Water

Greater Vancouver Water District
2014 Quality Control Annual Report

Volume 1

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metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION

Foreword

This report has been produced to meet the requirement for water suppliers to produce an annual report on water quality as per the BC Drinking Water Protection Regulation and as described in the Water Quality Monitoring and Reporting Plan. Volume I of the annual report uses data summaries and graphics to highlight the water quality issues and Volume II provides Chemical and Physical Monitoring results (the actual data). Both Volume I and Volume II will be available on the Metro Vancouver website.

This report discusses numerous water quality parameters with potential health effects. For detailed information on drinking water health effects, the following web sites are suggested:

Health Canada:
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/index-eng.php
US EPA:
http://www.epa.gov/safewater/mcl.html
World Health Organization:
http://www.who.int/water_sanitation_health/publications/2011/dwq_guidelines/en/index.html

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1 EXECUTIVE SUMMARY

- Source Water Quality

  - In 2014, the turbidity levels of the delivered water easily met the requirements of the Guidelines for Canadian Drinking Water Quality (GCDWQ).

  - The Capilano supply was out of service for much of 2014 due to high or unstable turbidity (Capilano was in service for 119 days during the year). Capilano started the year out of service and remained that way until May 28th. On September 23rd, the turbidity of Capilano started to increase and the source was removed from service and remained out of service for the rest of the year. During the time this source was in service in 2014, the turbidity of Capilano water did not exceed 1 NTU.

  - The Seymour supply was in service for the entire year and Seymour water was treated at the Seymour Capilano Filtration Plant (SCFP) before delivery. Water entering the GVWD transmission system from the SCFP had turbidity of mostly <0.1 Nephelometric Turbidity Unit (NTU) for the entire year. For water entering the SCFP, turbidity was generally less than 1 NTU throughout the year except during the heavy rainfall events in late October to December that resulted in source water turbidity peaking at 18 NTUs. Even with the higher turbidity the delivered filtered Seymour water was mostly less than 0.1 NTU.

  - The Coquitlam supply was in service for the entire year. The average daily turbidity of the Coquitlam source (this source is not filtered) was over 1 NTU for sixteen days and there were no days in 2014 when the average turbidity was over 5 NTU. Water treatment levels were increased during periods of higher turbidity in accordance with operating protocols.

  - The microbiological quality of the three source waters was good in 2014. The levels of bacteria and protozoa detected were low and indicative of high quality source water. All three sources easily met the bacteriological requirements for avoiding filtration outlined in the Turbidity section of the 2012 Guidelines for Canadian Drinking Water Quality.

  - Results of the analyses of the source water for herbicides, pesticides, and volatile organic compounds and radionuclides were all found to be below the recommended limits for these substances as listed in the Guidelines for Canadian Drinking Water Quality.

- Water Treatment

  - There was no loss of primary disinfection (chlorination) for the Capilano water source in 2014.

  - UV treatment at the Coquitlam Water Treatment Plant was completed and opened on June 10th, 2014. UV became the primary treatment for Coquitlam source, allowing it to meet the log reduction requirements as specified in the GVWD's operating permit.

  - The Seymour-Capilano Filtration Plant provided full filtration and the plant performance, as measured by the quality of the delivered water, was good in 2014. The daily average turbidity of water leaving the clearwells to enter the GVWD transmission system was less than 0.06NTU in 2014.

  - Turbidity levels for individual filters met the turbidity requirements of the GCDWQ except for one minor incident in Nov 2014.

  - Filtration consistently removed iron, colour and organics from Seymour source water.

- Levels of total aluminum in filtered water were consistently below the Guidelines for Canadian Drinking Water Quality operational guideline value of 0.2 mg/L for direct filtration plants using aluminum-based coagulants. The maximum value for 2014 was 0.06 mg/L.

- The secondary disinfection stations that receive filtered water were seldom required to boost chlorine as a result of the reduced chlorine demand of filtered water. Secondary disinfection stations receiving water from either the Capilano source (when it was in operation) or the Coquitlam source (both of these sources are unfiltered) routinely operated to boost chlorine levels and operated well.

- Distribution System Water Quality

  - Bacteriological water quality was good in the GVWD transmission mains. One sample was positive for *E. coli* in 2014. When an *E. coli* is detected, a response protocol is triggered, which includes an evaluation and repeat sampling. This process was implemented for all samples in 2014 that were *E. coli* positive and in all cases the sample was determined to be anomalous and not related to the safety of the water.

  - Bacteriological water quality was good in the GVWD in-system storage reservoirs. There was no *E. coli* detected in any of the samples collected.

  - Bacteriological water quality was good in the distribution systems of the member municipalities. Of approximately 20,000 municipal samples collected for testing in 2014 a high percentage (99.9%) were free of total coliforms which was similar to 2013 (99.9%). In 2014, two *E. coli* positive samples were detected.

  - The running average levels of the trihalomethane group of chlorine disinfection by-products detected in the delivered water in the GVWD and municipal systems were well below the Maximum Acceptable Concentration (MAC) in the GCDWQ of 100μg/L (0.1 mg/L). The running average levels for the haloacetic acid group of chlorine disinfection by-products were below the GCDWQ MAC of 80μg/L (0.08 mg/L).

2 ACRONYMS

AO	Aesthetic Objective (characteristics such as taste, colour, appearance, temperature that are not health related)
BCDWPR	British Columbia Drinking Water Protection Regulation
BTEX	Benzene, Ethylbenzene, Toluene, Xylene
CALA	Canadian Association for Laboratory Accreditation
CFE	Combined Filter Effluent
CFU	Colony Forming Units
D.S.	Distribution System
DBP	Disinfection By-product
DOC	Dissolved Organic Carbon
DWTP	Drinking Water Treatment Program
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency (USA)
ESWTR	Enhanced Surface Water Treatment Rule (USA)
GCDWQ	Guidelines for Canadian Drinking Water Quality
GVWD	Greater Vancouver Water District
HAA	Haloacetic Acid
HPC	Heterotrophic Plate Count
IFE	Individual Filter Effluent
IMAC	Interim Maximum Acceptable Concentration
MAC	Maximum Acceptable Concentration
MCL	Maximum Contaminant Level
MDA	Minimum Detectable Activity
MDL	Method Detection Limit
mg/L	Milligram per litre (0.001 g/L)
μg/L	Microgram per litre (0.000001 g/L)
mL	Milliliter
MF	Membrane Filtration
mJ/cm^2	Millijoule per centimeter squared
MPN	Most Probable Number
MV	Metro Vancouver
N/A	Not Available
NTU	Nephelometric Turbidity Unit
PAH	Polynuclear Aromatic Hydrocarbon
pH	Measure of acidity or basicity of water; pH 7 is neutral
ppb	Parts per Billion (Equivalent of microgram per litre)
ppm	Parts per Million (Equivalent of milligram per litre)
RCW	Recycled Clarified Water
SCADA	Supervisory Control and Data Acquisition
SCFP	Seymour-Capilano Filtration Plant
T.S.	Transmission System
$THAA_5$	Total $Haloacetic_5$ Acids
THM	Trihalomethane
TOC	Total Organic Carbon
TTHM	Total Trihalomethane
UV_{254}	Ultraviolet Absorbance at 254 nm
WHO	World Health Organization
WQMRP	Water Quality Monitoring and Reporting Plan

3 WATER SAMPLING AND TESTING PROGRAM

Water Type	Parameter	Frequency
Untreated, source water	Total coliform and *E. coli*	Daily
	Turbidity	Daily
	Giardia and *Cryptosporidium*	Monthly at Capilano and Coquitlam
	Ammonia, colour, iron, organic carbon, pH	Weekly
	Alkalinity, chloride, calcium, hardness, magnesium, manganese, nitrate, nitrite, potassium, phosphate, sulphate	Monthly
	Aluminum, copper, sodium, total and suspended solids	Bi-monthly
	Trihalomethanes, haloacetic acids	Quarterly
	Antimony, arsenic, barium, boron, cadmium, cyanide, chromium, lead, mercury, nickel, phenols, selenium, silver, zinc	Semi-annually
	Pesticides and herbicides	Annually
	PAHs, BTEXs	Annually
	VOC	Annually
	Radioisotopes	Annually
Treated water	Total coliform and *E. coli*	Daily
	Turbidity	Daily
	Ammonia, colour, iron, organic carbon, pH, aluminum at SCFP	Weekly
	Aluminum, copper, sodium, total and suspended solids	Bi-monthly
	Trihalomethanes, haloacetic acids	Quarterly
	Antimony, arsenic, barium, boron, cadmium, cyanide, chromium, lead, mercury, nickel, phenols, selenium, silver, zinc	Semi-annually
Metro Vancouver Water Mains	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
	Trihalomethanes, haloacetic acids, pH	Quarterly at selected sites
	PAHs, BTEXs	Semi-annually at selected sites
Metro Vancouver Reservoirs	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
Municipal Distribution system sites	Total coliform and *E. coli*	Weekly per site
	Heterotrophic plate count	Weekly per site
	Free chlorine	Weekly per site
	Turbidity	Weekly per site
	Trihalomethanes, haloacetic acids, pH	Quarterly at selected sites

4 SOURCE WATER QUALITY

The first barrier in place to protect the quality of the drinking water supply is the protection of the watershed to ensure the best quality source water. Source water monitoring provides ongoing confirmation that the barrier is effective, identifies seasonal changes and provides the monitoring information necessary to adjust the level of water treatment that is in place. Regular monitoring of the water sources is also a requirement of the Water Quality Monitoring and Reporting Plan (WQMRP).

4.1 BACTERIOLOGICAL QUALITY OF THE SOURCE WATER

The bacteriological quality of the source water is an important indicator of the degree of contamination, and the treatment required to ensure a safe water supply. The Canadian Guideline for Turbidity (October 2003) stipulates bacteriological quality of the source water in its criteria for avoiding filtration as follows: Prior to the point where the disinfectant is applied, the number of *Escherichia coli (E. coli)* bacteria in the source water can exceed 20/100 mL (or, if *E. coli* data are not available, the number of total coliform bacteria can exceed 100/100 mL) in not more than 10% of the weekly samples from the previous 6 months.

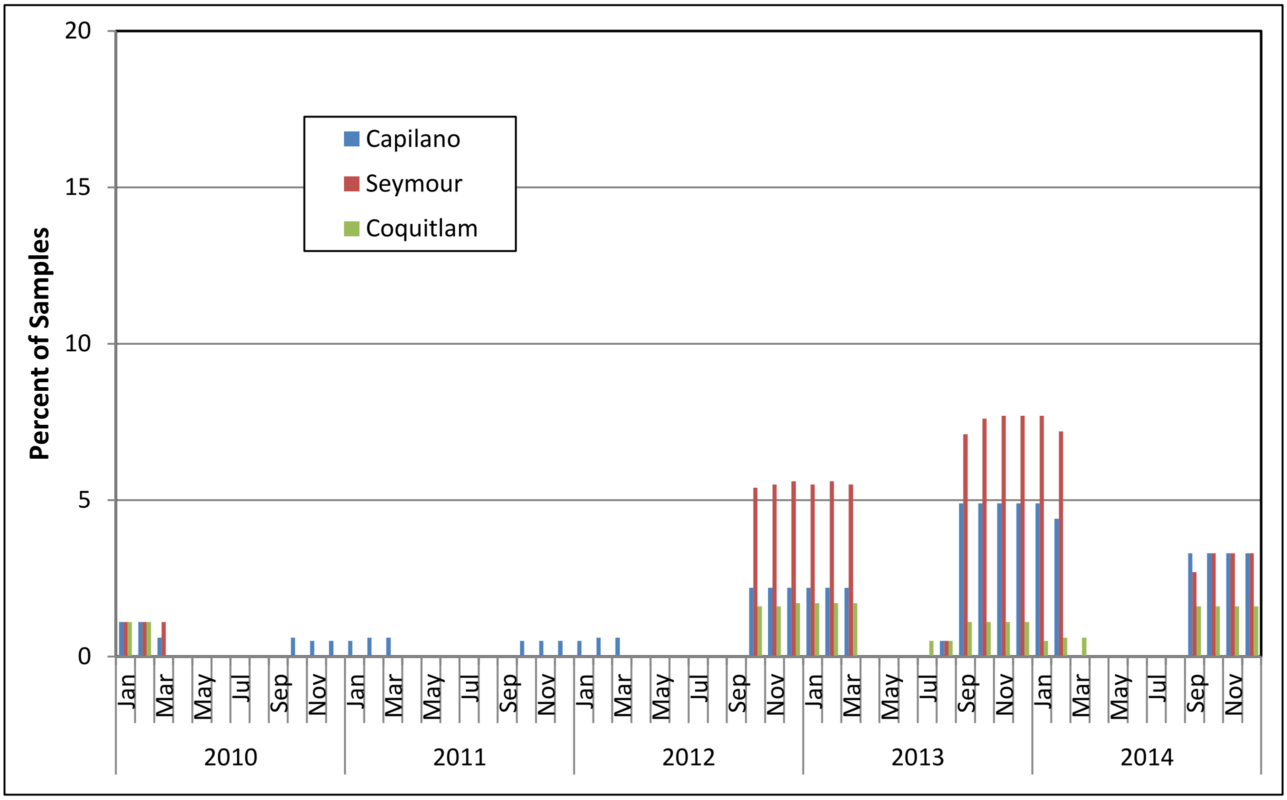
Table 1 below summarizes *E. coli* data for all three Metro Vancouver water sources and indicates that levels of *E. coli* for all three sources were well below the 10% limit in the turbidity guideline.

Table 1: Percent of samples in six months (current month plus five previous months) where number of *E. coli* /100 mL exceeded 20

	Capilano	Seymour	Coquitlam
Jan	4.9	7.7	0.5
Feb	4.4	7.2	0.6
Mar	0	0	0.6
Apr	0	0	0
May	0	0	0
Jun	0	0	0
Jul	0	0	0
Aug	0	0	0
Sep	3.3	2.7	1.6
Oct	3.3	3.3	1.6
Nov	3.3	3.3	1.6
Dec	3.3	3.3	1.6

Figure 1 shows the results of the analysis of the source water from 2010 to 2014 at all three intakes compared to the limits for source water bacterial levels in the 2003 turbidity guideline. As in the previous years, all three sources easily met the limit of not more than 10% exceeding 20 *E. coli*/100 mL. As was also the case in previous years, samples collected at the intakes in the fall and winter had the highest *E. coli* levels. These *E. coli* can be traced back to high levels at the main tributaries of the supply lakes and a first flush phenomenon after a period of dry weather.

Figure 1: **Percent of samples exceeding 20 *E. coli*/100 mL at all three sources**



Because of the protection of the watersheds from human sources of fecal waste, it is most likely that animals are the source of the *E. coli* detected in the watersheds.

4.2 SOURCE WATER MONITORING FOR *GIARDIA* AND *CRYPTOSPORIDIUM*

Unfiltered surface water supplies have the potential of containing the protozoan pathogens *Giardia* and *Cryptosporidium*. Outbreaks of Giardiasis occurred in a number of locations in B.C. and Washington State in the late 1980s, and the District has been monitoring raw water and animal droppings for *Giardia* since 1987. Since 1992, Metro Vancouver has participated in a project with the Enhanced Water Testing Laboratory, University of British Columbia, to gather more information about the number and nature of the cysts found in the Greater Vancouver water supplies. The project involves collecting samples from the Capilano and Coquitlam supplies upstream of disinfection. Routine monitoring of Seymour source water was discontinued in 2011 because water treatment at the SCFP meets the disinfection requirements for both *Giardia* and *Cryptosporidium* in the GCDWQ. At the SCFP, monitoring for *Giardia* and *Cryptosporidium* has focused on the recycled water returning to the head of the plant and this monitoring has confirmed that the procedures in place effectively control the levels of *Giardia* and *Cryptosporidium* in the recycled wash water from the filters.

The results of the 2014 testing program are contained in the "Report to Metro Vancouver - *Giardia* and *Cryptosporidium* Study January - December, 2014" which was prepared by the BC Public Health Microbiology & Reference Laboratories, Environmental Microbiology, and can be found in

Appendix 3. Two of 12 (18%) samples collected at Capilano and 1 of 12 (8%) at Coquitlam were positive for *Giardia* (Table 2). As discussed in the previous paragraph Seymour samples for 2014 are all process control samples and not Seymour source water as they were prior to 2011 (shown as N/A in the table).

Table 2: Percentage of Water Samples Positive for Giardia

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Capilano	20	52	64	52	49	73	50	75	50	18
Seymour	8	26	29	14	24	47	N/A	N/A	N/A	N/A
Coquitlam	9	19	27	54	27	53	51	50	23	8

One of 11 (9%) samples collected at Capilano were positive for *Cryptosporidium*, 0 of 12 (0%) were positive at Coquitlam. As discussed in the section on Giardia above, Seymour samples for 2014 are all process control samples and not Seymour source water as they were prior to 2011 (shown as N/A in the table). Table 3 shows a comparison of *Cryptosporidium* levels in our water supplies for Capilano and Coquitlam from 2005 through 2014 and Seymour source water from 2005 to 2010.

