Investigation of the Presence of Heavy Metals and Compounds in Salish Creek: ***Potential Contaminants and Impacts***

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ABSTRACT

With recent declines in wild salmon stock across British Columbia (Noakes et al., 2000), it is imperative for spawning locations to be as conducive to salmon health as possible. With the recent restoration efforts to the mouth of Salish Creek, our team investigated potential contamination of the stream water to ensure that spawning salmon will have the best chance of survival. Ten different abiotic factors were considered: soil pH, alkalinity, chlorine, iron, nitrites, nitrates, water pH, total water hardness, copper and lead. Measurements were conducted at three different sites along Salish creek: the source of the creek, the head of the creek, and the rehabilitated mouth of the creek. Measurement of the abiotic factors was done according to the 9 in 1 test kit with the exception of soil pH, which was measured according to the Streamkeepers' Handbook. Overall, total water hardness and soil pH were found to be significantly different between the sites (p-value = 0.00702 and 0.0281 respectively). In addition, only nitrate was found to have a significant correlation with soil pH (p-value = 0.00594). Considering the results of this investigation, we believe that there are no potential toxic compounds that may interfere with salmon health present in the waters at Salish Creek.

INTRODUCTION

The aim of this investigation is to assess aspects of water quality at Salish Creek, and examine potential correlations between these factors and soil pH. Salish Creek has undergone restoration efforts in hopes of it providing a suitable spawning location for local salmon. Our team is interested in investigating whether the restoration process had an effect on the soil pH and the corresponding levels of heavy metals and other harmful compounds found in the stream water. A previous study conducted by our team indicated that the soil pH of one creek site was low enough that warrant concern regarding heavy metal leaching from the soil to the creek water. The low soil pH sparked curiosity and concern over whether or not the low soil pH could be directly affecting the stream water that is earmarked for salmon spawning.

Human activity has had significant effects on both the environment and living organisms. Rapid industrialization and development have led to a drastic increase in soil pollution in the form of heavy metal contamination (Mico et al. 2006). This increase in heavy metal contamination in the environment is a serious problem as heavy metals are toxic and can therefore affect local biodiversity (Sheng et al. 2012; Blake & Goulding, 2002). Chemical processes such as soil acidification and leaching can cause heavy metal mobilization resulting in heavy metals entering water bodies such as streams and lakes (Calmano et al. 1993). In British Columbia, salmon play a key role in the nutrient dynamics of forests and serves as a vital member in both aquatic and terrestrial food webs (Hocking & Reynolds, 2011). Therefore, as human development continues, there is a growing concern surrounding the effect of human activity on local salmon populations.

It is well known that salmon live the majority of their lives in the open ocean while returning to freshwater streams to spawn (Moore et al. 2004). Salmon undergo many transformations in order to adapt to the differences in salinity such as changing the structure of their gills (Morgan and Iwama, 1991). Studies have shown that the presence of toxins can reduce the efficiency of these transformations resulting in salmon mortality (Regish et al., 2018). For example, aluminum ions specifically impact salmon's ability to osmoregulate with its environment by reducing the efficiency of their gills (Regish et al., 2018). In addition, soil acidification has been shown to increase heavy metal mobilization which may runoff into nearby water sources (Calmano et al. 1993**).**

METHODS

Study Area

Measurements were taken at three distinct sites along Salish Creek: source of the creek, head of the creek and mouth of the creek.

Figure 1. Map of Salish Creek. Red dots show the location of the 3 sites. Retrieved from: www.metrovancouver.org/services/parks/ParksPublications/PacificSpiritParkMap.pdf

