

**A Comparison of Water Quality and Fecal Coliform in Water Samples from
Six Rivers in King, Pierce, and Thurston Counties in Washington State**

Mele Vulangi

Senior Seminar

Saint Martin's University

Table of Contents

Table of Contents.....	2
Abstract.....	3
Introduction.....	3
Methods & Materials.....	11
Results.....	15
Discussion.....	17
Acknowledgements.....	21
Literature Cited.....	22

Abstract

High fecal coliform (fecal bacteria that show presence of waterborne diseases) levels and low water quality for rivers increase the chance of waterborne diseases. Fecal coliform can lead to diseases such as typhoid fever, Traveler's diarrhea, and Asiatic cholera. As a natural resource of water, rivers need to maintain low levels of fecal coliform and high water quality. In this study, I hypothesized that there would be an increase of fecal coliform levels and low water quality in rivers from King County compared to rivers of Pierce and Thurston Counties. Fecal coliform along with other water quality tests such as turbidity, nitrates, pH, dissolved oxygen (D.O), and biochemical oxygen demand (B.O.D.) were measured. Two rivers from each county were sampled by collecting three replicates per river. According to the results obtained from the fecal coliform tests, there were no significant differences among the rivers ($p=0.605$) or the three counties ($p=0.588$). There were also no differences found in the turbidity, nitrates, pH, and D.O. results. However, there were significant differences from the B.O.D. results among the rivers ($p=0.011$) but none among the counties ($p=0.734$). Due to the low values in water quality and fecal coliform, the water qualities for these rivers are overall in good condition. Most of the rivers meet the required optimal levels for the water quality tests and the fecal coliform counts are very low.

Introduction

One of the many beneficial aspects of living in America is the availability of clean water. Water quality in the United States has been an important factor for over a century. Brown (1893), Stoiler (1893), Krauss (1897), and Tucker (1892) detail research dating as far back as 1870 that were written in regards to America's water supply and discuss the importance of having clean water supplies to obtain clean drinking water. We have made major technological advances in

our water filtration systems and purification processes. As a country, we have obtained many processes to eliminate high levels of bacterial contamination in our water supplies. Although bacterial contamination found in drinking water in the United States is highly unlikely due to water treatment facilities, water drawn from rivers, streams, or lakes may contain damaging microorganisms such as bacteria, viruses, and parasites (Meehan, 1991). These microorganisms are known to cause diseases such as typhoid fever, Traveler's diarrhea, and Asiatic cholera (Cooke, 1914). To ensure quality water, a variety of standards are set which enable researchers to test water samples and gather pertinent information dealing with our drinking water. This information measures such things as dissolved oxygen for aquatic organisms, river acidity, temperature, and the presence of harmful bacteria, such as *Escherichia coli* (Meehan, 1991).

We have six natural sources from which we obtain our water supply: rivers, lakes, springs, wells, oceans, and rain water (Cooke, 1914). Water from rivers and lakes originate from pure springs, but with a growing population in the early 1900s, the rivers and lakes became polluted (Cooke, 1914). Spring and well water are closely related in their purity, although differing in the presence of salts (Cooke, 1914). The purest form of well water comes from artesian wells, in which the well is man-made and the water flows from natural pressure without pumping. Artesian wells cannot be used too freely because they contain excessive amounts of mineral matter that can cause damage to the kidneys (Cooke, 1914). Seawater contains large amounts of atmospheric gases and salts, and rain water is found to be the purest of all sources of our water supply, but only at the moment of condensation (Cooke, 1914).

There are two types of impurities that may be found in water: organic and inorganic (Cooke, 1914). Organic impurities include either dead organic material or living organisms. Inorganic impurities include gaseous impurities such as hydrogen sulfide and sulfur dioxide

(Cooke, 1914). Bacteria are found in all these sources of water and their presence can be hazardous to our health. I tested for organic impurities such as fecal coliform bacteria because inorganic impurities mainly take the gaseous state and are difficult to measure accurately. Fecal bacteria show the presence of water-borne pathogenic bacteria, such as *E. coli* (Meehan, 1991).

