watershed (WET season)

Analyte	Source (n=1)	Stream and river (n=1)	Road runoff (n=1)	Tap (n=1)	Marine (n=1)
6PPD-q (ng/L)	0	0.06	2.37	0	0.05

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

Conclusions

- 6PPD-quinone concentrations in water samples from highest to lowest are as follows: road runoff > stream and river > marine > tap = source.
- As expected, the highest concentration of the tire-related chemical 6PPD-quinone was detected in the Road Runoff sample.

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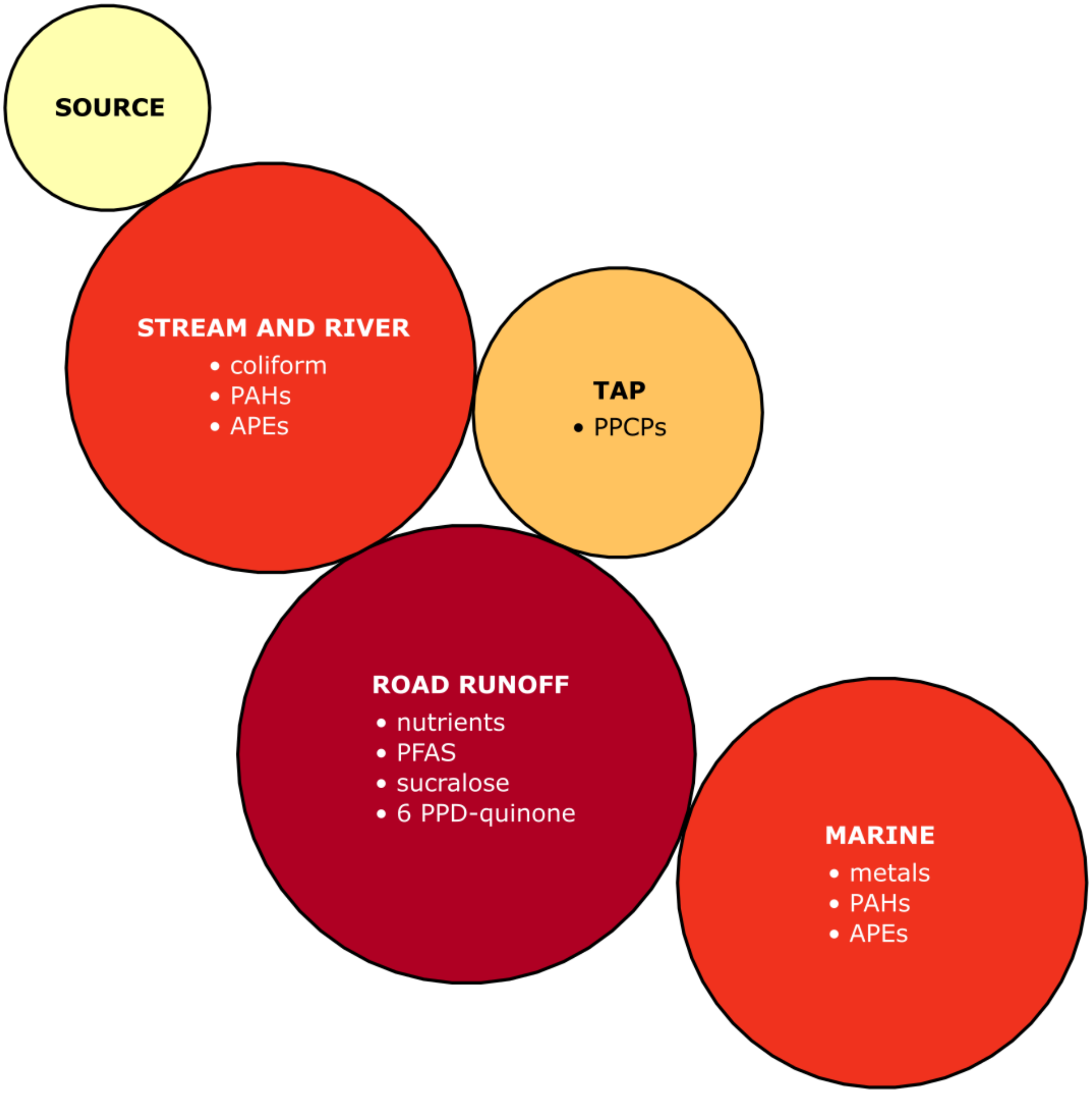
- The concentration of 6PPD-quinone detected in the Road Runoff sample is much lower than the LC50 for Coho salmon of 41 ng/L.
- There are not currently any Environmental Quality Guidelines available for 6PPD-quinone.