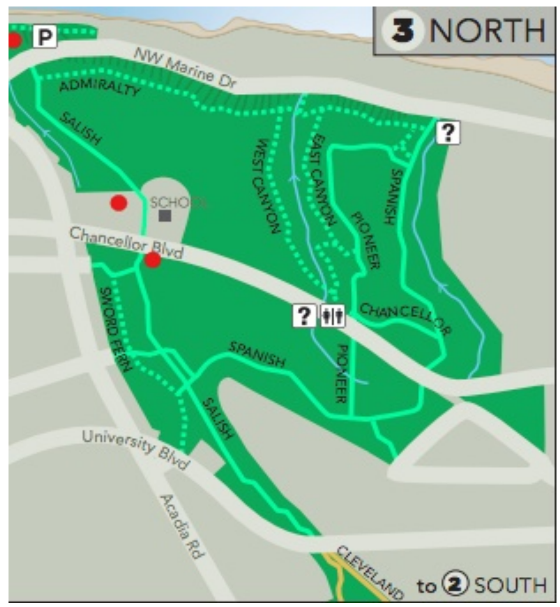

Figure 2. Salish Creek: Source (Upper site) of the Creek. Picture taken November 8th 2018, 4:20 PM.

Figure 3. Salish Creek: Head (Middle site) of the Creek. Picture taken November 8th 2018, 2:20 PM.

Figure 4. Salish Creek: Mouth (Lower site) of the Creek. Picture taken November 8th 2018, 3:30 PM.

Observations

The experiment was conducted at Salish Creek on November 8th 2018 from 2pm - 5pm. The weather was overcast, and the ground was damp at all sites. It had rained for the past 2 days.

The source of the creek was marshy with many fallen leaves and a water pipe leading to a culvert which ran the length of Chancellor Blvd and drained into a continuation of the creek on the other side of the road (Figure 2). In addition, the water was flowing near the culvert but was fairly still a just upstream, where we took our samples.

The head of the creek was beside a road which led to an elementary school and also contained many downed leaves and vegetation (Figure 3). The soil was damp and the stream flow was comparatively faster than the source creek and the mouth of the creek.

The mouth of the creek had previously been restored, including the addition of logs for shade and replanting and conditioning of the area (Figure 4). Furthermore, with Spanish Banks being a popular beach, there were signs of dogs and other tracks surrounding the creek. The water level was deepest in this part of the creek, with the fastest flow.

Measurements

Soil pH was measured according to The Streamkeepers' Handbook . Soil was sampled at four randomly generated locations using a random number generator along a 30m transect line at each site. Top soil adjacent to the river was collected using a metal spatula and transferred to a soil pH container. The amount of soil sampled was determined by the dotted line provided on the soil pH container. The powder from a capsule was added followed by the addition of distilled water up to the second dotted line on the soil pH container. The soil pH container was then shaken vigorously for 3 - 5 seconds and let to rest for a minute. The resulting color change was compared to a pH chart and the colour of the solution was matched with the corresponding pH value. This procedure was performed for each of the four locations at each site.

The levels of lead, chlorine, nitrites, nitrate, copper, iron, alkalinity, total hardness and water pH were measured using a 9 in 1 water test kit . The water test kit consisted of single strips which tested for all the variables listed at the same time. Water was collected using sample jars at four randomly generated locations along a 30m transect line at each. One strip was dipped in each sample jar for two seconds. The strip was then removed, and excessive water was carefully removed by gently waving the strip up and down. The strip was then allowed to sit horizontally for 30 seconds before being compared to a color-coded chart provided with the test kit which allowed us to read off the amount of each variable in the sample of water. This procedure was performed for each of the four locations at each site.

Figure 5. Soil pH kit (left) and water test kit strip (bottom).

Analysis of data

A one-way ANOVA was used to investigate if the means of each of the variables measured was significantly different across the creek sites. Each abiotic variable was put through a separate one-way ANOVA analysis to determine significance. A TukeyHSD test was performed on all significant abiotic variables from the ANOVA analysis to determine between which sites the abiotic variable was significantly different. In addition, each abiotic variable measured using the test kit was analyzed using a correlation test in conjunction with soil pH and creek site.

RESULTS

ppm)	Water pH	Lead	Copper	Hardness	Alkalinity	Nitrates
Correlation Coefficient	0.563	0.0225	0.113	0.256	0.182	0.740
P-value	0.0565	0.945	0.727	0.422	0.571	0.00594*

Figure 6. P-values and correlation coefficients for water pH, lead, nitrates, copper, total hardness, and alkalinity with soil pH respectively. * represents significance for p-values less than 0.05.