A group of researchers from Virginia studied the Blackwater River watershed to identify sources of fecal pollution (Booth *et al.*, 2003). Located in Franklin County, south-central Virginia, Blackwater River watershed contains many possible sources of fecal bacteria. Surrounding this watershed is an abundance of wildlife, private septic systems, and the third highest population of dairy cattle in the state. Before collecting the water samples, these researchers used antibiotic resistance analysis (ARA) as a tracking method for bacteria, to produce a bacteria profile library of the various fecal bacteria. They then compared these fecal bacteria to ones collected in the water samples (Booth *et al.*, 2003).

The profile library consisted of livestock, wildlife, and human fecal samples (Booth *et al.*, 2003). Depending upon its form, solid or liquid, the fecal samples collected from various areas of Franklin County, Virginia were placed into separate containers. Solid fecal material was placed in sterilized Whirlpac™ bags, or Petri plates, and liquid samples were collected in sterilized polystyrene bottles (Booth *et al.*, 2003). After collection, the samples were placed on ice and transported to the lab. To isolate *Enterococci* (a nonpathogenic form of fecal *streptococci* in the intestine) from these bacteria, researchers diluted 10 grams of the solid samples or 10 milliliters of the liquid fecal samples, one to four times in a sterile phosphate buffer (Booth *et al.*, 2003). Preceding incubation at 37° C for 48 hours, 0.1 mL of each dilution was placed and spread twice on *mEnterococcus* (type of *enterocci* agar) agar (Booth *et al.*, 2003). Water samples were collected in sterile 250 mL polystyrene bottles, packed in a cooler and transported back to

the lab (Booth *et al.*, 2003). Filtering occurred on the same day and was screened for *E. coli* using a system called Colilert (Booth *et al.*, 2003). Four samples were taken from the 6 sub-watersheds of Blackwater River.

The researchers found the ARA bacterial source tracking method was a very effective tool in analyzing sources of fecal coliform bacteria by the high rates of correct classification from the profile library (Booth *et al.*, 2003). They also found the samples taken from Blackwater River contained fecal coliform from livestock, wildlife, and human sources (Booth *et al.*, 2003). This paper relates to the development of my hypothesis by showing if rivers were located in a more industrialized or farmland area, fecal coliform may be present. Periodically, the Virginia Department of Environmental Quality monitors the Blackwater River and performs a variety of the water quality tests mentioned in the previous paragraphs. These tests included temperature, pH, dissolved oxygen, and nitrate levels (Booth *et al.*, 2003), which were the tests I performed to compare water quality in the South Puget Sound, Tacoma, and Seattle areas.

Dissolved oxygen (D.O.) is a crucial water quality parameter for characterizing the health of an aquatic system (Meehan, 1991). It is a measurement of oxygen dissolved in water that is available for fish and other aquatic life (Meehan, 1991). An experiment was performed on 14 stream sites across Alum Fork, Arkansas of the Saline River drainage by Love *et al.* (2005). Most of the areas sampled ranged from being completely altered by humans to a more natural surrounding, with little to no human tampering. Samples were collected and measured for dissolved oxygen during midday. Using the Yellow Springs Instrument Model 85, dissolved oxygen was measured in milligrams per liter (Love *et al.*, 2005). River volume, width, length, and depth were calculated to give a more accurate measurement of dissolved oxygen. Macroinvertebrates were collected using two instruments specifically designed for collecting

them; 1) D-frame sweep nets and, 2) Hester-Dendy samplers (Love *et al.*, 2005). The sweep nets covered all possible habitats of microorganisms and the Hester-Dendy samplers were secured to metal stakes and anchored in the stream (Love *et al.*, 2005). The researchers found this method very effective because they left the samplers in the stream for one month. If insects were found, they were placed in 70% ethanol mixed with Rose Bengal dye for preservation, and using Merritt and Cummins (1984), they were able to identify the aquatic insects (Love *et al.*, 2005). Using Gee minnow traps, double-ended wire traps that were clipped together, fish were sampled for 48 hours and the traps were checked and rotated after 24 hours (Love *et al.*, 2005). Fish were identified and before released; their fins were clipped to ensure recapturing would not occur.