Table 3: Percentage of Water Samples Positive for Cryptosporidium

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Capilano	2	20	19	18	10	12	6	16	9	9
Seymour	2	3	0	2	0	0	N/A	N/A	N/A	N/A
Coquitlam	7	0	2	0	2	2	3	8	9	0

Year to year fluctuations are demonstrated for *Giardia* by Capilano (50% positive in 2013 and 18% positive in 2014) and for *Cryptosporidium* by Coquitlam (9% positive in 2013 and 0% positive in 2014). There has always been considerable variation in the results from year to year.

4.3 TURBIDITY

MV water sources have historically been susceptible to turbidity upsets due to high runoff from storms which can cause slides and stream scouring in the watersheds or from re-suspension of sediment from the edges of the lakes during periods of low water levels. Health Canada published a turbidity guideline in 2003 which recommends filtration for all surface water supplies but the guideline has a provision for exemption from this requirement for filtration if a source meets certain criteria including a turbidity provision. The 2003 guideline allows a utility to avoid filtration if the turbidity does not exceed the requirements (see next paragraph) and provided that a number of other provisions including source water protection and water treatment requirements are in place. Historically the turbidity levels on both the Capilano and Seymour sources would not meet these criteria therefore plans were developed to filter both supplies. Filtration of 100% of the Seymour supply began on January 15, 2010 and filtration of the Capilano supply will begin in spring 2015, once the twin tunnel project is complete.

Section 3.3 of the 2003 Guidelines for Canadian Drinking Water Quality Supporting Documentation titled "Turbidity, Criteria for Exclusion of Filtration in Waterworks Systems" contains the following requirement for the turbidity: "Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are around 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period." In the GVWD, the turbidity of source water is monitored upstream of disinfection using an in-line turbidity meter. The data is captured as 10 minute averages and is stored in the Supervisory Control and Data

Acquisition (SCADA) system. These 10-minute average data points (144/day) have been averaged to produce a daily average turbidity which is shown in Figure 2.

Until the Capilano supply is filtered in 2015, MV's turbidity response protocol focuses on minimizing the amount of water with turbidity greater than 1 NTU entering the system. Following this protocol, the Capilano source was out of service for the first five months of 2014, was taken out of service on September 23rd, 2014 and stayed out of service for the remainder of the year. As a result of these actions, no Capilano source water was delivered that had a turbidity that exceeded 1 NTU at any time during 2014.

Figure 2: 2014 Average Daily Turbidity of Source Water (from In-Line Readings)

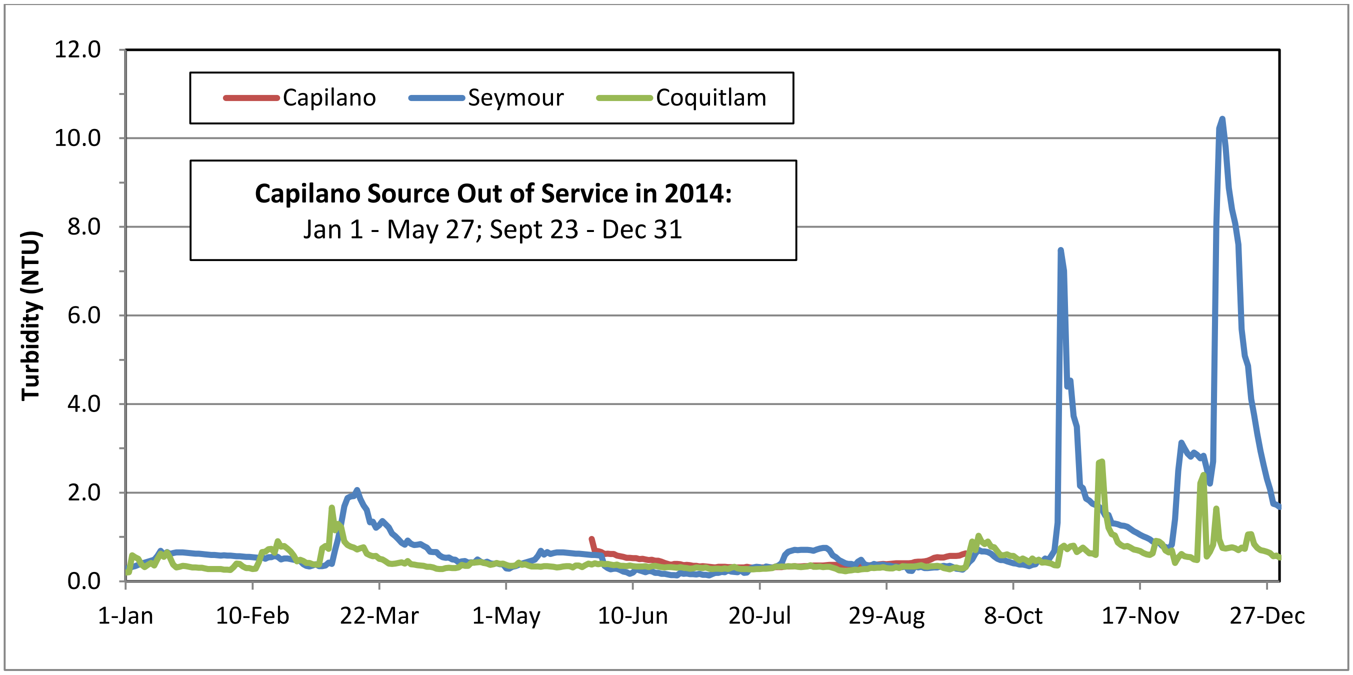


Table 4: Delivered Water Turbidity Summaries (Non Filtered Sources) 2014

Source	Percent of Days with Average Daily Turbidity >1 NTU	Number of Days with Average Daily Turbidity >5 NTU
Capilano *	0	0
Seymour**	N/A	N/A
Coquitlam***	4.4	0

*Capilano was in service for 119 days in 2014.
**Seymour was in service for all of 2014, 100% of Seymour water was filtered so these source water criteria don't apply to the delivered water.
*** Coquitlam was in service for all of 2014.

4.4 CHEMISTRY

4.4.1 Chemical and Physical Characteristics of the Source Water

The chemical and physical characteristics of the Metro Vancouver source water are summarized in Appendix 1 of this report; detailed analytical results are provided in Volume II. The results from the chemical and physical analyses of the source water in 2014 were similar to those for other years.

4.4.2 Herbicides, Pesticides, Volatile Organic Compounds, Radioactivity, and Uranium

Analyses of the source water for a variety of organic compounds including all the compounds with Maximum Acceptable Concentrations (MACs) in the Guidelines for Canadian Drinking Water Quality is usually carried out on annual basis in accordance with the WQMRP. The results are contained in Appendix 2 of this report and in Volume II of the QC Annual Report. One constituent was detectable in the Seymour, Capilano and Coquitlam sources and it was below the applicable Canadian Guideline health based limits (MAC); these levels are indicative of erosion of natural deposits, meaning the contribution to total radiation exposure from our drinking water is small, and typical of most areas.

4.5 LIMNOLOGY

The Reservoir Water Quality Monitoring Program started in 2014 as a sampling and analysis structure for the limnology (chemical, physical and biological parameters) of the Capilano, Seymour and Coquitlam Reservoirs. Reservoir monitoring information is important in proactively managing our reservoirs as water quality could be impacted by environmental variability and climate change. This program will assist in ensuring that trends and possible changes are tracked with scientific data.

Water sampling of the source reservoirs is conducted between April and November of each year when biological productivity is highest. The Reservoir Monitoring Program will provide important baseline data for future management decisions. Analysis and interpretation of the program data is underway and findings will be included in future annual reports.

5 QUALITY CONTROL ASSESSMENT OF WATER TREATMENT

Water treatment is the second barrier (after source protection) used to assure the quality of the water supply.

5.1 PRIMARY DISINFECTION OF CAPILANO SOURCE

Primary disinfection is the treatment of the source water to destroy disease-causing or pathogenic microorganisms. Metro Vancouver uses the strong oxidizing agent, chlorine, for primary disinfection of the Capilano source. The dosage required for disinfection is based on a number of factors, including the temperature and pH of the water. Disinfection also requires contact time of the oxidant with water to provide adequate disinfection.

Table 5 provides information on the disinfection process at the Capilano source. On the days it was in service, the performance of the Capilano primary disinfection (chlorination) facilities was at 100%.

Table 5: Performance of Capilano Primary Disinfection Facilities

Facility	Performance	Discussion
Capilano Chlorination	The average of residual chlorine concentration was ≥ 1.20 mg/L while this source was in service.	The Capilano facility was in service for 119 days (May 28 to Sept 23).

5.2 SEYMOUR-CAPILANO FILTRATION PLANT

The Seymour-Capilano Filtration Plant (SCFP) is a chemically assisted direct filtration plant which uses alum or poly aluminum chloride (PACl) as a coagulant with polymers to improve particle removal. These substances help aggregate particles to form a visible floc. The flocculated particles are removed by passing this water through a filter medium of anthracite and sand. The result is the production of filtered water which is then exposed to UV light as the water leaves the filter. Post UV filtered water has sodium hypochlorite (chlorine) and lime added before the water enters the Clearwells. The West and East Clearwells are large water storage reservoirs that store and allow controlled passage of water with some mixing or blending of the lime and chlorine that have been added. Clearwells allow sufficient retention or contact time with chlorine to provide any further disinfection required after filtration and UV. Carbon dioxide in solution may be added to trim pH. After stabilization of the filtered water in the Clearwells, the finished water is ready to enter the transmission system at the Seymour Treated Water Valve Chamber.

SCFP has been operational since December 2009 and the quality of the water produced has been excellent, improving year after year.

5.2.1 Filtration

As a result of treatment now in place on the Seymour water source there have been a number of changes in the characteristics of the delivered water. Some of these changes are visible, some not. The most obvious visible change in the water is the decrease in colour and increase in the clarity. There is a total loss of the brown hue that is characteristic of Seymour water before filtration. This change in colour is because the natural components that cause the brown hue are removed in the filtration process. Suspended particles in water that cause light to scatter (turbidity) are also removed. The end product is water that is very clear. Due to the purity of the water it may have a slight bluish colour.

Figure 3 is a graph of the apparent colour of Seymour filtered water and Seymour source water for 2014. In late fall of 2014 the apparent colour of the Seymour source water that was feeding the filtration plant looked brown and exceeded 35 ACU; after the removal of its natural brown colours through filtration, the colour of the filtered water that was delivered to the public was never greater than 3 ACU.

Figure 3: Apparent Colour Levels Before and After Filtration 2014

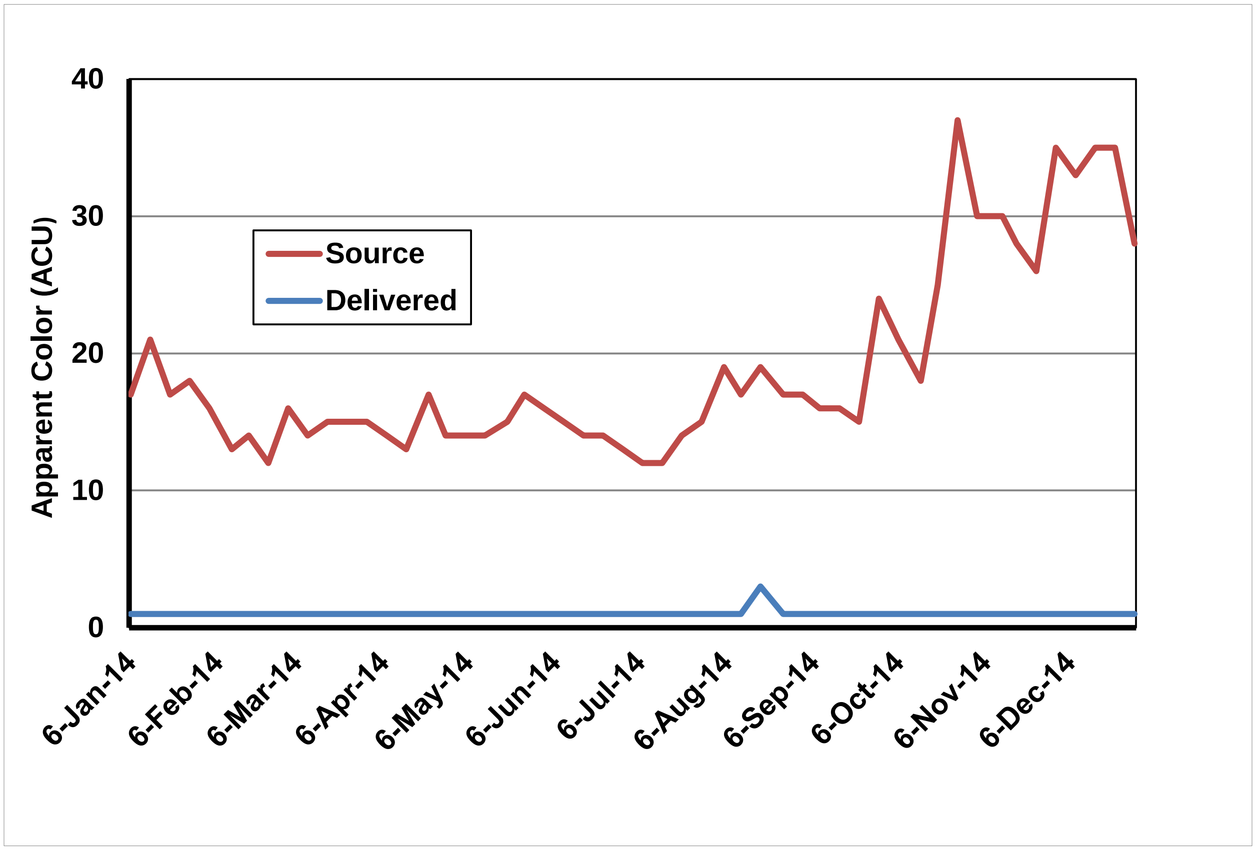
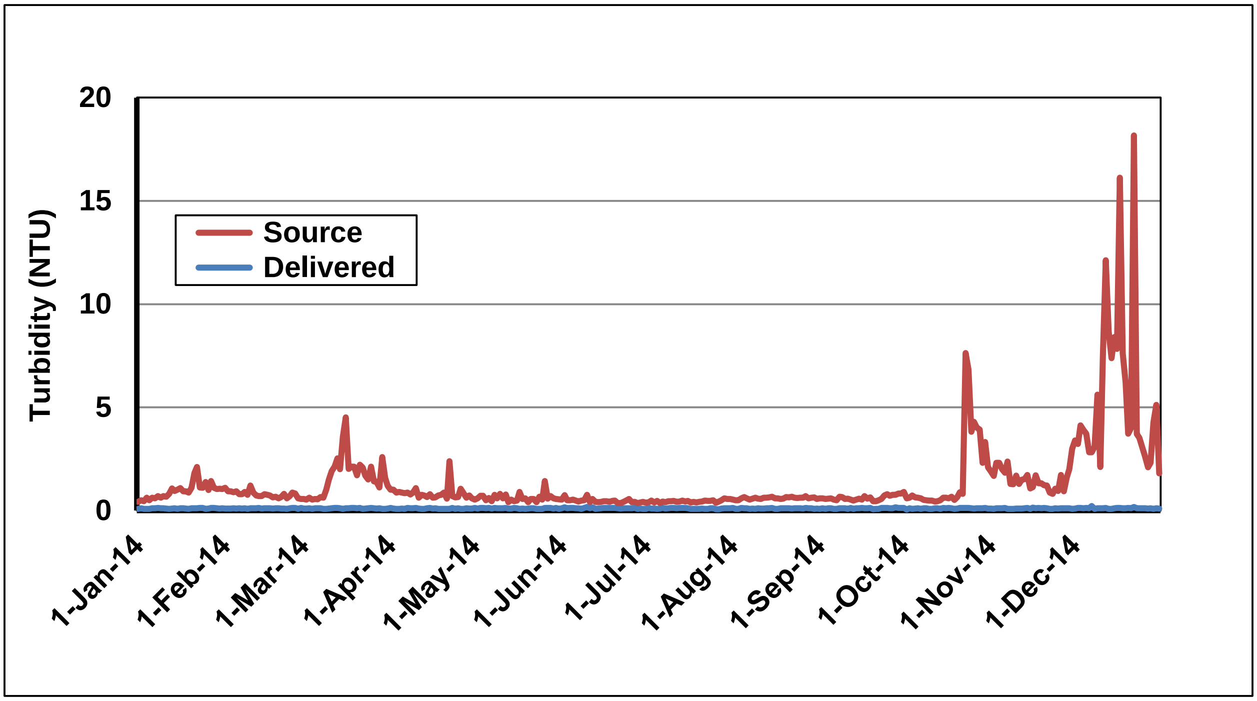


Figure 4 compares turbidity of source water that feeds the filtration plant to the turbidity level of the finished filtered water for 2014. Without filtration the Seymour source would have delivered water with an average daily turbidity greater than 1 NTU for 80 days and turbidity > 10 NTU (visible as cloudy water) on a number of occasions during the year. With filtration, the maximum average daily turbidity of the delivered water was 0.08 NTU and the average was 0.06 NTU.