Wet season water quality summary

Figure 19: Preliminary snapshot: The road runoff category had the most contaminant classes with the highest concentration in the Anderson Creek watershed (WET Season)



The larger the circle, the greater the number of contaminant classes that were detected at the highest concentration. Road runoff had the highest number of contaminant classes with the highest concentration (n=4).

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This report encapsulates a single wet season water sampling event comprising pooled samples in five water categories: source water, stream & river water, road runoff, tap water, and marine water. Results suggest that Anderson Creek waters are in relatively good condition, but follow-up study is warranted to confirm or build upon initial observations of some contaminants of concern in the watershed. Collectively, these findings will provide an integrated evaluation of the contaminants, activities and sectors that are influencing water quality in the Anderson Creek watershed. This may, in turn, provide guidance on mitigation, stewardship and restoration initiatives that protect and restore fish habitat throughout the watershed.

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: 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 C(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 mg/L (long-term) >5.0 mg/L (short-term)	-	6.5-9.5 mg/L	80 mg/L	-
Conductivity	-	-	-	-	-	-
Turbidity	-	-	-	narrative	narrative	≤ 1.0 NTU
Metals (mg/L)						
Aluminum, total	-	variable	-	0.005 if pH < 6.5	-	2.9
Lead, total	-	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)						
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 2: The top 6 PCBs in each water category sampled in the Anderson Creek watershed and their concentrations (WET Season)

	Source	Stream and river	Road runoff	Tap	Marine
	PCB-7 (2.3)	PCB-7 (3.9)	PCB-2 (0.84)	PCB-7 (5.4)	PCB-7 (7.4)
	PCB-44+47+65 (0.88)	PCB-6 (0.59)	PCB-110+115 (0.79)	PCB-3 (1.4)	PCB-52 (0.99)
	PCB-110+115 (0.65)	PCB-93+95+98+100+102 (0.37)	PCB-147+149 (0.68)	PCB-8 (1.0)	PCB-110+115 (0.97)
	PCB-129+138+160+163 (0.65)	PCB-136 (0.25)	PCB-3 (0.51)	PCB-31 (0.74)	PCB-6 (0.85)
	PCB-3 (0.58)	PCB-141 (0.24)	PCB-141 (0.40)	PCB-20+28 (0.72)	PCB-61+70+74+76 (0.82)
	PCB-153+168 (0.57)	PCB-3 (0.20)	PCB-176 (0.34)	PCB-1 (0.62)	PCB-90+101+113 (0.81)
Total concentrations of top 6 (% contribution to total PCBs)	5.6 (44%)	5.5 (80%)	3.6 (49%)	9.9 (55%)	11.9 (57%)

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Appendix 3: Total analyte concentrations in water sampled in the Anderson Creek watershed (WET Season)

Analyte	Source	Stream and river	Road runoff	Tap	Marine
E. coli (MPN)	8	**36**	30	0	0
Total NO^{-3} and PO_4^{3} (mg/L)	0.141	0.179	**0.894**	0.24	0
Metals (mg/L)	18.5	13.7	38.4	27.3	**12789**
Pesticides (ng/L)	0.22	0.29	0.30	0.26	**0.36**
PCBs (pg/L)	12.8	6.9	7.2	18.0	**21.0**
PAHs (ng/L)	7.8	**34.1**	25.9	6.9	14.9
PPCPs (ng/L)	0.990	0.630	33.9	**99.3**	24.4
PFAS (ng/L)	0	0	**3.1**	1.2	0
APEs (ng/L)	28.4	**30.5**	15.4	29.8	16.3
bisphenols (ng/L)	0	0	0	0	0
Sucralose (ng/L)	0	17.2	**250**	30.1	0
6-PPDq (ng/L)	0	0.06	**2.37**	0	0.05

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

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

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