The researchers found that the dissolved oxygen levels from each of the pools ranged from 3.54 to 8.23 mg/l (Love *et al.*, 2005). The acceptable optimal level of dissolved oxygen ranges from 7-8 mg per liter (Meehan, 1991). Therefore, if dissolved oxygen levels were below three milligrams per liter, most forms of aquatic life had a reduced chance of survival. If the water quality is harmful for aquatic creatures to live, there is a high probability that it is unhealthy for drinking (Meehan, 1991). Based on the findings of this experiment, when I tested a stream for dissolved oxygen, I compared the acceptable optimal levels of dissolved oxygen to the levels gained by sampling. I also assumed a river within vicinity of a drainage site may alter dissolved oxygen levels. Love *et al.* (2005) did not mention turbidity and nitrates tests, though I measured both in my study.

Turbidity accounts for solids in water that reduce the transmission of light through absorption or scattering (Meehan, 1991). A team of researchers from New Zealand examined the influence of turbidity on fish abundance and depth distribution (Rowe *et al.*, 2003). The researchers sampled five lakes in New Zealand; Tekapo, Pukaki, Ruataniwha, Hawea, and

Wanaka (Rowe *et al.*, 2003). All lakes except Lake Ruataniwha, were formed by glacial action (Rowe *et al.*, 2003). Lake Ruataniwha was an artificial reservoir that Pukaki and Tekapo flowed into and was the only lake, out of the five, that was not relatively deep and not oligotrophic, which was high oxygen content due to low organic content (Rowe *et al.*, 2003).

In order to sample the fish, these researchers deployed minnow traps in the littoral zone (pertaining to the shore) of each lake from depths of 0.5 m to 30 m (Rowe *et al.*, 2003). Baited with yeast extract, the traps were set at intervals along a rope. Trapping was performed in three to four areas in the main basin of the lake (Rowe *et al.*, 2003). Traps were left in the lakes overnight and raised the next morning. The fish were then identified and recorded.

Data were analyzed using an analysis of variance (ANOVA) and Tukey post hoc tests (Rowe *et al.*, 2003). In regards to turbidity, these researchers found the koaro fish were 3 to 20 times more abundant in the turbid lakes, which were Pukaki and Tekapo, than in the clear lakes, Wanaka and Hawea (Rowe *et al.*, 2003). Trout, the main predator of koaro, were greatly decreased in numbers because of the high turbidity levels in the waters (Rowe *et al.*, 2003). Most aquatic organisms such as trout were unable to adapt to such high turbidity levels, thus causing their numbers to be reduced and their prey, the koaro, numbers to be increased. This experimental research supports the development of my hypothesis by showing some organisms preferred to live in turbid waters to escape predators. However, in terms of drinking water, high levels of turbidity suggest there is an abundant amount of suspended solids that may endanger our health, as well as other organisms.

Although I conducted several water quality tests, my main focus was fecal coliform bacteria in water systems that may serve as a source for drinking water. Dorner *et al.* (2004) conducted an experiment to determine sources of pathogenic bacteria in a primary water supply.

Located in southwest Ontario, the Grand River watershed served as a direct drinking water supply to more than 500,000 people and was used for both home and agricultural use (Dorner *et al.*, 2004). Possible sources of pathogenic contaminants included runoff from home owners and agricultural estates, livestock that had direct access to the river, and wildlife (Dorner *et al.*, 2004). The sampling points were selected to obtain concentrations upstream and downstream of major possible pathogenic sources (Dorner *et al.*, 2004).