Figure 4: Average Daily Turbidity Levels Before and After Filtration 2014



Removal of turbidity in the source water improves the appearance of the water but it also has the benefit of removing certain types of pathogenic microorganisms that may be present in source water. At a minimum, properly run direct filtration plants such as SCFP will remove up to 2.5 log (one log is a 90% reduction) of *Cryptosporidium* and *Giardia* plus 1 log of viruses. To ensure this removal it is critical that the performance of each filter, determined by the turbidity of its effluent, is monitored on a continuous basis.

The GCDWQ (2012) states, "Where possible, filtration systems should be designed and operated to reduce turbidity levels as low as possible with a treated water turbidity target of less than 0.1 NTU at all times." If <0.1 NTU is not achievable, the treated water turbidity levels from individual filters (Individual Filter Effluent IFE):

> "for chemically-assisted filtration, shall be less than or equal to 0.3 NTU in at least 95% of the measurements made, or at least 95% of the time for each calendar month, and shall not exceed 1.0 NTU at any time."

Ideally the turbidity from each individual filter would never exceed 0.1 NTU; however, there are rare occurrences of turbidity readings that exceed the ideal level. The turbidity performance of all twenty-four filters was measured by examining the percent of time that the turbidity of each individual filter effluent (IFE) met the turbidity guidelines of not greater than 1.0 NTU and at least 95% of time less than 0.3 NTU (Table 6).

Table 6: Monthly Filter Effluent Turbidity Summary

Month	Incident of IFE Turbidity Greater than 1.0 NTU None allowed	Percent of Time IFE Turbidity Less than 0.3 NTU Minimum 95% allowed
Jan.	0	99.999%
Feb.	0	100%
Mar.	0	100%
Apr.	0	100%
May	0	100%
Jun.	0	100%
Jul.	0	100%
Aug.	0	100%
Sep.	0	100%
Oct.	0	99.999%
Nov.	1	99.999%
Dec.	0	99.999%

A water treatment facility such as SCFP should be able to produce a filter effluent that is less than 0.1 NTU. Under normal operating conditions the turbidity of the filtered water at SCFP is less than 0.08 NTU.

In 2014 there was one event when the IFE turbidity reading was greater than 1 NTU. This occurred on November 29 when SCFP experienced breakthrough on an individual filter. The individual filter effluent (IFE) turbidity on one filter rose above 1 NTU for 3 minutes and 49 seconds to a maximum turbidity of 2.002 NTU. Investigation of the cause determined that an instrument had frozen in the cold weather.

The incident was caused when condensation inside the level instrument froze creating a false high water level signal. Thinking the filter was too full, the system automatically opened the filter flow control valve quickly. This rapid opening, combined with the cold temperatures at the time caused the breakthrough to occur. UV treatment directly follows filtration and the UV reactor on this filter was operating throughout this event and increased UV dosage automatically in response to the increased turbidity. In addition, chlorination occurs in the clearwells which is downstream of filtration and UV. The turbidity of the water entering the distribution system only increased slightly from 0.06 to 0.08 NTU after this event. It is important to note that 99.999% of the water produced in November at SCFP met the 3 log Giardia and 3 log Cryptosporidium removal/inactivation requirement (99.9% removal).

5.2.2 Ultraviolet Treatment

The effluent from each filter is treated with UV as the water exits the filter. UV treatment is effective in altering the DNA structure of *Cryptosporidium* and *Giardia* thus rendering oocysts and cysts of these parasites non-infectious. Other disinfectants, especially chlorine, are ineffective against Cryptosporidia oocysts. In the unlikely event of a breakthrough of Cryptosporidia oocysts, especially at the end of a filter run, UV light is present to render any potentially present parasites non-infectious. Oocysts are not able to proliferate inside the intestines of human hosts to cause illness after a sufficient dose of UV light. The target dose for UV to achieve 2 Log (99%) of *Cryptosporidium* and *Giardia* inactivation is 21mJ/cm2.

Under normal operating conditions two rows of lamps operating at 75% power provides enough UV to meet the dosage requirement for 2 log reduction of *Cryptosporidium* and *Giardia*.

Note that with the Coquitlam UV plant coming on line we changed our method of monitoring the dosage for consistency between the two plants. We started the year measuring the percent of time the UV was greater than or equal to 21 mJ/cm2 and then changed in May to monitor the percent of monthly volume (of water produced) when the UV dosage was greater than or equal to 2 log *Giardia* and *Cryptosporidium* inactivation.

Table 7 summarizes the performance of the SCFP UV system in 2014. Note that with the Coquitlam UV plant coming on line we changed our method of monitoring the dosage for consistency between the two plants. We started the year measuring the percent of time the UV was greater than or equal to 21 mJ/cm2 and then changed in May to monitor the percent of monthly volume (of water produced) when the UV dosage was greater than or equal to 2 log *Giardia* and *Cryptosporidium* inactivation.

Table 7: Percent of Time/Volume UV Dosage Met Requirements

Month	Percent of Time UV ≥ 21 mJ/cm^2	Percent of Monthly Volume UV ≥ 2 log Giardia Inactivation
Jan.	99.978	-
Feb.	100.000	-
Mar.	99.998	-
Apr.	99.998	-
May	-	99.989
Jun.	-	99.887
Jul.	-	99.668
Aug.	-	99.977
Sep.	-	99.994
Oct.	-	99.987
Nov.	-	99.982
Dec.	-	99.971

Note: Monitoring method changed in May to match Coquitlam UV.

5.3 COQUITLAM WATER TREATMENT PLANT

Construction of the Coquitlam Ultraviolet (UV) Disinfection facility began in spring 2011. This facility began commissioning in May 2014 but full operation and transfer of ownership to the GVWD did not officially occur until June 10, 2014. The Coquitlam UV facility provides for primary disinfection capability (3-log reduction) of *Cryptosporidium* and *Giardia*. Ozonation provides pre-treatment, and chlorination is used for secondary disinfection at the source as well as at secondary disinfection stations servicing Coquitlam water, to minimize bacterial regrowth in the distribution system. Ozonation and chlorination each provide 4-log virus inactivation. Soda ash is added for pH and alkalinity adjustment to combat corrosion.

Ozone helps remove micro-organisms from the water, reduces disinfection by-products and improves water clarity, which increases the efficiency of the subsequent UV process. The water is directed into eight ultraviolet units, each containing 40 ultraviolet lamps encased in protective sleeves. As water flows through the units, UV light emitted from the lamps passes through the water, and aids in achieving 3-log inactivation of chlorine-resistant micro-organisms, such as *Cryptosporidium* and *Giardia*. The US EPA requires that the UV disinfection process results in target *Cryptosporidium* and *Giardia* inactivation in at least 95% of the treated water volume on a monthly basis (the US EPA standard is used because there isn't a similar Canadian standard).

Table 8 provides an assessment of the disinfection process at the Coquitlam source.

Table 8: Performance of Coquitlam Primary Disinfection Facilities

Facility	Performance	Discussion
Ozonation	In operation 99.9% of time	Reasons for ozone loss in 2014 include power interruptions, high ambient ozone spikes (room sensors for worker safety), and software updates. As the UV facility took over the primary disinfection on June 10th, the role of ozone was changed to pretreatment, enhancing the removal of organics.
Ultra Violet	Since June 10th (official opening date), 99.7 % of volume on spec	UV performance met US EPA requirements. (95% of monthly volume required)
Chlorination	This facility provides secondary disinfection most of the time but during ozone outages it is used for primary disinfection. The chlorine residual was > 1.0 mg/L 100% of the time when the facility was used for primary disinfection.	When Coquitlam Chlorination was used as primary disinfection facility, Cl_2 residual was increased by 0.2 mg/L to partially offset the loss of ozonation.

Table 9 summarizes the performance of the COQ UV system in 2014. No values are included for January to May as the UV plant was not officially operating during this time.

Table 9: Percent of Time/Volume UV Dosage Met Requirements

Month	Percent of Monthly Volume UV ≥ 3 log Giardia Inactivation Minimum 95% Required
Jan.	-
Feb.	-
Mar.	-
Apr.	-
May	-
Jun.	99.836%
Jul.	99.344%
Aug.	99.864%
Sep.	99.537%
Oct.	99.823%
Nov.	99.752%
Dec.	99.627%

5.4 SECONDARY DISINFECTION

There are eight secondary disinfection stations operated by Metro Vancouver. The purpose of these stations is to increase the chlorine residual in the water flowing through the stations to meet a target residual based on a number of factors including source water turbidity, the amount of bacterial regrowth detected in the municipal distribution system samples and the chlorine demand in the water. Prior to 2010, under usual water conditions, the target average residual was 1 mg/L for water leaving Rice Lake (location near SCFP). With filtered water, the rate of chlorine decay has been reduced to a level that the amount of chlorine required to maintain a residual in the distribution system is significantly lower. This has allowed reduction of the target chlorine dose leaving the secondary facilities (receiving filtered water) to between 0.6 to 0.8 mg/L. The secondary disinfection stations receiving the filtered water rarely have an incoming chlorine residual low enough to require boosting, thus the amount of sodium hypochlorite being used at these stations has been considerably reduced. Consequently, many secondary disinfection stations are running in stand-by mode when supplied with filtered Seymour water. When supplied with unfiltered Capilano and Coquitlam water, the secondary disinfection stations activate to boost chlorine.

Table 10: Performance of Secondary Disinfection Facilities

Facility	Performance*	Discussion
Clayton	Whalley/Clayton: 99.7% Jericho/Clayton: 99.7%	No operational issues.
Chilco and Alberni	99.6%	Supplied by filtered Seymour water whenever Capilano source was offline. The target chlorine residual for water leaving the facility was 0.7 mg/L for filtered water and increased to 1.0 mg/L for Capilano water. No operational issues.
Pitt River Secondary	Haney Main No.2: 99.7% Haney Main No.3: 99.7%	No operational issues.
Newton	100%	No operational issues.
Kersland	99.5%	Supplied by filtered Seymour water whenever Capilano source was offline. The target chlorine residual for water leaving the facility was 0.7 mg/L for filtered water and increased to 1.0 mg/L for Capilano water. No operational issues.
Central Park	South Burnaby Main No.1: 99.4% South Burnaby Main No.2: 99.3%	No operational issues. No operational issues.
Cape Horn	Coquitlam Main No.2: 99.7% Coquitlam Main No.3: 99.7%	No operational issues.
Boundary and Eaton	99.6%	Supplied by filtered Seymour water whenever Capilano source was offline. The target chlorine residual for water leaving the facility was 0.7 mg/L for filtered water and increased to 1.0 mg/L for Capilano water. No operational issues.

*Percent of time that free chlorine residual in water leaving facility met target when operating.

5.5 CORROSION CONTROL

Before 1998, the delivered water from all three sources had a pH lower than the aesthetic limit of the GCDWQ of pH 6.5. As part of the upgrade of the water treatment of the Seymour source water, a corrosion control facility using soda ash (sodium carbonate) was put into service at Rice Lake in 1998. A similar facility was added at Coquitlam in 2000 simultaneously with the ozonation facility. Since early 2010 corrosion control for the Seymour source was moved to the SCFP. In the SCFP process, filtered water receives a lime / water slurry to raise its pH and boost its alkalinity before it enters the clearwells; it is finally adjusted with the addition of carbon dioxide gas (CO_2). The average pH of the treated water from Seymour and Coquitlam was approximately 7.5 during 2014 and met the aesthetic objective.

In October 2003, the source of chlorine for disinfection at Capilano was switched from gaseous chlorine to liquid sodium hypochlorite. When sodium hypochlorite (bleach) is used as the source of chlorine for disinfection, there is no drop in pH because sodium hypochlorite is alkaline (there is actually a slight increase in pH). Since the switch, the treated water has a pH greater than or equal to pH 6.5 most of the time. Starting in 2015, Capilano water will be treated at the SCFP and will undergo the lime/CO_2 treatment process for pH and alkalinity adjustment. The addition of the corrosion control facilities on the Seymour and Coquitlam supplies and the switch from gaseous chlorination to sodium hypochlorite at Capilano has resulted in a decrease in corrosion-related calls from the public.

Table 11: Performance of Corrosion Control Facilities

Facility	Performance	Discussion
Seymour - SCFP Corrosion Control	Excellent	June 5 – 15 the East clearwell and chambers 1 & 2 were bypassed and from June 19 – 30 the West clearwell and chambers 2 & 3 were bypassed. This was done in order to upgrade roof hatches. During this period, the CO_2 system was not operational, lime was still added but at a lower dosage. Despite this, the pH was maintained in the range recommended in the GCDWC at all times.
Coquitlam - Corrosion Control	Excellent	The pH was <6.5 for 41.5 hours (0.5% of the time) in 2014 due to soda ash system maintenance and chlorine system preventive maintenance.

The chemical and physical characteristics of the Metro Vancouver treated water are summarized in Appendix 1 of this report; detailed analytical results are provided in Volume II.

6 DISTRIBUTION SYSTEM WATER QUALITY

Schedule A of the BC Drinking Water Protection Regulation contains standards for the bacteriological quality of potable water in the province. There are three components of this standard that apply to large utilities such as the GVWD and its members.

Part 1: no sample should be positive for *E. coli*

Part 2: not more than 10% of the samples in a 30 day period should be positive for total coliform bacteria when more than 1 sample is collected

Part 3: no sample should contain more than 10 total coliform bacteria per 100 mL

The BC Regulation does not contain any water standards other than the three limits for *E. coli* and total coliform bacteria. Information on the significance of the detection of these organisms can be found in the Guidelines for Canadian Drinking Water Quality - Supporting Documents. "*E. coli* is a member of the total coliform group of bacteria and is the only member that is found exclusively in the faeces of humans and other animals. Its presence in water indicates not only recent faecal contamination of the water but also the possible presence of intestinal disease-causing bacteria, viruses, and protozoa." "The presence of total coliform bacteria in water in the distribution system (but not in water leaving the treatment plant) indicates that the distribution system may be vulnerable to contamination or may simply be experiencing bacterial regrowth." To summarize, the detection of an *E. coli* bacteria in a sample of treated water is an indication of a potentially serious risk. The detection of total coliform bacteria may indicate intrusion into the system or it may indicate that these bacteria are growing in the distribution system itself (regrowth).

The number of *E. coli* detected in both the GVWD and the municipal drinking water samples is typically very low – out of approximately 28,000 samples collected from the GVWD and municipal systems, analyzed in 2014, only three samples were positive for *E. coli*. The detection of an *E. coli* triggers a protocol which involves immediate notification of health and municipal officials, re-sampling and a thorough investigation into the possible causes. In these three cases, the problems did not appear to originate from the transmission system which had chlorine residuals of <0.01, 0.19, and 0.56 mg/L at the point of sampling, but appeared to be a sampling or lab contamination issue. All subsequent repeat samples were negative for *E.coli* and total coliforms.

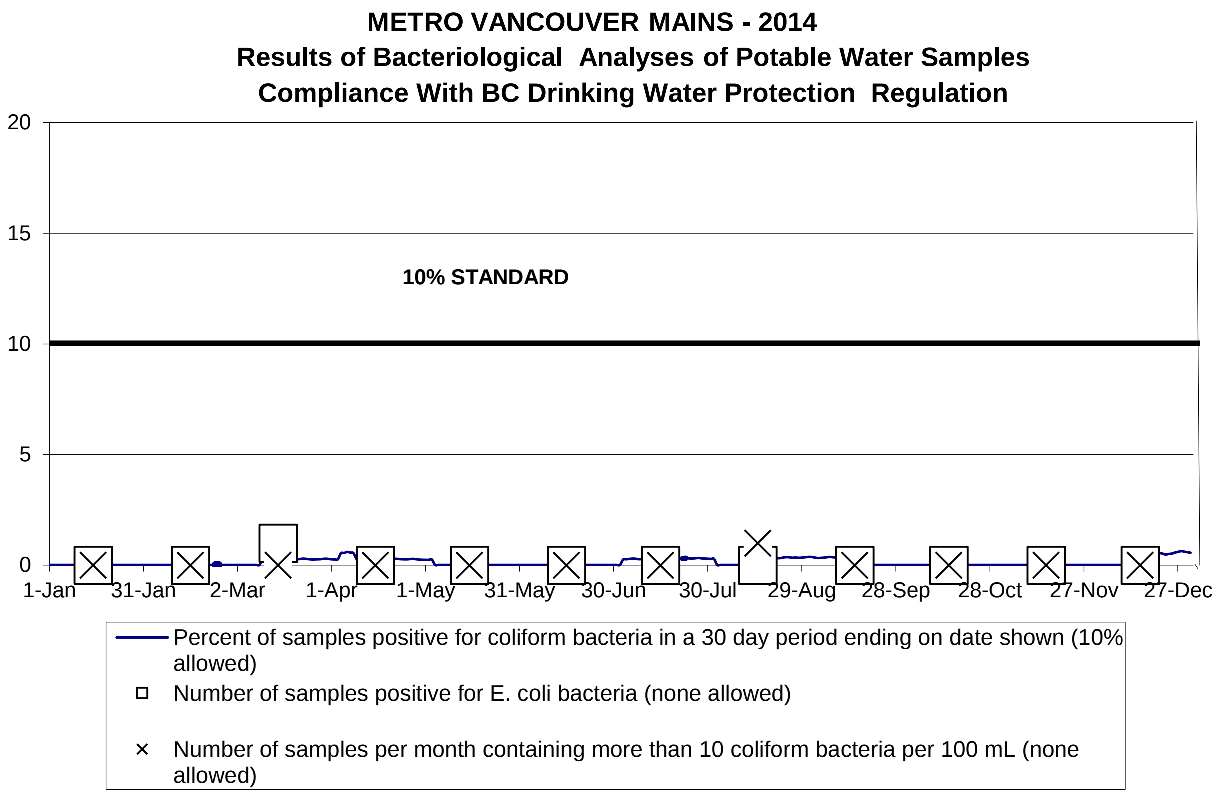
Only 21 of the approximately 20,000 samples collected from the municipal distribution systems tested positive for total coliforms in 2014. The majority of the coliforms in the municipal system appeared in the warmer water months (67% in July through October) and at sites with a measurable free chlorine residual. The most likely source of these organisms can be attributed to bacterial regrowth. The one fact that should be emphasized is that 99.9% of the samples in 2014 had no coliforms present – a good indicator of effective water treatment and good distribution water quality.

6.1 MICROBIOLOGICAL WATER QUALITY IN THE GVWD SYSTEM

6.1.1 GVWD Water Mains

Over 4600 GVWD water main samples were collected and tested for the presence of indicator bacteria. The compliance of monitoring results from GVWD transmission mains with the criteria in the BC Drinking Water Protection Regulation is shown below in Figure 5. There were another 2100 samples collected from the chlorine evaluation stations and the 10-minute chlorine line at each source but these samples are not included in the calculations for compliance monitoring.

Figure 5: Bacteriological Quality of Water in GVWD Mains, 2014



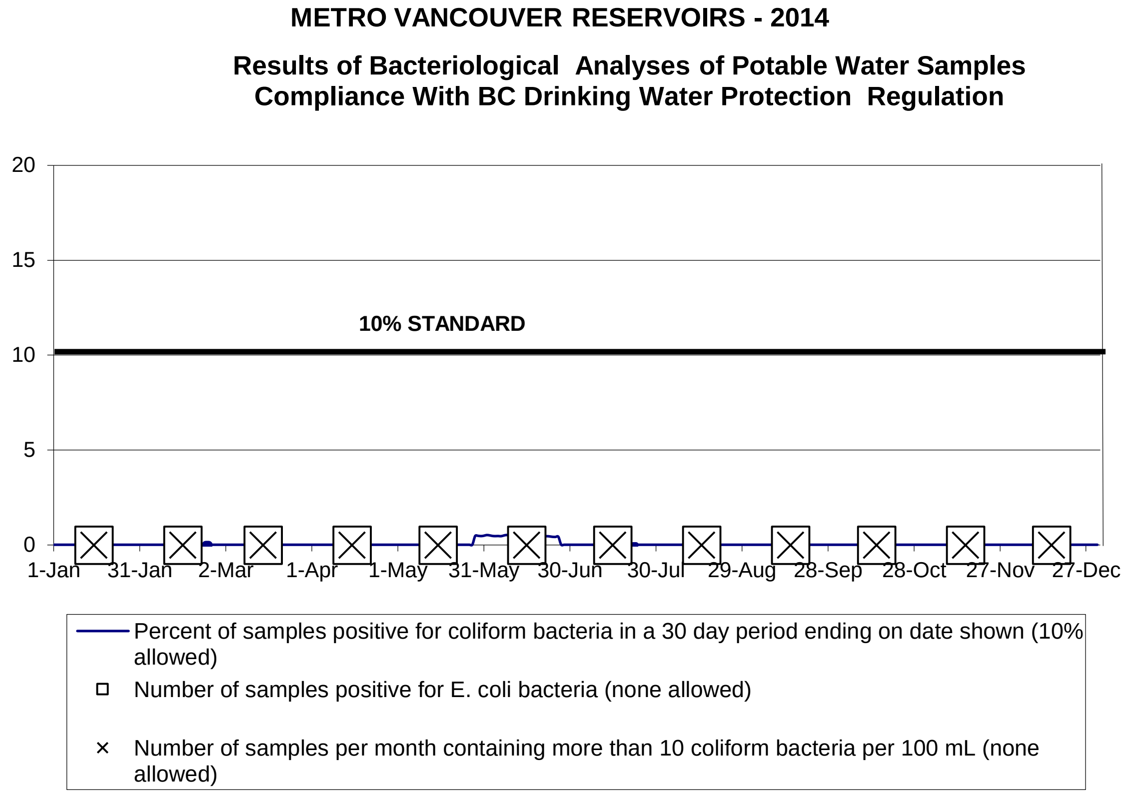
In 2014 the percentage of samples positive for total coliform bacteria from the GVWD mains was very low, well below the 10% standard. Of the more than 4600 samples processed, only 6 samples was positive for total coliforms and one sample was positive for *E. coli* bacteria.

6.1.2 GVWD Reservoirs

In 2014, over 2,200 samples were collected from the 21 reservoirs and tanks that are located throughout the GVWD water system. Only 1 sample was positive for total coliforms. No sample from a reservoir was positive for *E. coli.*

The compliance of monitoring results from GVWD reservoirs with the criteria in the BC Drinking Water Protection Regulation is shown below in Figure 6.

Figure 6: Bacteriological Quality of Water in GVWD Reservoirs, 2014



Reservoir water quality is optimized by the use of secondary disinfection coupled with an active reservoir exercising program that includes a minimum of weekly monitoring of the chlorine residuals and bacteriology results which can result in changes to filling levels if necessary. Table 10 below provides an overview of the status of the GVWD reservoirs. During certain times of the year, it is not possible to cycle reservoirs as much as would be desired due to operational constraints. Despite these constraints, water quality as determined by coliform bacteria was satisfactory in all reservoirs.

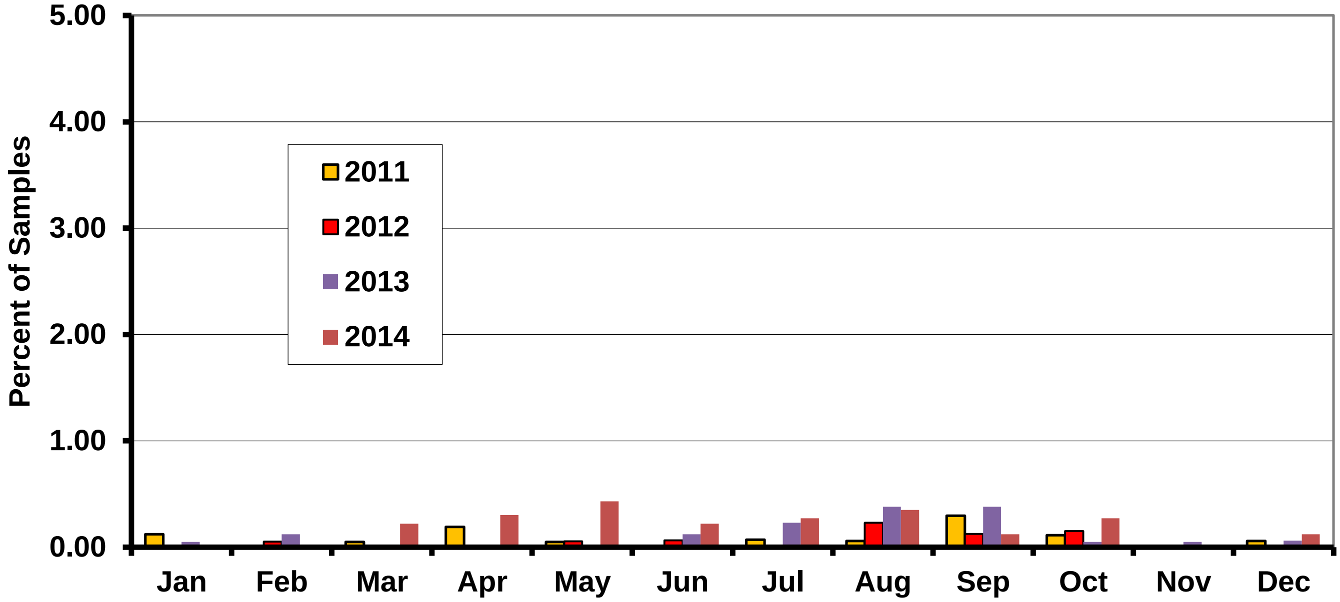
Table 12: Status of GVWD Reservoirs 2014

Reservoir (Capacity in Million Gallons)	Average Free Chlorine (mg/L)				2014 Comments (if applicable)
	2011	2012	2013	2014	
Burnaby Mtn. Reservoir (3.0)	0.48	0.49	0.47	0.47	
Burnaby Tank (0.5)	0.62	0.62	0.51	0.50	
Cape Horn Reservoir (9.6)	0.50	0.44	0.40	0.42	
Clayton Tank (1.6)	0.59	0.62	0.54	0.69	
Central Park (8.1)	0.47	0.44	0.50	0.55	
Glenmore Tanks (0.5)	0.60	0.59	0.53	0.52	
Grandview Reservoir (3.0)	0.68	0.70	0.72	0.70	
Greenwood Reservoir (2)	0.70	0.69	0.59	0.55	
Hellings Tank (1)	0.44	0.44	0.42	0.40	
Kennedy Reservoir (3.8)	0.45	0.47	0.48	0.47	
Kersland Reservoirs (17)	0.60	0.55	0.52	0.56	
Little Mountain Reservoirs (40.7)	0.73	0.68	0.66	0.70	
Maple Ridge Reservoir (4.8)	0.61	0.63	0.57	0.53	
Newton Reservoirs (7.2)	0.39	0.47	0.42	0.42	
Pebble Hill Reservoirs (9.9)	0.49	0.57	0.48	0.42	Cells #1 & #2 were cleaned and disinfected before peak usage season and then removed from service in fall of 2014 to allow increased turnover and residuals in cell #3.
Prospect Reservoir (1.2)	0.71	0.70	0.62	0.63	
Sasamat Reservoir (6)	0.48	0.51	0.45	0.46	Cleaned, disinfected, tested and returned to service in February. In the fall this reservoir was drained and not in service during September and October for pump station work. Reservoir was disinfected and tested prior to return to service.
Sunnyside Reservoirs (5.3)	0.40	0.55	0.60	0.49	
Vancouver Heights Reservoir (10)	0.74	0.75	0.68	0.65	
Westburnco Reservoir (17)	0.64	0.59	0.58	0.55	
Whalley Reservoir (7.8)	0.53	0.47	0.66	0.63	

6.2 MICROBIOLOGICAL WATER QUALITY IN MUNICIPAL SYSTEMS

For samples collected from municipal systems, the percent positive per month for total coliform bacteria from 2011 - 2014 is shown in Figure 7:

Figure 7: Percent of Samples per Month Positive for Total Coliform Bacteria 2011 to 2014



The percentage of samples positive for total coliform bacteria in 2014 was about the same percentage for 2013.

Schedule A of the BC Drinking Water Protection Regulation contains standards for the bacteriological quality of potable water in the province. There are three components of this standard that apply to municipalities:

Part 1: no sample should be positive for *E. coli*

Part 2: not more than 10% of the samples in a 30 day period should be positive for total coliform bacteria when more than 1 sample is collected

Part 3: no sample should contain more than 10 total coliform bacteria per 100 mL

For samples from municipal systems, this requirement was met in 2014 with the following exceptions:

Part 1:

- One sample in August and one sample in October were positive for E.coli.

Part 2:

- One municipality (low number of samples per month) had >10% positive samples in May and June.

Part 3:

- One sample in May contained more than 10 total coliform bacteria.
- One sample in September contained more than 10 total coliform bacteria.
- One sample in October contained more than 10 total coliform bacteria.
- One sample in December contained more than 10 total coliform bacteria.

Table 13 shows the compliance of the samples collected in the member municipal distribution systems with the three bacteriological standards in the BC DWPR.

Table 13: Municipal Water Quality Compared to the Bacteriological Standards of the BC DWPR for 2014 for 20 Member Jurisdictions.

Month	Number that met Part 1	Number that met Part 2	Number that met Part 3	Number meeting all DWPR
January	20	20	20	20
February	20	20	20	20
March	20	20	20	20
April	20	20	20	20
May	20	**19**	**19**	**19**
June	20	**19**	20	**19**
July	20	20	20	20
August	**19**	20	20	**19**
September	20	20	**19**	**19**
October	**19**	20	**19**	**19**
November	20	20	20	20
December	20	20	**19**	**19**

6.3 DISINFECTION BY-PRODUCTS IN THE DISTRIBUTION SYSTEM

As the treated water moves through the GVWD and later the municipal infrastructure of pipes and reservoirs changes in water quality occur mainly due to the reaction between the chlorine in the water (added during primary and secondary disinfection) and naturally occurring organic matter in the water.

One of the most significant changes is the production of chlorinated disinfection by-products (DBPs). DBP is a term used to describe a group of organic and inorganic compounds formed during water disinfection.

Reactions between dissolved natural organic matter and chlorine can lead to the formation of a variety of halogenated DBPs. There are two major groups of chlorinated DBPs: the total trihalomethanes (TTHMs) and the total haloacetic acids ($THAA_5$). Factors that affect DBP formation are: amount of chlorine added to water, reaction time, concentration and characteristics of dissolved organic materials (precursors), water temperature, and water pH. In general, DBPs continue to form as long as chlorine and reactive DBP precursors are present in the water.

The maximum acceptable concentration (MAC) in the Canadian Guidelines for TTHMs is a locational yearly running average of 100 µg/L (0.1 mg/L) based on quarterly samples. Comparison of TTHM levels in 2009 and 2014 is shown in Figures 8 & 9. As in previous years, all TTHM results were below the MAC of 100 µg/L.

The other group of disinfection by-products of interest is the Haloacetic Acid ($THAA_5$) group. The maximum acceptable concentration (MAC) in the Canadian Guidelines for Total HAAs ($THAA_5$) is a locational yearly running average of 80 µg/L (0.08 mg/L) based on quarterly samples. Comparison of $THAA_5$ levels for 2009 and 2014 is shown in Figures 10 & 11. All $THAA_5$ results were below the MAC of 80 µg/L.