Samples were taken from four sub-watershed locations: Canagagigue Creek, Conestogo River, Grand River north, and Grand River south (Dorner *et al.*, 2004). Canagagigue Creek receives treated wastewater from Elmira, a town of approximately 8,000 people and the Conestogo River received wastewater from St. Jacobs, a town with a population of 1,400 people (Dorner *et al.*, 2004). The other areas tested were upstream of the Mannheim Water Treatment Plant and upstream of the city of Brantford. Water treated in the Mannheim Plant was mixed with groundwater and the entire water supply of the city of Brantford came from the Grand River (Dorner *et al.*, 2004). The sources of pathogenic bacteria were clear and water samples were collected every week. They were analyzed for total coliform, fecal coliform, temperature, dissolved oxygen, turbidity, pH, and nitrate concentrations (Dorner *et al.*, 2004).

Water samples were collected in one liter sterilized glass bottles to ensure that no disturbance of silt from the bottom occurred. Much like the other experiments, the samples were placed on ice, taken back to laboratories for analysis, and transferred to a 4° C refrigerator (Dorner *et al.*, 2004). Quantification of bacteria that were discovered was conducted using the Method 9221 of Standard Methods for the Examination of Water and Wastewater (Dorner *et al.*, 2004). *E. coli* was determined by a filtration process and was verified by injection into lauryl tryptose broth (Dorner *et al.*, 2004).

The researchers found both *E. coli* and *Campylobacter* were not present in any of the water samples (Dorner *et al.*, 2004). They also found there were no differences between fecal coliform numbers upstream and downstream of any of the wastewater treatment plants. This experiment supports the development of my hypothesis by showing evidence that there may be no differences of fecal coliform growth in the rivers of the three counties that I tested that have water treatment plants nearby. If I tested a river that had been treated, my results may have contained no fecal coliform bacteria.

For this research project, I collected water samples from two rivers in King, Pierce, and Thurston counties, for a total of six rivers and analyzed them for fecal coliform growth. I also conducted other water quality tests such as nitrates, temperature, dissolved oxygen, pH, biochemical oxygen demand, and turbidity. Nitrate tests determine levels of nitrates contained in the river that can synthetically increase plant growth, which in turn speeds up the aging process of an aquatic system (Meehan, 1991). Nitrate levels should be below one milligram per liter. Optimal temperature levels for a stream or river should be no higher than 18°C and the colder the water is, the more dissolved oxygen it can hold. Dissolved oxygen, or D.O., measures the amount of oxygen dissolved in the water that is available to fish along with other aquatic organisms. Optimal levels for D.O. are 7 to 8 milligrams per liter, and anything lower than 3 mg/L is too stressful for most invertebrates (Meehan, 1991). The pH tests measure the quantity of concentration of ions contained in the river and should be between 6.5 to 8.5, and no less than a pH of 6.5. Biochemical oxygen demand, or B.O.D., tests, according to Meehan (1991) measures the oxygen consumed by the respiration of microorganisms that feed on decaying organic material, such as algae or other dead plants. The B.O.D. of rivers should not be higher than 6 mg/L or higher, because this is an intolerable level of oxygen demand. Finally, turbidity

measures the amount of light passing through the solids contained in the river (Meehan, 1991). The more solids contained in the river, the less light passes through. Turbidity is measured in Jackson Turbidity Units, or JTUs, and the optimal level of turbidity should not be higher than 5 JTUs (Meehan, 1991).

Using these six parameters for testing water quality and fecal coliform, I tested rivers of King, Pierce, and Thurston counties. In my research experiment, I tested these parameters and focused primarily on fecal coliform, such as *E. coli.*, contained in the rivers. I chose the specific rivers due to their location and collected samples randomly in areas of the river. King County is surrounded by abundance of industrial areas and according to the U.S Census Bureau (2005); it hosts a population of about 1,793,583 out of 6,287,759 in Washington State. Pierce County has an estimated 753,787 people and Thurston has an estimated 228,867 people (Census Bureau, 2005). Due to the high population and more industrialized areas in the county, I hypothesized King County rivers would contain a higher fecal colony count and a lower water quality compared to the lower populated counties of Pierce and Thurston.

Materials and Methods

For the experimental portion of my research, there were six sampling units and these units consisted of six different rivers. Specifically, there were 2 rivers located in three different counties; King, Pierce, and Thurston Counties; Green and Cedar River of King County, Puyallup and White River of Pierce County, and the Deschutes and Nisqually River of Thurston County. Before any tests were conducted, I made observations of each river's surroundings. Most sampling areas of the rivers were located near residential areas. They were surrounded by many trees and tall grass and most had many ducks. Logs and fallen branches were also in the river and there was an accumulation of tree debris surrounding the edges.

Collecting the Samples

I used eight sterile glass bottles to collect the replicates used for the dissolved oxygen (D.O.), biochemical oxygen demand (B.O.D.), and fecal coliform tests for each river (Booth *et al.*, 2003). I used two plastic 500 mL containers to collect water samples used for the pH, nitrates, and turbidity tests. Samples from each county were taken over a course of two weeks, sampling two rivers a week. I used three sterile glass bottles for each D.O. and B.O.D. test and two sterile glass bottles for the fecal coliform tests. The two plastic 500 mL bottles were used for the nitrates, turbidity, and pH tests. Arriving at my test site, I walked into the river approximately two meters and at about 0.5 meters in depth, rinsed the 8 bottles and their caps three times with the river water, and filled them to make sure no bubbles were present. All bottles were placed in the cooler for further testing. Sampling was conducted in random areas of the river to ensure samples were not biased and that it granted an equal amount of variability between the rivers (Heath, 1994).

River Site Tests

At the river sites, I conducted temperature and D.O. tests. By placing two thermometers in the river for approximately two minutes, river temperature was determined. For the D.O. tests, I rinsed three bottles with river water and filled them without the presence of bubbles. I returned to the river bank and used the LaMotte Test Kit to conduct the D.O. tests. To the first bottle, I added 8 drops of manganous sulfate and 8 drops of alkaline potassium iodide, capped, and mixed the bottle. While mixing, the sample contained somewhat of a brown precipitate and once it settled, 8 drops of sulfuric acid was added to the bottle then it was capped and mixed once again (LaMotte Company, 1994). I filled the titration tube provided in the kit to the suggested line and capped it. According to the directions given by LaMotte Company (1994), the titrator, a specific

kind of tube used for titrating chemicals, was filled with sodium thiosulfate and was added one drop at a time to my sample. Each addition required me to swirl the tube until a faint yellow color was present. The titrator and cap were removed and 8 drops of starch indicator solution was added (LaMotte Company, 1994). I replaced the titrator and cap, and continued to add sodium thiosulfate, drop wise, to my sample until the blue color disappeared. I read the titrator scale for my results and recorded my observations. I performed these procedures two more times with the other two bottles of samples and calculated the average D.O. for each river. The bottles were placed in the cooler to dispose of in the laboratory and three other sterile glass bottles were rinsed and filled with river water ensuring no added bubbles were present. These bottles were then wrapped in foil and placed in the cooler to be tested for B.O.D. after 5 days of collection.

Laboratory Tests

Nitrates Test:

For the nitrates test, according to LaMotte Company (1994), I filled the provided sample bottle and a test tube to the required line with my sample. I then diluted the tube with Mixed Acid Reagent to the suggested line, capped it, and waited for 2 minutes. Using the 0.1 g spoon, I added 1 measurement of Nitrate Reducing Reagent to the tube, capped it, inverted it gently 60 times for 1 minute, and then waited 10 minutes for the reaction to take place (LaMotte Company, 1994). I placed the tube into the comparator, a device containing tubes with different colored liquids lined with numerical values, and compared my sample color to one that was in the comparator. I recorded my numbers and repeated this test two more times.