Figure 8: Average Total Trihalomethane Levels in Municipal Samples 2009

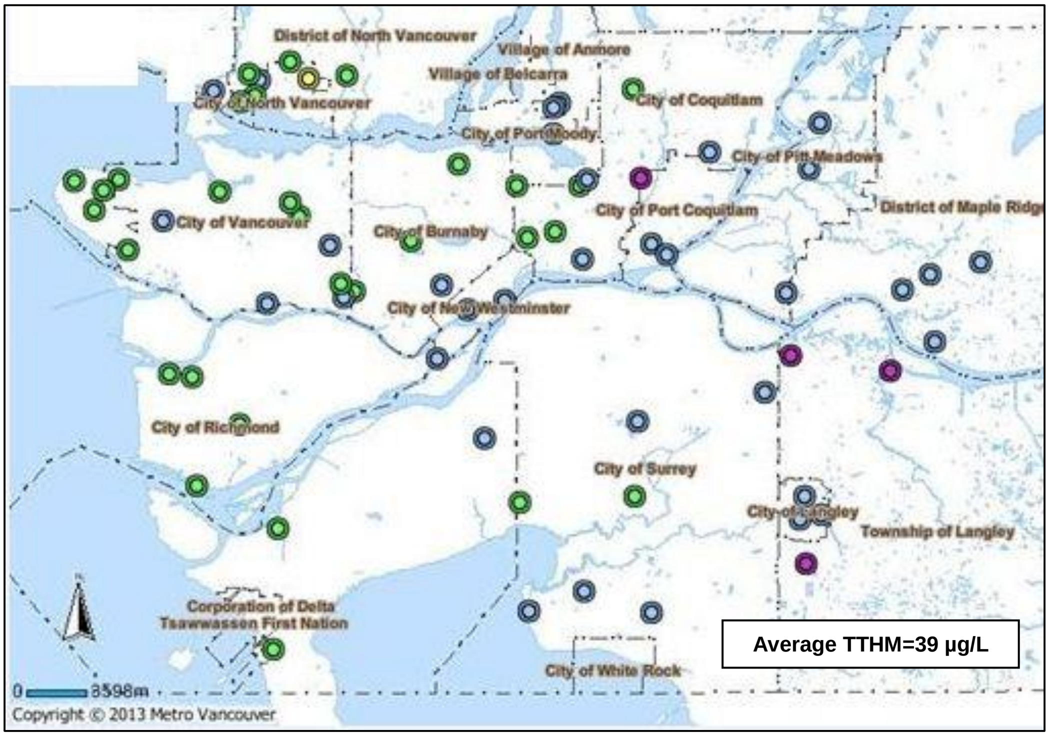
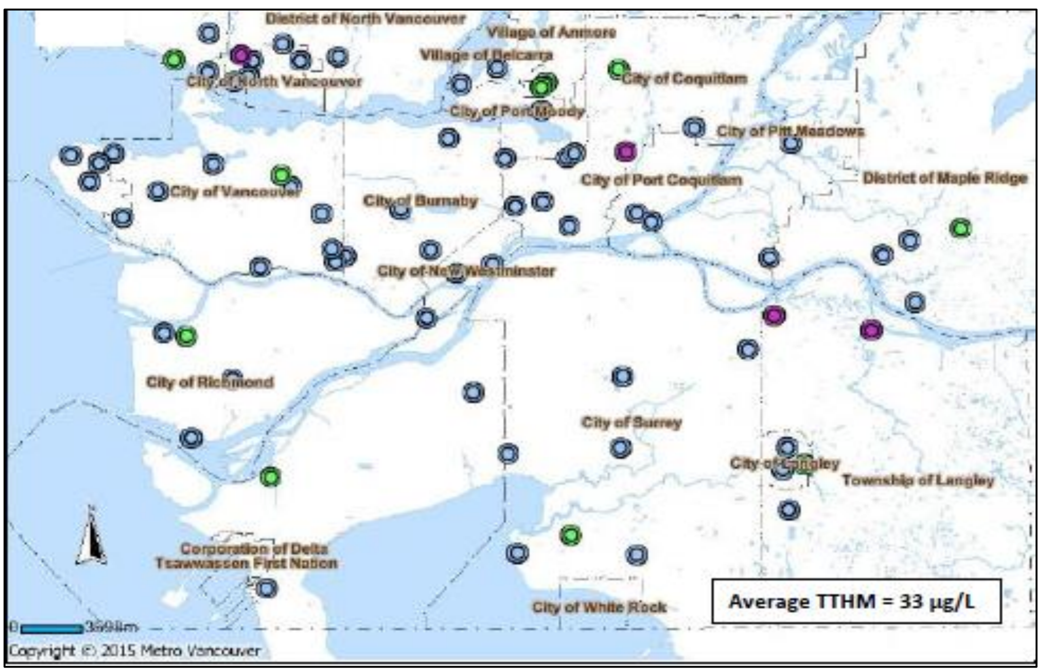


Figure 9: Average Total Trihalomethane Levels in Municipal Samples 2014



0 - 19 parts/billion	60 - 79 parts/billion
20 - 39 parts/billion	80 - 99 parts/billion
40 - 59 parts/billion	> 100 parts/billion

MAC for total THM values is 100 µg/L or (ppb)

Figure 10: Average Total Haloacetic Acid Levels in Municipal Samples 2009

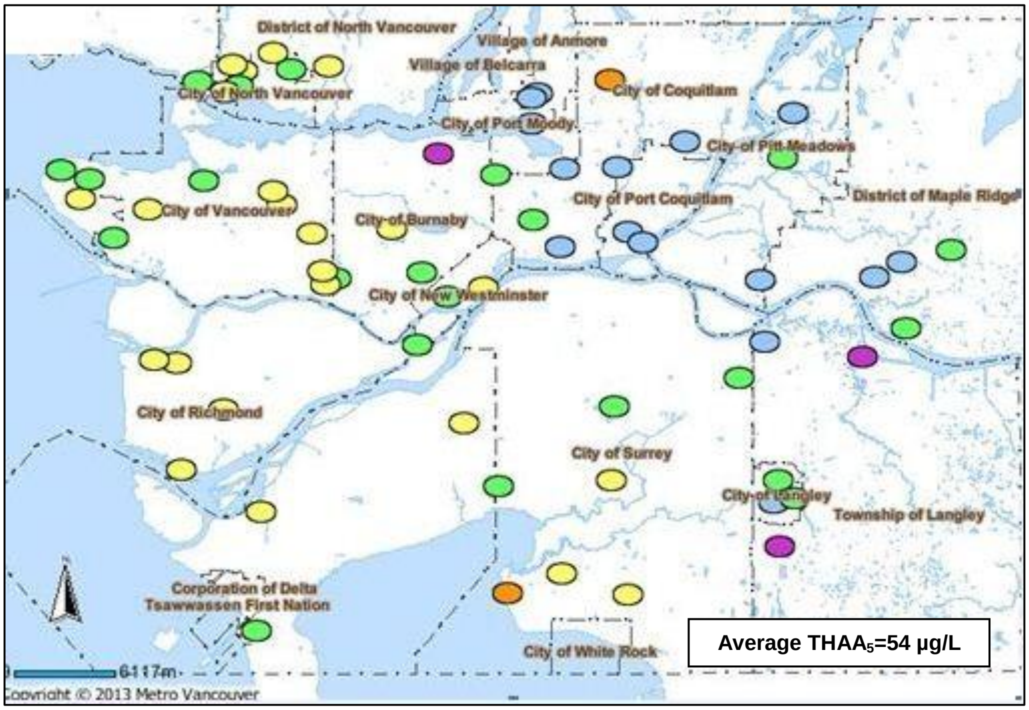
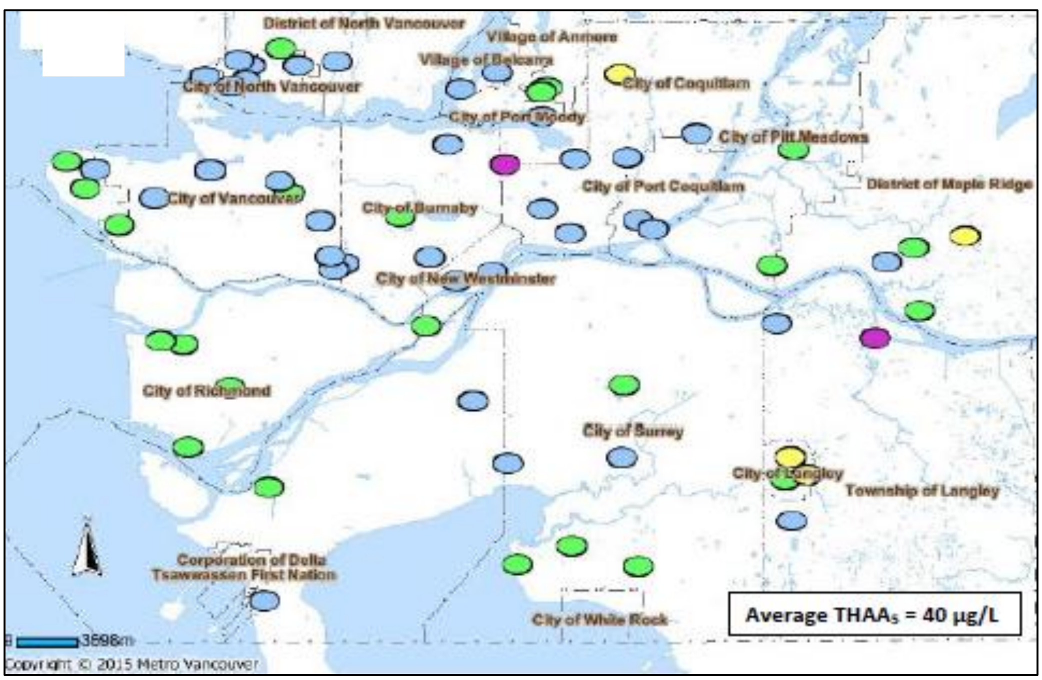
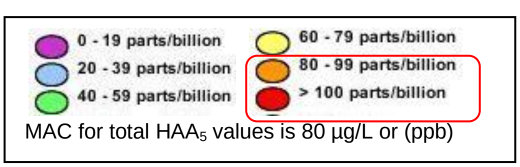


Figure 11: Average Total Haloacetic Acid Levels in Municipal Samples 2014





7 QUALITY CONTROL / QUALITY ASSURANCE

In 1994, as required by a new Ministry of Health program, the Bacteriology Section of the Metro Vancouver laboratory received approval from the Provincial Medical Health Officer to perform bacteriological analysis of potable water as required in the B.C. Safe Drinking Water Regulation (changed to the BC Drinking Water Protection Regulation in 2001). An ongoing requirement of this approval is successful participation in the Clinical Microbiology Proficiency Testing (CMPT) program or its equivalent. The bacteriological laboratory has successfully participated in this program since 1994. Representatives of the Approval Committee for Bacteriology Laboratories carried out an inspection of the Metro Vancouver laboratory facilities at LCOC in the fall of 2012 as part of the process leading up to approval of the laboratory by the Provincial Health Officer which has been received. The next inspection is scheduled for 2015.

In addition to the approval process discussed above, the Metro Vancouver Laboratory is accredited by the Canadian Association for Laboratory Accreditation (CALA) for the analysis of parameters for which the laboratory has requested certification. The MV Laboratory has been inspected by representatives from CALA bi-annually since 1995, and most recently in 2013 as required by the accreditation process. Accreditation for the laboratory from the Standards Council of Canada was first received early in 1996 and continued until the middle of 2005, when accreditation was granted by CALA directly. Based on the 2013 inspection, CALA issued the latest accreditation for the Metro Vancouver Laboratory in February 2014. Details are available in the Quality Control office. The next CALA inspection will take place in the fall of 2015.

Appendix 1

Chemical & Physical Analysis Summaries

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2014 - Capilano Water System

Parameter	Untreated	Treated				
	Average	Average	Range	Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	3.1	3.7	3.2-4.3		none	
Aluminium Dissolved (µg/L)	67	65	56-74		none	
Aluminium Total (µg/L)	88	97	84-110		none	
Antimony Total (µg/L)	<0.5 (0.021)	<0.5	<0.5	0	6	health
Arsenic Total (µg/L)	<0.5 (0.095)	<0.5	<0.5	0	10	health
Barium Total (µg/L)	6.3	2.2	2.2	0	1000	health
Boron Total (mg/L)	<0.01	<0.01	<0.01		5	
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	health
Bromide (mg/L)	<0.01	<0.01	<0.01	0	none	health
Cadmium Total (µg/L)	<0.2 (0.008)	<0.2	<0.2	0	5	health
Calcium Total (mg/L)	1.29	1.28	1.19-1.39		none	
Carbon Organic Dissolved (mg/L)	1.4	1.4	1.1-1.5		none	
Carbon Organic Total (mg/L)	1.3	1.4	1.2-1.5		none	
Chlorate (mg/L)	<0.01	0.08	<0.06-0.10	0	1.0	health
Chloride Total (mg/L)	0.5	2.0	1.8-21	0	≤ 250	aesthetic
Chromium Total (µg/L)	<0.05	<0.05	<0.05	0	50	health
Color Apparent (ACU)	12	8	6-10		none	
Color True (TCU)	8	3	<1-5	0	≤ 15	aesthetic
Conductivity (umhos/cm)	12	18	16-19		none	
Copper Total (µg/L)	32 (0.503)			0	≤ 1000	aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	health
Hardness as $CaCO_3$ (mg/L)	3.88	3.85	3.62-4.15		none	
Iron Dissolved (µg/L)	45	46	24-75		none	
Iron Total (µg/L)	127	143	66-230	0	≤ 300	aesthetic
Lead Total (µg/L)	<0.5 (0.095)	<0.5	<0.5	0	10	health
Magnesium Total (mg/L)	162	160	154-168		none	
Manganese Dissolved (µg/L)	4.7	3.7	1.9-6.1		none	
Manganese Total (µg/L)	5.5	4.6	2.8-7.2	0	≤ 50	aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	health
Molybdenum Total (µg/L)	(0.148)					
Nickel Total (µg/L)	<0.5 (0.100)	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.07	0.08	0.07-0.09	0	45	health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	health
pH	6.5	6.6	6.6	0	6.5 to 8.5	aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (mg/L)	178	138	138		none	
Residue Total (mg/L)	16	18	16-19		none	
Residue Total Dissolved (mg/L)	12	14	12-16	0	≤ 500	aesthetic
Residue Total Fixed (mg/L)	10	11	10-12		none	
Residue Total Volatile (mg/L)	6	7	6-7		none	
Selenium Total (µg/L)	<0.5 (<0.040)	<0.5	<0.5	0	50	health
Silica as SiO_2 (mg/L)	3.3	3.3	3.3		none	
Silver Total (µg/L)	<0.5 (<0.005)	<0.5	<0.5		none	
Sodium Total (mg/L)	5.66	1.82	1.81-1.83	0	≤ 200	aesthetic
Sulphate (mg/L)	0.8	0.8	0.80	0	≤ 500	aesthetic
Turbidity (NTU)	0.35	0.36	0.20-0.60			
Uranium Total (µg/L)	0.027			0	20	health
UV254 (Abs/cm)	0.055	0.042	0.034-0.053		none	
UV254 App. (Abs/cm)					none	
Zinc Total (µg/L)	<3 (0.91)	<3	<3	0	≤ 5000	aesthetic

These figures are average values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake prior to chlorination, treated water is from a single site in the GVWD distribution system downstream of chlorination. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996, updated to Oct 2014. Capilano water is treated with chlorine for primary and secondary disinfections which increases pH and alkalinity. Capilano source was out of service from January 1- May 27, and September 24 -December 31. It was operational for only 119 days in 2014. In parenthesis ( ) analytical results

Corrections made Aug 5, 2015

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2014 - Seymour Water System

Parameter	Untreated Average	Treated Average	Treated Range	Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	3.7	8.1	5.8-10.3		none	
Aluminium Dissolved (µg/L)	64	31	15-61		none	
Aluminium Total (µg/L)	130	36	17-70	0	200	aesthetic
Antimony Total (µg/L)	<0.5	<0.5	<0.5	0	6	health
Arsenic Total (µg/L)	<0.5	<0.5	<0.5	0	10	health
Barium Total (µg/L)	3.9	3	2.9-3.0	0	1000	health
Boron Total (mg/L)	<10	<10	<10		5	
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	health
Bromide (mg/L)	<0.01	<0.01	<0.01	0	none	health
Cadmium Total (µg/L)	<0.2	<0.2	<0.2	0	5	health
Calcium Total (mg/L)	1.8	3.89	3.00-4.58		none	
Carbon Organic Dissolved (mg/L)	1.6	0.67	0.5 - 1.1		none	
Carbon Organic Total (mg/L)	2.00	0.74	0.56 -1.37		none	
Chlorate (mg/L)	<0.01	0.04	0.01 - 0.10	0	1.0	health
Chloride Total (mg/L)	<0.5	<0.5	<0.5	0	≤ 250	aesthetic
Chromium Total (µg/L)	0.08	<0.05	<0.05 - 0.05	0	50	health
Color Apparent (ACU)	18	<1	<1		none	
Color True (TCU)	12	<1	<1	0	≤ 15	aesthetic
Conductivity (umhos/cm)	14	29	22-36		none	
Copper Total (µg/L)	9	<0.5	<0.5	0	≤1000	aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	health
Hardness as $CaCO_3$ (mg/L)	5.2	10.4	8-12.2		none	
Iron Dissolved (µg/L)	71	<5	<5		none	
Iron Total (µg/L)	211	6	<5-14		≤ 300	aesthetic
Lead Total (µg/L)	<0.5	<0.5	<0.5	0	10	health
Magnesium Total (µg/L)	169	167	125-196		none	
Manganese Dissolved (µg/L)	5.2	4.3	2.3-7.2		none	
Manganese Total (µg/L)	7.3	5.7	2.6-9.6	0	≤ 50	aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	health
Nickel Total (µg/L)	<0.5	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	<0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.07	0.07	0.01 - 0.11	0	45	health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	health
pH	6.6	7.2	7.0-7.4	0	6.5 to 8.5	aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (µg/L)	156	142	140-143		none	
Residue Total (mg/L)	20	24	20-27		none	
Residue Total Dissolved (mg/L)	15	20	14-27	0	≤ 500	aesthetic
Residue Total Fixed (mg/L)	13	18	14-21		none	
Residue Total Volatile (mg/L)	7	6	4-8		none	
Selenium Total (µg/L)	<0.5	<0.5	<0.5	0	50	health
Silica as SiO_2 (mg/L)	3.3	3.3	2.8-3.8		none	
Silver Total (µg/L)	<0.5	<0.5	<0.5		none	
Sodium Total (mg/L)	0.56	1.43	1.22-1.68	0	≤ 200	aesthetic
Sulphate (mg/L)	1.4	2.5	0.9-3.3	0	≤ 500	aesthetic
Turbidity (NTU)	1.21	0.11	0.06-0.22		≤0.3	
Uranium Total (µg/L)	0.022	0.014			20	health
UV254 {cm^{-1} (% Trans)} App					none	
UV254 (cm^{-1}) True	0.071	0.01	0.008-0.016		none	
Zinc Total (µg/L)	<3	<3	<3	0	≤ 5000	aesthetic

These figures are average values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake or a sample site prior to coagulation, treated water is from a sample site downstream of SCFP clearwell. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996, updated to Oct 2014. Seymour source water is filtered, disinfected with UV light and sodium hypochlorite for primary disinfection, respectively; lime is added to increase pH and alkalinity while CO_2 is added to adjust pH. Turbidity and pH for raw and treated waters were taken from SCADA. TOC and UV254 (cm^{-1} and % Transmittance) were taken from SCFP WQC Lab data. Seymour Source was operational for 365 days in 2014. In parenthesis ( ) analytical results from a private lab.

Corrections made Aug 5, 2015

Physical and Chemical Analysis of Water Supply

Greater Vancouver Water District

2014 - Coquitlam Water System

Parameter	Average	Average	Range	Days Guideline Exceeded	Canadian Guideline Limit	Reason Guideline Established
Alkalinity as $CaCO_3$ (mg/L)	1.8	8.7	6.4-10.4		none	
Aluminium Dissolved (µg/L)	59	58	44-80		none	
Aluminium Total (µg/L)	86	86	69-117		none	
Antimony Total (µg/L)	<0.5	<0.5	<0.5	0	6	health
Arsenic Total (µg/L)	<0.5 (0.026)	<0.5	<0.5	0	10	health
Barium Total (µg/L)	2.33	2.3	2.1-2.4	0	1000	health
Boron Total (mg/L)	<0.01	<0.01	<0.01	0	5	health
Bromate (mg/L)	<0.01	<0.01	<0.01	0	0.01	health
Bromide (mg/L)	<0.01	<0.01	<0.01		none	
Cadmium Total (µg/L)	<0.2 (0.006)	<0.2	<0.2	0	5	health
Calcium Total (mg/L)	0.91	0.91	0.86-0.93		none	
Carbon Organic Dissolved (mg/L)	1.6	1.5	1.1-2.3		none	
Carbon Organic Total (mg/L)	1.58	1.51	1.20-2.30		none	
Chlorate (mg/L)	<0.01	<0.01	<0.01	0	1.0	health
Chloride Total (mg/L)	0.5	2.1	1.9-2.6	0	≤ 250	aesthetic
Chromium Total (µg/L)	<0.05	<0.05	<0.05	0	50	health
Color Apparent (ACU)	13	2	<1-3		none	
Color True (TCU)	9	1	<1-2	0	≤ 15	aesthetic
Conductivity (umhos/cm)	8	28	24-34		none	
Copper Total (µg/L)	5.1	<0.5	<0.5		≤ 1000	aesthetic
Cyanide Total (mg/L)	<0.02	<0.02	<0.02	0	0.2	health
Fluoride (mg/L)	<0.05	<0.05	<0.05	0	1.5	health
Hardness as $CaCO_3$ (mg/L)	2.68	2.67	2.56-2.76		none	
Iron Dissolved (µg/L)	17	19	9-27		none	
Iron Total (µg/L)	49	49	36-73	0	≤ 300	aesthetic
Lead Total (µg/L)	<0.5	<0.5	<0.5		10	health
Magnesium Total (µg/L)	0.10	0.10	0.9-0.11		none	
Manganese Dissolved (µg/L)	3.4	2.3	1.6-3.5		none	
Manganese Total (µg/L)	3.9	3.0	2.1-3.9	0	≤50	aesthetic
Mercury Total (µg/L)	<0.05	<0.05	<0.05	0	1.0	health
Molybdenum Total (µg/L)	0.062					
Nickel Total (µg/L)	<0.5 (0.062)	<0.5	<0.5		none	
Nitrogen - Ammonia as N (mg/L)	<0.02	<0.02	<0.02		none	
Nitrogen - Nitrate as N (mg/L)	0.09	0.1	0.07-0.12	0	45	health
Nitrogen - Nitrite as N (mg/L)	<0.01	<0.01	<0.01	0	3.0	health
pH	6.3	7.5	6.4-8.6	0	6.5 to 8.5	aesthetic
Phenols (µg/L)	<5	<5	<5		none	
Phosphorus Total (µg/L)	<5	<5	<5		none	
Potassium Total (µg/L)	107	113	104-123		none	
Residue Total (mg/L)	13	26	23-28		none	
Residue Total Dissolved (mg/L)	10	22	11-25	0	≤ 500	aesthetic
Residue Total Fixed (mg/L)	8	19	16-21		none	
Residue Total Volatile (mg/L)	5	8	7-9		none	
Selenium Total (µg/L)	<0.5 (<0.040)	<0.5	<0.5	0	50	health
Silica as SiO_2 (mg/L)	2.5	2.5	2.3-2.6		none	
Silver Total (µg/L)	<0.5 (<0.005)	<0.5	<0.5		none	
Sodium Total (mg/L)	0.46	0.50	0.44-0.58	0	≤200	aesthetic
Sulphate (mg/L)	0.7	0.7	0.6-0.7	0	≤500	aesthetic
Turbidity (NTU)	0.49	0.42	0.18-2.5			
Uranium Total (µg/L)	0.039			0	20	health
UV254 (Abs/cm)	0.065	0.019	0.011-0.038		none	
UV254 App (Abs/cm)	0.072	0.024	0.016-0.045			
Zinc Total (µg/L)	<3 (1.54)	<3	<3	0	≤ 5000	aesthetic

These figures are average values from a number of laboratory analyses done throughout the year. Where the range is a single value no variation was measured for the samples analysed. Methods and terms are based on those of "Standard Methods of Water and Waste Water" 22nd Edition 2012. Less than (<) denotes not detectable with the technique used for determination. Untreated water is from the intake prior to chlorination, treated water is from a sample line after 10 minutes chlorine contact time. Guidelines are taken from "Guidelines for Canadian Drinking Water Quality - Sixth Edition" Health and Welfare Canada 1996, updated to Oct 2014. Coquitlam water is treated with ozone for primary disinfection, chlorine for secondary disinfection, soda ash to increase pH and alkalinity. UV disinfection for primary treatment was in service starting June 10th. Coquitlam was operational for 365 days in 2014. In parenthesis ( ) analytical results from

Corrections made Aug 5, 2015

Appendix 2

Analysis of Water for Selected Organic Components and Radionuclides

Analysis of Source Waters for Herbicides, Pesticides, Volatile Organic Compounds, and Uranium

	Units	Date Sampled	MAC	AO	Capilano	Seymour	Coquitlam
Atrazine	µg/L	27-Mar-14	5		<1	<1	<1
Azinphos-Methyl	µg/L	27-Mar-14	20		<1	<1	<1
Bendiocarb	µg/L	27-Mar-14	40		<2	<2	<2
Benzene	µg/L	27-Mar-14	5		<0.5	<0.5	<0.5
Bromoxynil	µg/L	27-Mar-14	5		<0.02	<0.02	<0.02
Carbaryl	µg/L	27-Mar-14	90		<5	<5	<5
Carbofuran	µg/L	27-Mar-14	90		<5	<5	<5
Carbon Tetrachloride	µg/L	27-Mar-14	2		<0.50	<0.50	<0.50
Chlorpyrifos	µg/L	27-Mar-14	90		<2	<2	<2
Diazinon	µg/L	27-Mar-14	20		<2	<2	<2
Dicamba	µg/L	27-Mar-14	120		<0.0050	<0.0050	<0.0050
Dichlofop-Methyl	µg/L	27-Mar-14	9		<0.080	<0.080	<0.080
Dichlorobenzene, 1,2-	µg/L	27-Mar-14	200	≤ 3	<0.50	<0.50	<0.50
Dichlorobenzene, 1,4-	µg/L	27-Mar-14	5	≤ 1	<0.50	<0.50	<0.50
Dichloroethane, 1,2-	µg/L	27-Mar-14	5		<0.50	<0.50	<0.50
Dichloroethylene, 1,1-	µg/L	27-Mar-14	14		<0.50	<0.50	<0.50
Dichloromethane	µg/L	27-Mar-14	50		<2.0	<2.0	<2.0
Dichlorophenol, 2,4-	µg/L	27-Mar-14	900	≤ 0.3	<0.10	<0.10	<0.10
Dichlorophenoxyacetic acid, 2,4-(2,4-D)	µg/L	27-Mar-14	100		<0.050	<0.050	<0.050
Dimethoate	µg/L	27-Mar-14	20		<2	<2	<2
Diquat	µg/L	27-Mar-14	70		<7	<7	<7
Diuron	µg/L	27-Mar-14	150		<10	<10	<10
Ethylbenzene	µg/L	27-Mar-14	140	≤ 1.6	<0.40	<0.40	<0.40
Glyphosate	µg/L	27-Mar-14	280		<10	<10	<10
Malathion	µg/L	27-Mar-14	190		<2	<2	<2
Methyl t-butyl ether (MTBE)	µg/L	27-Mar-14		≤ 15	<4	<4	<4
Metolachlor	µg/L	27-Mar-14	50		<5	<5	<5
Metribuzin	µg/L	27-Mar-14	80		<2.5	<2.5	<2.5
Monochlorobenzene	µg/L	27-Mar-14	80	≤ 30	<0.50	<0.50	<0.50
Nitrilotriacetic Acid (NTA)	mg/L	27-Mar-14	400		<0.05	<0.05	<0.05
Paraquat (as Dichloride)	µg/L	27-Mar-14	10		<1	<1	<1
Pentachlorophenol	µg/L	27-Mar-14	60	≤30	<0.10	<0.10	<0.10
Phorate	µg/L	27-Mar-14	2		<1	<1	<1
Picloram	µg/L	27-Mar-14	190		<0.080	<0.080	<0.080
Simazine	µg/L	27-Mar-14	10		<2	<2	<2

	Units	Date Sampled	MAC	AO	Capilano	Seymour	Coquitlam
Terbufos	µg/L	27-Mar-14	1		<1	<1	<1
Tetrachloroethylene	µg/L	27-Mar-14	30		<0.50	<0.50	<0.50
Tetrachlorophenol, 2,3,4,6-	µg/L	27-Mar-14	100	≤ 1	<0.10	<0.10	<0.10
Toluene	µg/L	27-Mar-14	60	24	<0.40	<0.40	<0.40
Trichloroethylene	µg/L	27-Mar-14	5		<0.50	<0.50	<0.50
Trichlorophenol, 2,4,6-	µg/L	27-Mar-14	≤2	≤ 2	<0.10	<0.10	<0.10
Trifluralin	µg/L	27-Mar-14	45		<5	<5	<5
Uranium	µg/L	27-Mar-14	20		0.027	0.022	0.039
Vinyl Chloride	µg/L	27-Mar-14	2		<0.50	<0.50	<0.50
Xylene (Total)	µg/L	27-Mar-14	90	≤ 20	<1.0	<1.0	<1.0

Analysis of Source Waters for PAHs

PAHs	Units	Date Sampled	MAC	AO	Capilano	Seymour	Coquitlam
Acenaphthylene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Anthracene	µg/L	27-Mar-14			<0.010	<0.010	<0.010
Benzo(a)anthracene	µg/L	27-Mar-14			<0.010	<0.010	<0.010
Benzo(b)fluoranthene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Benzo(k)fluoranthene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Benzo(g,h,i)perylene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Benzo(a)pyrene[1]	µg/L	27-Mar-14	0.01		<0.0090	<0.0090	<0.0090
Chrysene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Dibenzo(a,h)anthracene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Fluoranthene	µg/L	27-Mar-14			<0.020	<0.020	<0.020
Fluorene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Indeno(1,2,3-c,d)pyrene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Naphthalene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Phenanthrene	µg/L	27-Mar-14			<0.050	<0.050	<0.050
Pyrene	µg/L	27-Mar-14			<0.020	<0.020	<0.020

Analysis of Source Waters for Radioactivity

		Date Sampled		Capilano		Seymour		Coquitlam	
Radioactivity	**Units**		MAC[1]	MDA[3]	Activity	MDA[3]	Activity	MDA[3]	Activity
Gross Alpha	Bq/L	10-Mar	<0.5	0.28	<0.28	0.04	<0.04	0.04	<0.04
Gross Beta	Bq/L	10-Mar	<1.0	0.07	<0.07	0.07	<0.07	0.06	0.06
Cobalt-60	Bq/L	10-Mar	2 [2]	0.20	<0.20	0.21	<0.21	0.22	<0.22
Cobalt-60	Bq/L	12-Nov	2 [2]	0.14	<0.14	0.13	<0.13	0.14	0.06
Cesium-134	Bq/L	10-Mar	7 [2]	0.16	<0.16	0.24	<0.24	0.24	<0.24
Cesium-134	Bq/L	12-Nov	7 [2]	0.14	<1.04	0.13	0.037	0.14	<0.14
Cesium-137	Bq/L	10-Mar	10	0.19	<0.19	0.21	<0.21	0.21	<0.21
Cesium-137	Bq/L	12-Nov	10	0.02	<0.14	0.12	0.75	0.12	0.09
Iodine-131	Bq/L	10-Mar	6	0.20	<0.20	0.23	<0.23	0.24	<0.24
Lead-210	Bq/L	10-Mar	0.2	0.04	<0.04	0.04	<0.04	0.04	0.16
Lead-210	Bq/L	12-Nov	0.2	1.04	<0.14	0.87	<0.87	0.83	<0.83
Radium-226	Bq/L	10-Mar	0.5	0.01	<0.01	0.012	<0.012	0.13	<0.13
Radon-222	Bq/L	10-Mar	none	0.75	<0.75	1.12	<1.12	1.10	<1.10
Strontium-90	Bq/L	NS	5	-	-	-	-	-	-
Tritium (H-3)	Bq/L	10-Mar	7000	3.81	<3.81	3.74	<3.74	3.77	<3.77

Notes:

[1]MAC from Guidelines for Canadian Drinking Water Quality (GCDWQ), Oct.2014

[2]MAC from Guidelines for Canadian Drinking Water Quality (GCDWQ), 6th Ed.1996

[3]MDA Minimum Detectable Activity

NS Not Sampled due to Lab problem

Monitoring of Selected GVWD Water Mains for BTEXs

Parameters	Units	Date Sampled	MAC µg/L	AO µg/L	Maple Ridge Main at Reservoir	Barnston Island Main at Willoughby PS	Jericho-Clayton Main	South Burnaby Main #2
Benzene	µg/L	12-Nov-14	5		<0.4	<0.4	<0.4	<0.4
Ethylbenzene	µg/L	12-Nov-14	140	1.6	<0.4	<0.4	<0.4	<0.4
Toluene	µg/L	12-Nov-14	60	24	<0.4	<0.4	<0.4	<0.4
Xylenes (Total)	µg/L	12-Nov-14	90	20	<1	<1	<1	<1

MAC = Maximum Acceptable Concentration

AO = Aesthetic Objective

Monitoring of Selected GVWD Mains for PAHs

Parameters	Units	Date Sampled	MAC	Coquitlam Main 2/3	Westburnco Reservoir	Barnston Island	Queens-burough	Whalley-Kennedy Link	Haney Main	36 Ave. Main
Acenaphthene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Acenaphthylene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Anthracene	µg/L	12-Nov-14		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Benzo(a)anthracene	µg/L	12-Nov-14		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Benzo(b)fluoranthene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(k)fluoranthene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(g,h,i)perylene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Benzo(a)pyrene[1]	µg/L	12-Nov-14	0.01	<0.0090	<0.0090	<0.0090	<0.0090	<0.0090	<0.0090	<0.0090
Chrysene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Dibenzo(a,h)anthracene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Fluoranthene	µg/L	12-Nov-14		<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Fluorene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Indeno(1,2,3-c,d)pyrene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Naphthalene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phenanthrene	µg/L	12-Nov-14		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Pyrene	µg/L	12-Nov-14		<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020

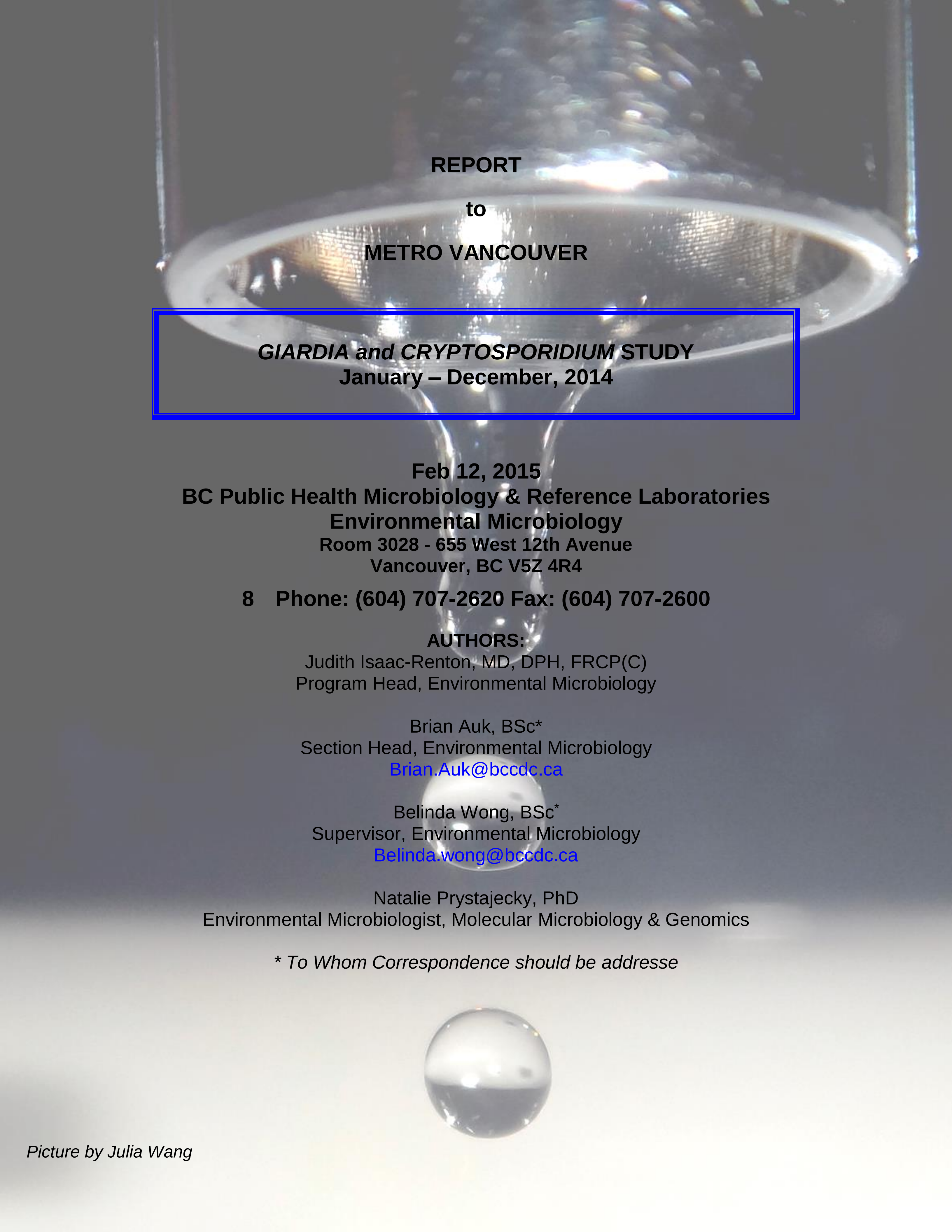
[1]Benzopyrene is the only PAH compound that has guideline limit.