Turbidity Test:

For the turbidity tests I used the LaMotte test kit which required me to fill one turbidity column to the required line with my sample water. There were two turbidity columns in the kit

and they each contained a black dot on the bottom. If the black dot was not visible after pouring my sample in one of the columns, I needed to pour out the sample to the next suggested line (LaMotte Company, 1994). Using distilled water, I filled the other turbidity column with the same amount as my sample column. I placed the columns side by side and recorded any differences of clarity. According to the LaMotte Company (1994), if the black dot was equally visible in both columns, then turbidity was zero. If the black dot was not visible, I needed to vigorously shake the Standard Turbidity Reagent provided in the kit and add 0.5mL to the column with distilled water. Using the stirring rod, I mixed the mixture and checked the amount of turbidity by looking at the black dot (LaMotte Company, 1994). I continued this process until the distilled water column had an equal amount of turbidity as my sample.

pH Test:

For the pH tests, I filled a test tube with my sample to the required line and holding the provided bromothymol blue indicator bottle upright, I added 8 drops to the tube, capped, and mixed it (LaMotte Company, 1994). I placed the tube into an octet comparator provided in the kit and compared the color of my sample to the colors of the comparator. I recorded my results and repeated this test two more times.

Fecal coliform Test:

For the fecal coliform testing, I used three samples of 100 mL of river water from the three sterile glass bottles. Each sample was filtered onto gridded filter paper and transferred by sterile forceps to a sterile Petri dish that contained 2 mL of nutrient broth, which assisted growth of *Escherichia coli*. The three dishes were incubated at 44°C and colonies were counted after 24 hours (Dorner *et al.*, 2004). I also sampled Hicks and Chambers Lake of Thurston County as a comparison of fecal coliform between rivers and lakes.

B.O.D. Test:

For the B.O.D. tests, I unwrapped the foil from the bottles and once again conducted a D.O. test after five days of collection. I recorded the average of the three bottles and subtracted this D.O. number from the D.O. recorded from the river site five days earlier. This number was the B.O.D. I recorded all data in a table similar to Table 1.

Table 1. Data sheet for water quality tests conducted on rivers in King, Pierce, and Thurston Counties.

	King		Pierce		Thurston	
	Green	Cedar	Puyallup	White	Deschutes	Nisqually
D.O.						
Temperature						
Nitrates						
Turbidity						
pH						
Fecal Coliform						
B.O.D.						

Data Analysis

Data were statistically analyzed using a Fully Nested ANOVA test conducted in Minitab® (2005) to see if statistical differences were found for each parameter among the rivers and the three counties.

Results

Turbidity, pH, and Nitrates

After conducting the turbidity, pH, and nitrates tests on the six specified rivers, the averages taken from these tests showed no drastic differences among the rivers and counties (Table 2). For all rivers except Puyallup, turbidity was 0 JTU. According to the Nested ANOVA test conducted with Minitab® (2005), there were no statistical differences for the turbidity results among the rivers ($F = 49$; d.f. = 3; $p = 0.05$) or the three counties ($F = 1$; d.f. = 2; $p = 0.465$). The

pH tests performed on the rivers measured pH values between 7.0 and 7.5. The Nested ANOVA test showed there were no statistical differences for the pH results among the rivers ($F = 13$; d.f. = 3; $p = 0.05$) or the counties ($F = 0.538$; d.f. = 2; $p = 0.631$). As shown in Table 2, the average nitrate levels among the rivers, with the exception of Cedar, were at a constant level of 1.1 mg/L. The Nested ANOVA test showed there were no statistical differences for the nitrates results among the rivers ($F = 1$; d.f. = 3; $p = 0.426$) or counties ($F = 1$; d.f. = 2; $p = 0.465$).

Table 2. Water quality tests conducted on six specified rivers in Washington State. Puyallup had the highest JTU value for turbidity. Mean pH was similar for all rivers. Data are means of 3 replicate samples for each river.

County	River	Turbidity (JTUs)	pH	Nitrates (mg/L)
King	Green	0	7.2	1.1
	Cedar	0	7.2	1.5
Pierce	Puyallup	11.7	7	1.1
	White	0	7.2	1.1
Thurston	Deschutes	0	7.2	1.1
	Nisqually	0	7.2	1.1

Dissolved Oxygen (D.O.), Biochemical Oxygen Demand (B.O.D.), and Fecal Coliform

After conducting the D.O. and B.O.D. tests, differences were found only with B.O.D. (Figure 1). According to the Nested ANOVA test conducted on the D.O. values, there were no statistical differences among the rivers ($F = 0.925$; d.f. = 3; $p = 0.458$) and King, Pierce, and Thurston counties ($F = 3.583$; d.f. = 2; $p = 0.160$). However, the B.O.D. levels obtained from the samples were significantly different among the rivers ($F = 5.816$; d.f. = 3; $p = 0.011$), but showed no statistical differences among the counties ($F = 0.343$; d.f. = 2; $p = 0.734$).

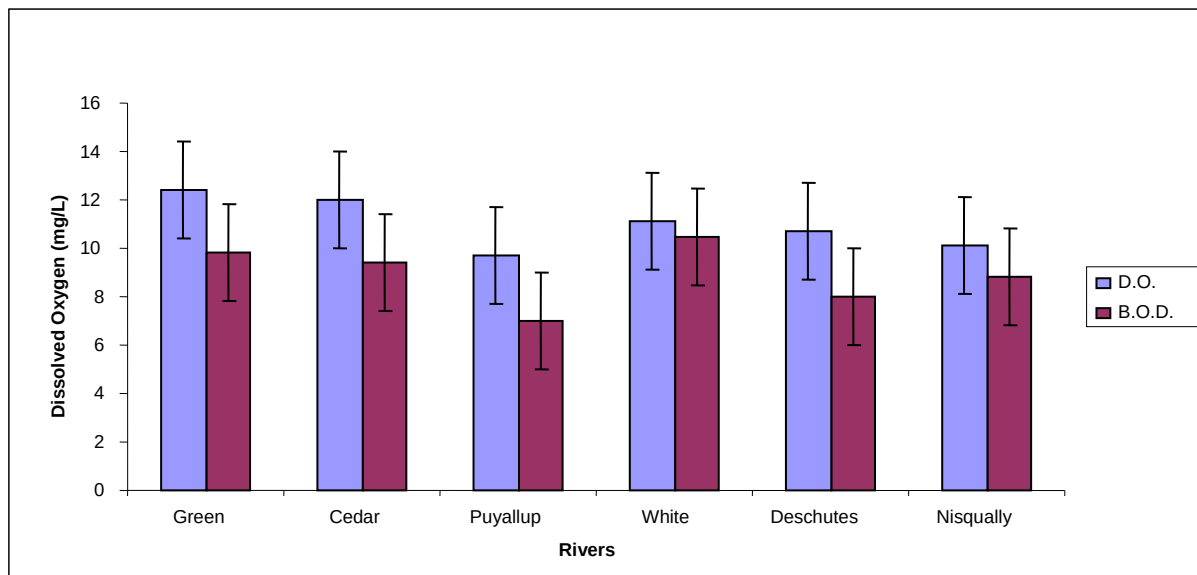


Figure 1. D.O and B.O.D means from three replicates of water samples taken from Green, Cedar, Puyallup, White, Deschutes, and Nisqually rivers in Washington State. B.O.D. levels were lower than D.O. in all six rivers. These values were determined using a LaMotte Dissolved Oxygen Kit. Error bars represent one standard deviation from the mean.

From the fecal coliform tests (Table 3), the values among the rivers were similar.

According to the Nested ANOVA test conducted with Minitab® (2005) on the fecal coliform values, there were no statistical differences among the rivers ($F = 0.638$; d.f. = 3; $p = 0.605$) or the three counties ($F = 0.636$; d.f. = 2; $p = 0.588$).

Table 3. The highest fecal coliform value found for each of the six rivers.

County	River	Fecal coliform (FC/100 mL)
King	Green	5
	Cedar	2
Pierce	Puyallup	5
	White	3
Thurston	Deschutes	4
	Nisqually	2

Discussion

The results of my study failed to support my hypothesis that King County Rivers had a higher fecal coliform count and lower water quality than those of Pierce and Thurston County. The data collected showed there were no differences in fecal coliform and water quality among the rivers or the three counties.