MAC = Maximum Acceptable Concentration

Appendix 3

REPORT TO METRO VANCOUVER

GIARDIA and *CRYPTOSPORIDIUM* STUDY
January – December, 2014



REPORT

to

METRO VANCOUVER

***GIARDIA and CRYPTOSPORIDIUM* STUDY**
January – December, 2014

Feb 12, 2015

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** To Whom Correspondence should be addresse*

Picture by Julia Wang

ATTACHED GRAPHS AND TABLES

1. Graphs and Tables of Metro Vancouver Weekly *Giardia* and *Cryptosporidium* Filter Results 2014.xls
   a) Graph 1 – 2014 Capilano Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water
   b) Graph 2 – 2014 Coquitlam Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water
   c) Graph 3 – 2014 SCFP-RCW *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of RCW
   d) Table 3 – 2014 Metro Vancouver Capilano Reservoir Weekly Filter Results
   e) Table 4 – 2014 Metro Vancouver Coquitlam Reservoir Weekly Filter Results
   f) Table 5 – 2014 Metro Vancouver SCFP - RCW Weekly Filter Results

2. 2014 Metro Vancouver Slide Examination Results - *Cryptosporidium*.xls
   a) Table 6 – Metro Vancouver Capilano Reservoir 2014 Slide Examination *Cryptosporidium* Results
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   c) Table 8 – Metro Vancouver SCFP - RCW 2014 Slide Examination *Cryptosporidium* Results

3. 2014 Metro Vancouver Slide Examination Results – *Giardia*.xls
   a) Table 9 – Metro Vancouver Capilano Reservoir 2014 Slide Examination *Giardia* Results
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   c) Table 11 – Metro Vancouver SCFP - RCW 2014 Slide Examination *Giardia* Results

Report to Metro Vancouver
Detection of Waterborne *Giardia* and *Cryptosporidium* Study
January - December, 2014

PURPOSE

To detect and quantify *Giardia* cysts and *Cryptosporidium* oocysts present in Filta-Max filters submitted regularly by Metro Vancouver from each of Capilano and Coquitlam reservoirs, as well as Recycled Clarified Water from Seymour-Capilano Filtration Plant (SCFP-RCW).

INTRODUCTION

Giardia cysts and *Cryptosporidium* oocysts are parasites that infect the intestinal tracts of a wide range of animals. In humans, infection with *Giardia lamblia* or *Cryptosporidium* species can cause gastroenteritis. As the cyst and oocyst forms of *Giardia* and *Cryptosporidium* are resistant to chlorination, they are of great concern for drinking water purveyors (1-3). On behalf of Metro Vancouver, BC Public Health Microbiology and Reference Laboratories (BCPHMRL) is currently examining the source water of Capilano and Coquitlam reservoirs, as well as Recycled Clarified Water at the Seymour Capilano Filtration Plant for presence of *Giardia* cysts and *Cryptosporidium* oocysts. All sample collection, testing, analysis and reporting occurred on a monthly basis.

METHODS

The Environmental Microbiology Laboratory at BCPHMRL uses the United States Environmental Protection Agency (USEPA) Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA (4) for the detection of oocysts and cysts in water. Method 1623 is a performance-based method applicable to the determination of *Cryptosporidium* and *Giardia* in aqueous matrices. It requires the filtration of a large volume of water and immunomagnetic separation (IMS) to further concentration and purification the oocysts and cysts from sample material captured. Immunofluorescence microscopy is performed after the IMS procedure for identification and enumeration of oocysts and cysts, with confirmation using 4’-6-diamidino-2-phenylindole (DAPI) staining and differential interference contrast (DIC) microscopy.

Raw water samples were collected by Metro Vancouver staff at specific locations in each of the Metro Vancouver sampling sites. Water was filtered at designated sites in the reservoirs and filtration plant using IDEXX Filta-Max foam filter modules. Filters were transported to the BCPHMRL, by Metro Vancouver staff, where they were processed and analysed.

RESULTS & DISCUSSIONS

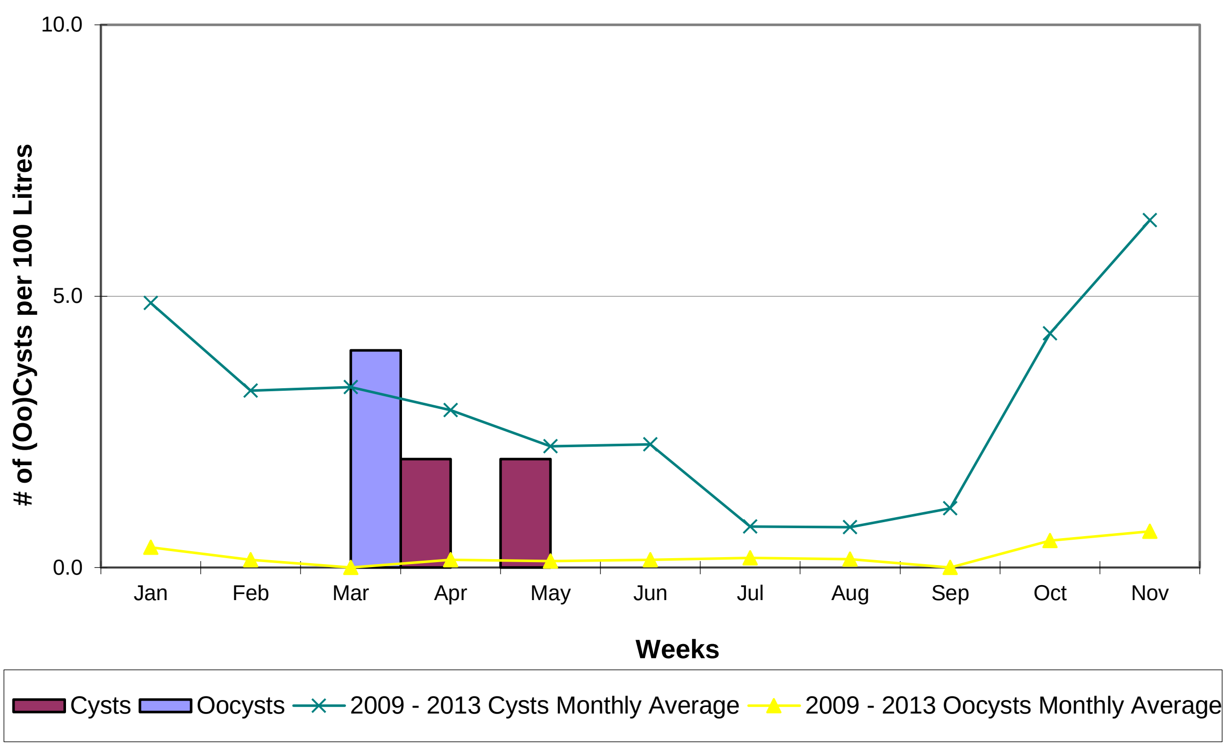
During 2014, a total of 35 Filta-Max filters were examined (excluding matrix spikes). These included:

- 11 filters from the Capilano reservoir
- 12 filters from the Coquitlam reservoir
- 12 filters from SCFP-RCW

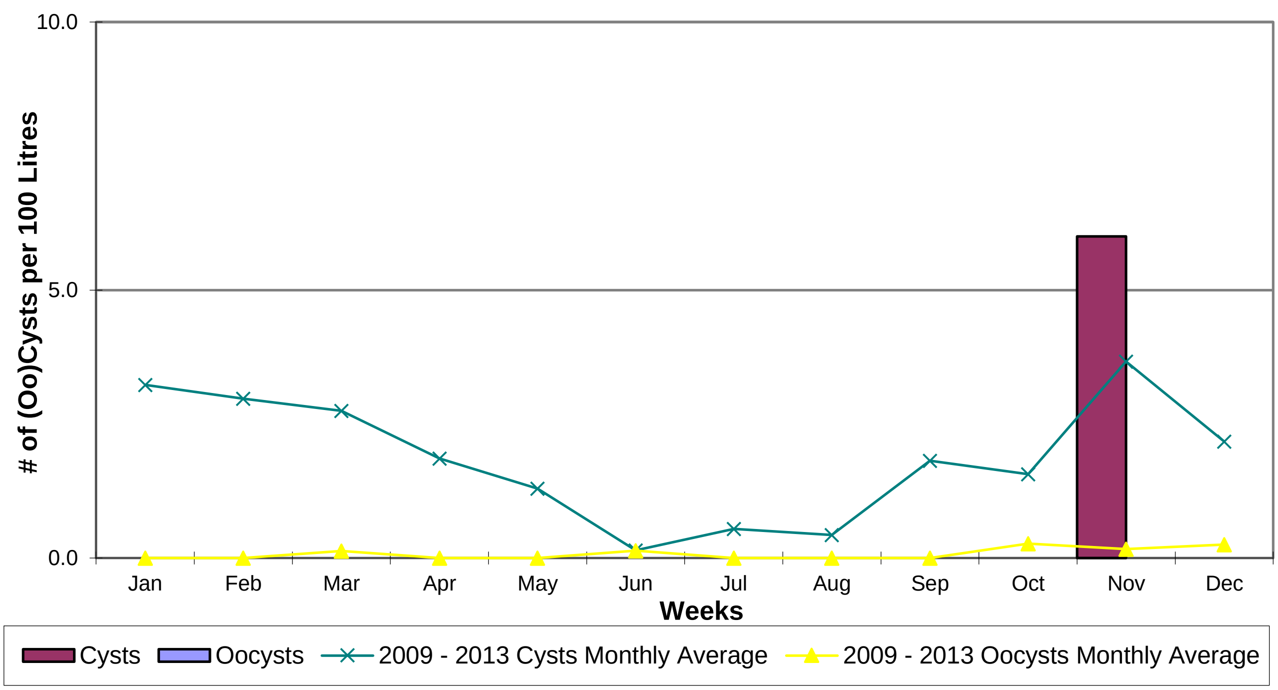
Negative and positive controls were tested as required by the Environmental Microbiology Laboratory's Quality Assurance program. Summary of our findings are presented in Graphs 1-3 and Tables 1-5. An average of 50.0 L of raw water was filtered for both Capilano and Coquitlam reservoir. Average detection limit for Capilano and Coquitlam were <2.0 and <2.2 (oo)cysts per 100 L respectively. Average volume of water filtered and detection limit for SCFP-RCW were 304.4 L and 0.5 (oo)cysts per 100 L respectively.

Giardia cysts were detected more frequently than *Cryptosporidium* oocysts. Capilano had the highest positive detection rate amongst all of the sampling sites, with *Giardia* cysts and *Cryptosporidium* oocysts at 18.2% and 9.1% respectively. In contrast, SCFP-RCW has the lowest incidence of *Cryptosporidium* oocysts and *Giardia* cysts, with none detected over 12 sampling events.

Graph 1 – 2014 Capilano Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 litres of Raw Water



Graph 2 – 2014 Coquitlam Reservoir *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 litres of Raw Water



Graph 3 - 2014 Seymour Capilano Filtration Plant - Recycled Clarified Water *Cryptosporidium* Oocysts and *Giardia* Cysts per 100 Litres of Raw Water

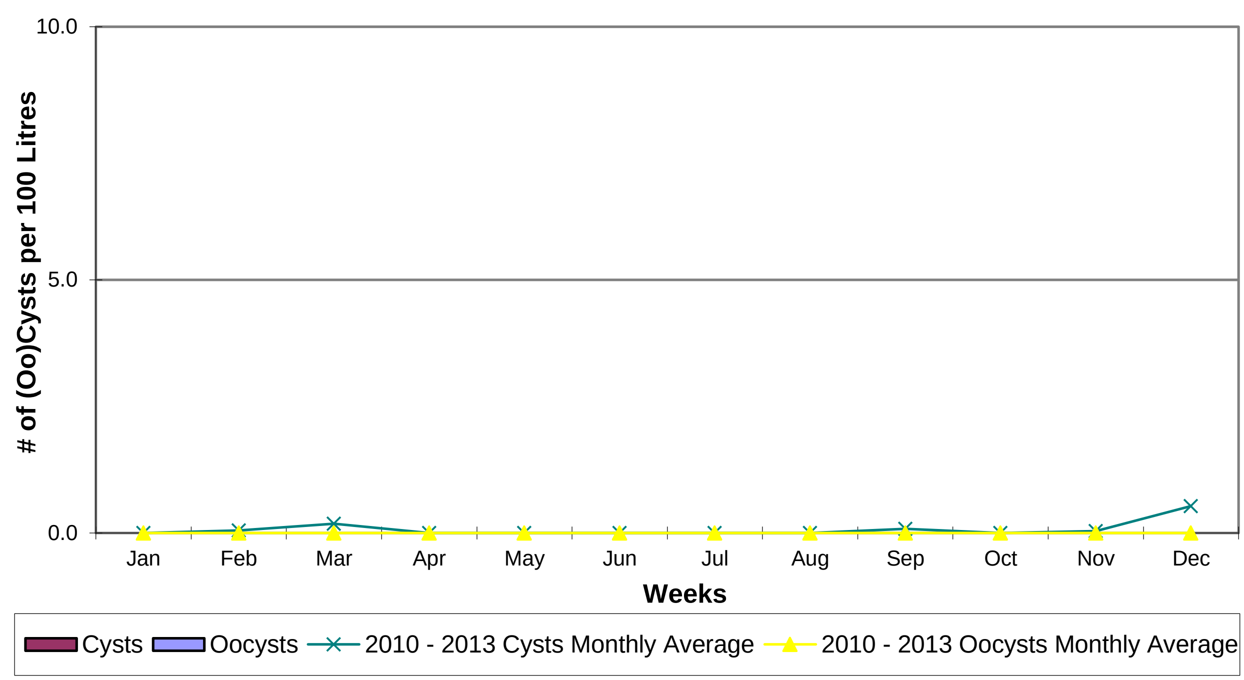


Table 1: *Giardia* and *Cryptosporidium* Percent Positives for Metro Vancouver Water Filters – 2014

	Capilano Reservoir	Coquitlam Reservoir	SCFP - RCW
Number of Water Filter Tested	11	12	12
% Filters – *Giardia* Positive	18.2%	8.3%	0.0%
% Filters – *Cryptosporidium* Positive	9.1%	0.0%	0.0%
% Filters – *Giardia* AND *Cryptosporidium* Positive	0.00%	0.0%	0.0%
% Filters – *Giardia* OR *Cryptosporidium* Positive	27.3%	8.3%	0.0%

Table 2: *Giardia* Cyst and *Cryptosporidium* Oocyst Concentrations for Positive Water Filters – 2014

Sampling Sites	# of Water Filters Tested	Average Detection Limit (oo)cysts/ 100 L	Max Detection Limit (oo)cysts/ 100L	Min Detection Limit (oo)cysts/ 100L	# of *Giardia* Positive Filters	Max # of Giardia cysts/ 100L	# of *Crypto* Positive Filters	Max # of Crypto oocysts/ 100L
All Sites	36	1.5	4.0	0.1	3	6.0	1	4.0
Capilano Reservoir	11	2.0	2.0	2.0	2	2.0	1	4.0
Coquitlam Reservoir	12	2.2	4.0	2.0	1	6.0	0	0.0
SCFP - RCW	12	0.5	1.4	0.1	0	0.0	0	0.0

Table 3: 2014 Metro Vancouver Capilano Reservoir Weekly Filter Results

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2009 - 2013 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7565	Capilano Reservoir	5-Jan-14	Jan	<2.0	0.0	0.0	50.0	4.9	0.4
2	7570	Capilano Reservoir	2-Feb-14	Feb	<2.0	0.0	0.0	50.0	3.3	0.1
3	7575	Capilano Reservoir	2-Mar-14	Mar	<2.0	0.0	4.0	50.0	3.3	0.0
4	7582	Capilano Reservoir	6-Apr-14	Apr	<2.0	2.0	0.0	50.0	2.9	0.1
5	7587	Capilano Reservoir	4-May-14	May	<2.0	2.0	0.0	50.0	2.2	0.1
6	7592	Capilano Reservoir	1-Jun-14	Jun	<2.0	0.0	0.0	50.0	2.3	0.1
7	7597	Capilano Reservoir	6-Jul-14	Jul	<2.0	0.0	0.0	50.0	0.8	0.2
8	7602	Capilano Reservoir	4-Aug-14	Aug	<2.0	0.0	0.0	50.0	0.7	0.2
9	7607	Capilano Reservoir	1-Sep-14	Sep	<2.0	0.0	0.0	50.0	1.1	0.0
10	7612	Capilano Reservoir	5-Oct-14	Oct	<2.0	0.0	0.0	50.0	4.3	0.5
11	7619	Capilano Reservoir	2-Nov-14	Nov	<2.0	0.0	0.0	50.0	6.4	0.7
				Averages	<2.0	0.4	0.4	50.0		

Table 4: 2014 Metro Vancouver Coquitlam Reservoir Weekly Filter Results.