From the turbidity results, Puyallup River of Pierce County showed a higher turbidity level than the other five rivers. This unexpected finding may be due to the location in which I sampled Puyallup River, since I sampled it in a more industrialized area rather than a residential area. A more industrialized area would increase solids in the river, reducing the transmission of light through absorption, thus increasing turbidity levels (Meehan, 1991). Not only was sampling conducted in an industrialized area, samples from Puyallup River were taken under a bridge, right along the roadside. For further studies, a turbidity test would be conducted on samples taken from a residential area with a decreased amount of turbidity rather than an industrialized area of Puyallup River. Sampling would be conducted in areas surrounding homes and neighborhood parks rather than in areas surrounding businesses and production factories. Contrary to expectation, Green and Cedar Rivers of King County were not affected by the location and industrial surroundings in which I collected their samples. Although located in King County, Green and Cedar Rivers were not completely surrounded by industrial areas and were located more near city and residential areas.

The pH and nitrates results showed no differences among the rivers or the counties. According to Meehan (1991), optimal pH levels are between 7.0 and 8.0 and the optimal nitrate levels should be below 1 mg/L. All six rivers had a similar amount of pH and nitrate levels. I expected King County Rivers to have lower pH and higher nitrate levels because of the surrounding area in which I collected the samples. The surrounding area of the rivers located in King County showed no effect on the pH and nitrate levels.

The B.O.D. results showed significant differences among the rivers ($p=0.011$), but no differences among the counties ($p=0.734$). Puyallup River showed the lowest B.O.D. result of 7 mg/L and White River had the highest result with 10.5 mg/L. Puyallup River resulting with the

lowest B.O.D outcome could be due to the decreased levels of decomposing organic matter contained in the river water. With such low quantities of decomposed organic matter, the demand of oxygen from microorganisms to process the matter are decreased as well (Meehan,1991). In the case of high B.O.D from White River, it is just the opposite. Due to the increased levels of decomposing organic matter, the demand for oxygen to process the matter are increased as well. It is then concluded that Puyallup River has a minimal level of organic matter contained in its river water compared to river water obtained from White River.

The D.O. values for all rivers except Puyallup's were greater than 10 mg/L. Although exceeding the optimal level of 7-8 mg/L, this only meant that there was an increased amount of oxygen contained in the rivers that were available to fish and other aquatic organisms (Meehan,1991). If the D.O. values resulted in anything lower than three milligrams per liter, this meant a decreased amount of oxygen available for the aquatic creatures and a stressful environment for most invertebrates. In terms of water quality, the higher the D.O. and lower the B.O.D, the better. When these conditions are met, it is concluded that a specified river has the potential to one day become our source of water supply.

Fecal coliform results showed no significant differences among the rivers ($p=0.605$) or the counties ($p=0.588$). Meehan (1991) states the optimal fecal coliform levels should not exceed 100 FC/100mL and fecal coliform levels < 50 FC/100mL are optimal. The fecal coliform results for all six rivers were < 10 FC/100mL. For fecal coliform tests, the highest value of fecal coliform is recorded to be most cautious of the levels found in rivers. Contrary to expectation, all the rivers had similar values for the fecal coliform colonies. This could be due to water contained in the rivers being treated by nearby plants or water facilities. For a river to be considered a Class A river in Washington State, it has to have optimal levels for these water quality tests (Meehan,

1991). Another reason could be due to the rivers being surrounded by facilities in which treated water runs down or into these rivers (Dorner *et al.*, 2004). The treated water combines with the river water and thus the river water is somewhat treated as well.

For further studies, fecal coliform tests would be conducted on more than three replicates of water samples and performed on more than two rivers for each county to gain more data. This would also apply to the D.O., B.O.D., nitrates, pH, and turbidity tests. Time of year for sampling would also be considered because there could be so many seasonal effects that could possibly alter the results of the tests. Considering all these factors for future studies, the river water quality here in Washington State, according to my data, is fairly good. If more studies were conducted on more rivers in the state, we would know more about the possibility of using the State's rivers for our water resources. If there is ever an outage of fresh, potable water, we would know where to go to obtain clean drinking water.

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