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2009 - 2013 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7566	Coquitlam Reservoir	05-Jan-14	Jan	<4.0	0.0	0.0	50.0	3.2	0.0
2	7571	Coquitlam Reservoir	02-Feb-14	Feb	<2.0	0.0	0.0	50.0	3.0	0.0
3	7576	Coquitlam Reservoir	02-Mar-14	Mar	<2.0	0.0	0.0	50.0	2.7	0.1
4	7583	Coquitlam Reservoir	06-Apr-14	Apr	<2.0	0.0	0.0	50.0	1.9	0.0
5	7588	Coquitlam Reservoir	04-May-14	May	<2.0	0.0	0.0	50.0	1.3	0.0
6	7593	Coquitlam Reservoir	01-Jun-14	Jun	<2.0	0.0	0.0	50.0	0.1	0.1
7	7598	Coquitlam Reservoir	06-Jul-14	Jul	<2.0	0.0	0.0	50.0	0.5	0.0
8	7603	Coquitlam Reservoir	04-Aug-14	Aug	<2.0	0.0	0.0	50.0	0.4	0.0
9	7608	Coquitlam Reservoir	01-Sep-14	Sep	<2.0	0.0	0.0	50.0	1.8	0.0
10	7613	Coquitlam Reservoir	05-Oct-14	Oct	<2.0	0.0	0.0	50.0	1.6	0.3
11	7620	Coquitlam Reservoir	02-Nov-14	Nov	<2.0	6.0	0.0	50.0	3.7	0.2
12	7631	Coquitlam Reservoir	07-Dec-14	Dec	<2.0	0.0	0.0	50.0	2.2	0.3
				Averages	<2.2	0.5	0.0	50.0		

Table 5: 2014 Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water (SCFP-RCW) Weekly Filter Results.

	WF#	Site Location	Sampling Date	Month	Detection Limit (per 100L)	No. of Cysts per 100L	No. of Oocysts per 100L	Volume of Water Filtered (L)	2010 - 2013 Monthly Average	
									No. of Cysts per 100L	No. of Oocysts per 100L
1	7568	SCFP - RCW	09-Jan-14	Jan	<0.6	0.0	0.0	178.6	0.0	0.0
2	7573	SCFP - RCW	04-Feb-14	Feb	<0.4	0.0	0.0	256.9	0.1	0.0
3	7577	SCFP - RCW	04-Mar-14	Mar	<0.4	0.0	0.0	265.9	0.2	0.0
4	7584	SCFP - RCW	08-Apr-14	Apr	<0.2	0.0	0.0	423.0	0.0	0.0
5	7590	SCFP - RCW	07-May-14	May	<1.4	0.0	0.0	73.9	0.0	0.0
6	7594	SCFP - RCW	03-Jun-14	Jun	<0.5	0.0	0.0	189.4	0.0	0.0
7	7599	SCFP - RCW	07-Aug-14	Jul	<0.4	0.0	0.0	269.8	0.0	0.0
8	7605	SCFP - RCW	06-Aug-14	Aug	<0.1	0.0	0.0	791.7	0.0	0.0
9	7610	SCFP - RCW	04-Sep-14	Sep	<0.2	0.0	0.0	499.4	0.1	0.0
10	7615	SCFP - RCW	07-Oct-14	Oct	<0.3	0.0	0.0	384.6	0.0	0.0
11	7623	SCFP - RCW	04-Nov-14	Nov	<0.4	0.0	0.0	233.2	0.0	0.0
12	7636	SCFP - RCW	09-Dec-14	Dec	<1.2	0.0	0.0	86.6	0.5	0.0
				Averages	<0.5	0.0	0.0	304.4		

Results for staining by IFA, DAPI and internal morphology, as determined through DIC microscopy, for every identified cyst and oocyst were recorded. Results are attached (Tables 6-11).

Table 6: Metro Vancouver Capilano Reservoir 2014 Slide Examination *Cryptosporidium* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure Number of sporozoites
7565	Capilano Reservoir	05-Jan-14	0								
7570	Capilano Reservoir	02-Feb-14	0								
7575	Capilano Reservoir	02-Mar-14	1	round	5.2	√				√	
7575	Capilano Reservoir	02-Mar-14	2	round	4.8			3		√	
7582	Capilano Reservoir	06-Apr-14	0								
7587	Capilano Reservoir	04-May-14	0								
7592	Capilano Reservoir	01-Jun-14	0								
7597	Capilano Reservoir	06-Jul-14	0								
7602	Capilano Reservoir	04-Aug-14	0								
7607	Capilano Reservoir	01-Sep-14	0								
7612	Capilano Reservoir	05-Oct-14	0								
7619	Capilano Reservoir	02-Nov-14	0								

Table 7: Metro Vancouver Coquitlam Reservoir 2014 Slide Examination *Cryptosporidium* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure Number of sporozoites
7566	Coquitlam Reservoir	05-Jan-14	0								
7571	Coquitlam Reservoir	02-Feb-14	0								
7576	Coquitlam Reservoir	02-Mar-14	0								
7583	Coquitlam Reservoir	06-Apr-14	0								
7588	Coquitlam Reservoir	04-May-14	0								
7593	Coquitlam Reservoir	01-Jun-14	0								
7598	Coquitlam Reservoir	06-Jul-14	0								
7603	Coquitlam Reservoir	04-Aug-14	0								
7608	Coquitlam Reservoir	01-Sep-14	0								
7613	Coquitlam Reservoir	05-Oct-14	0								
7620	Coquitlam Reservoir	02-Nov-14	0								
7631	Coquitlam Reservoir	07-Dec-14	0								

Table 8: Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water 2014 Slide Examination *Cryptosporidium* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (μm)	DAPI –	DAPI +		D.I.C.		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Oocysts with internal structure Number of sporozoites
7568	SCFP-RCW	09-Jan-14	0								
7573	SCFP-RCW	04-Feb-14	0								
7577	SCFP-RCW	04-Mar-14	0								
7584	SCFP-RCW	08-Apr-14	0								
7590	SCFP-RCW	07-May-14	0								
7594	SCFP-RCW	03-Jun-14	0								
7599	SCFP-RCW	07-Aug-14	0								
7605	SCFP-RCW	06-Aug-14	0								
7610	SCFP-RCW	04-Sep-14	0								
7615	SCFP-RCW	07-Oct-14	0								
7623	SCFP-RCW	04-Nov-14	0								
7636	SCFP-RCW	09-Dec-14	0								

Table 9: Metro Vancouver Capilano Reservoir 2014 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
											Cysts with internal structure		
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Number of nuclei	Median Body	Axoneme
7565	Capilano	Jan 05, 14	0										
7570	Capilano	Feb 02, 14	0										
7575	Capilano	Mar 02, 14	0										
7582	Capilano	Apr 06, 14	1	oval	12.8 x 9.6	✓			✓				
7587	Capilano	May 04, 14	1	oval	12.8 x 9.6	✓				✓			
7592	Capilano	Jun 01, 14	0										
7597	Capilano	Jul 06, 14	0										
7602	Capilano	Aug 04, 14	0										
7607	Capilano	Sep 01, 14	0										
7612	Capilano	Oct 05, 14	0										
7619	Capilano	Nov 02, 14	0										

Table 10: Metro Vancouver Coquitlam Reservoir 2014 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Cysts with internal structure		
											Number of nuclei	Median Body	Axoneme
7566	Coquitlam	Jan 05, 14	0										
7571	Coquitlam	Feb 02, 14	0										
7576	Coquitlam	Mar 02, 14	0										
7583	Coquitlam	Apr 06, 14	0										
7588	Coquitlam	May 04, 14	0										
7593	Coquitlam	Jun 01, 14	0										
7598	Coquitlam	Jul 06, 14	0										
7603	Coquitlam	Aug 04, 14	0										
7608	Coquitlam	Sep 01, 14	0										
7613	Coquitlam	Oct 05, 14	0										
7620	Coquitlam	Nov 02, 14	1	oval	8.8 x 6.8	✓				✓			
7620	Coquitlam	Nov 02, 14	2	oval	9.0 x 6.0	✓				✓			
7620	Coquitlam	Nov 02, 14	3	oval	15.0 x 9.5	✓				✓			
7631	Coquitlam	Dec 07, 14	0										

Table 11: Metro Vancouver Seymour Capilano Filtration Plant - Recycled Clarified Water 2014 Slide Examination *Giardia* Results.

Lab No.	Site Sampled	Date	Object located by FA	Shape (oval or round)	Size L x W (µm)	DAPI –	DAPI +		D.I.C.				
						Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Number of nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Cysts with internal structure		
											Number of nuclei	Median Body	Axoneme
7568	SCFP-RCW	Jan 09, 14	0										
7573	SCFP-RCW	Feb 04, 14	0										
7577	SCFP-RCW	Mar 04, 14	0										
7584	SCFP-RCW	Apr 08, 14	0										
7590	SCFP-RCW	May 07, 14	0										
7594	SCFP-RCW	Jun 03, 14	0										
7599	SCFP-RCW	Jul 08, 14	0										
7605	SCFP-RCW	Aug 06, 14	0										
7610	SCFP-RCW	Sep 04, 14	0										
7615	SCFP-RCW	Oct 07, 14	0										
7623	SCFP-RCW	Nov 04, 14	0										
7636	SCFP-RCW	Dec 09, 14	0										

While the primary purpose of the DAPI stain was to confirm the presence of *Giardia* cyst and *Cryptosporidium* oocyst, it can also serve as an indicator of nuclei integrity of cyst/oocyst as it indicates the presence of DNA. DAPI staining results of the cysts differ between each sampling sites (Table 12). Since the vast majority of cysts examined from Capilano and Coquitlam reservoirs were DAPI negative, this may indicate that most of the cysts detected were either aged or damaged.

Table 12: Summary of morphological results for *Giardia* cysts observed under fluorescence microscope.

Site	Total	DAPI -	DAPI +		D.I.C.				
							Cysts with internal structure		
		Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Nuclei stained sky blue	Empty cysts	Cysts with amorphous structure	Nuclei	Median body	Axoneme
Capilano	2	2 (100%)	0 (0.0%)	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Coquitlam	3	3 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	3 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
SCFP-RCW	0	0 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0(0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

Use of DIC microscopy is also primary for *Giardia* cyst and *Cryptosporidium* oocyst confirmation; however it can also serve as an indicator of cyst/oocysts' cytoplasm and cell wall integrity. As is similar to DAPI staining, no internal structure was observed for all cysts detected. One of the cysts observed also had no visible cytoplasm (empty cyst), thus indicating this cyst was no longer viable.

In contrast to *Giardia* cysts, a larger proportion of *Cryptosporidium* oocysts detected in Capilano and Coquitlam reservoirs contained visibly stained nuclei (Table 13 & 14). The differences in DAPI stained nuclei rates between *Giardia* cysts and *Cryptosporidium* oocysts likely reflects that *Cryptosporidium* oocysts are more resistant to environmental stresses than *Giardia* cysts, allowing oocysts to remain viable for longer periods in the environment. It should be noted that as only 2 oocysts were detected in all samples, true comparison to *Giardia* cysts cannot be made.

Table 13: Summary of morphological results for *Cryptosporidium* oocysts observed under fluorescence microscope.

Site	Total	DAPI -	DAPI +		D.I.C.		
							Oocysts with internal structure
		Light blue internal staining, no distinct nuclei, green rim	Intense blue internal staining	Nuclei stained sky blue	Empty oocysts	Oocysts with amorphous structure	Number of sporozoites
Capilano	2	1 (100.0%)	0 (0.0%)	1 (100.0%)	0 (0.0%)	2 (100.0%)	0 (0.0%)
Coquitlam	0	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
SCFP-RCW	0	-	-	-	-	-	-

Table 14: Comparisons of number of nuclei in each *Giardia* cysts and *Cryptosporidium* Oocysts between different sites.

Number of Nuclei	*Giardia* Cysts			*Cryptosporidium* Oocysts		
	Capilano	Coquitlam	SCFP-RCW	Capilano	Coquitlam	SCFP-RCW
0*	2 (100.0%)	3 (100.0%)	-	1 (50.0.0%)	-	-
1	0 (0.0%)	0 (0.0%)	-	0 (0.0%)	-	-
2	0 (0.0%)	0 (0.0%)	-	0 (0.0%)	-	-
3	0 (0.0%)	0 (0.0%)	-	1 (50.0%)	-	-
4	0 (0.0%)	0 (0.0.0%)	-	0 (0.0%)	-	-
Total # of (oo)cysts	2	3	0	2	1	0

* DAPI negative or only intense blue internal staining of cytoplasm.

Due to the variations of water chemistry and organic matters between geographical area and temporally within each sampling sites, a matrix spike that provides recovery rate estimation from each site was performed annually. The results of matrix spike recovery results are compiled in Table 15. As the results showed, matrix recovery rates fluctuate from year to year even within each site. This variation is not uncommon for the test and has been noted in EPA's Method 1623.

Table 15: Matrix water results from 2006 through 2014.

Year	Capilano		Coquitlam		SCFP-RCW	
	Cysts	Oocysts	Cysts	Oocysts	Cysts	Oocysts
2006	27.3%	7.1%	18.0%	10.0%	-	-
2007	37.4%	27.6%	54.0%	28.0%	-	-
2008	55.0%	25.0%	39.0%	28.0%	-	-
2009	40.0%	10.0%	37.0%	16.0%	-	-
2010	43.0%	28.0%	49.0%	26.0%	13.0%	17.0%
2011	44.0%	27.0%	47.0%	22.0%	0.0%	1.0%
2012	76.5%	38.4%	49.0%	35.0%	13.7%	7.0%
2013	59.4%	22.4%	64.4%	16.3%	14.9%	6.12%
2014	*-	*-	39.4%	55.0%	14.1%	18.0%

- no matrix sample collected

SUMMARY

These *semi-quantitative* data (reported oocyst and cyst levels) should be interpreted with caution as current standard laboratory methods for detecting and analysing parasites in water matrices are known to be imprecise, with recovery rates fluctuating widely depending on the water matrix.

In brief, we report that:

1. *Cryptosporidium* oocysts were detected sporadically from Capilano reservoir' raw water (9.1% of filters). *Cryptosporidium* oocysts were not detected in Coquitlam reservoir and SCFP-RCW.

2. *Giardia* cysts were detected in filters from Capilano and Coquitlam sampling sites. Cysts were present in 18.2% of raw water filtered from Capilano and 8.3% from Coquitlam. *Giardia* cysts were not detected from SCFP-RCW.

3. The highest level of *Giardia* cysts detected during 2014 was from Coquitlam reservoir at 6.0 per 100 L. Concentrations of *Cryptosporidium* oocysts were low for all sample sites, with a maximum of only 4.0 per 100 L for Capilano.

4. Most of the *Giardia* cysts detected appeared to have aged having succumbed to environmental degradation. The *Cryptosporidium* oocysts detected, in contrast, retained more of their nuclei and internal structure integrity.

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