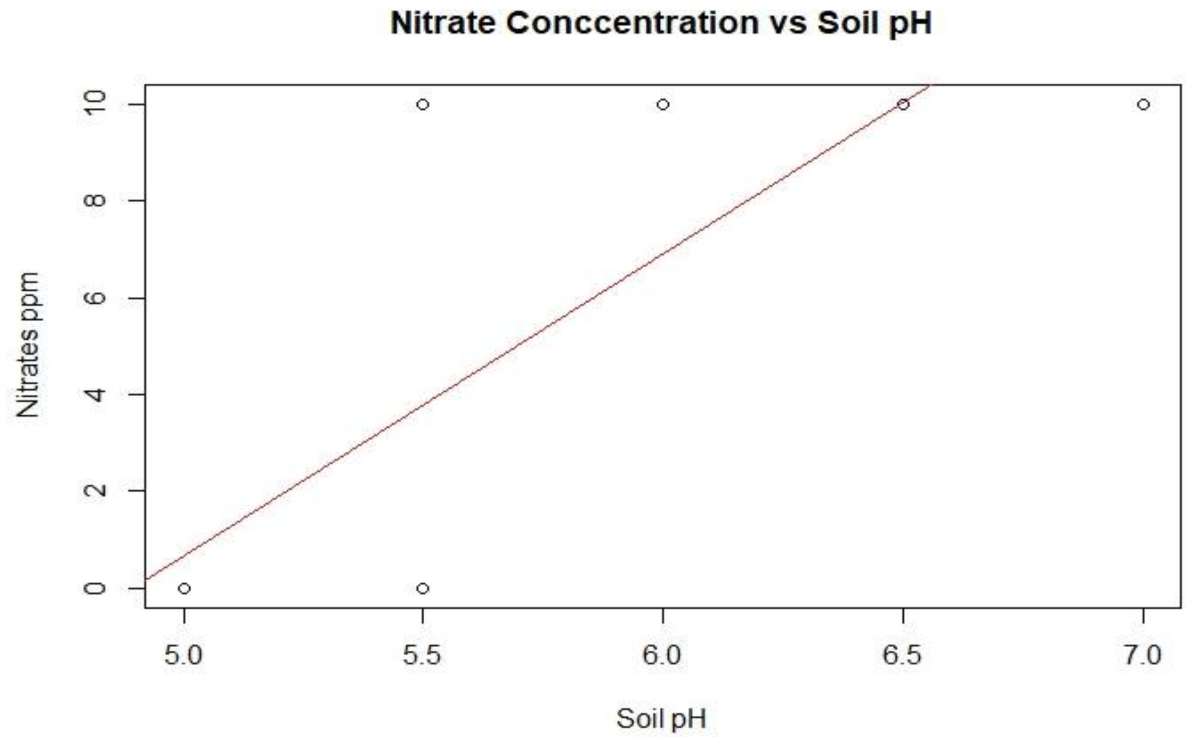

Figure 7. Graph showing the correlation between concentration of nitrate and soil pH.

Correlation coefficient = 0.740, p-value = 0.00594.

(ppm)	Water pH	Lead	Copper	Hardness	Alkalinity	Soil pH
P value	0.405	0.405	0.178	0.00702*	0.0742	0.0281*
F Value	1.000	1.000	2.100	9.0450	3.522	5.444

Figure 8. ANOVA analysis for water pH, lead, nitrates, copper, total hardness, and alkalinity.

N=4, df = 2, * represents significance for p-values less than 0.05.

Creek	P-value
Mouth - Source	1.000
Head - Source	0.045*
Head - Mouth	0.045*

Figure 9. TukeyHSD on Soil pH at the source (upper), head (middle) and mouth (lower) of the creek. * represents significance for p-values less than 0.05.

Creek	P-value
Mouth - Source	0.0095*
Head - Source	0.0177*
Head - Mouth	0.9116

Figure 10. TukeyHSD on Hardness at the source (upper), head (middle) and mouth (lower) of the creek. * represents significance for p-values less than 0.05.

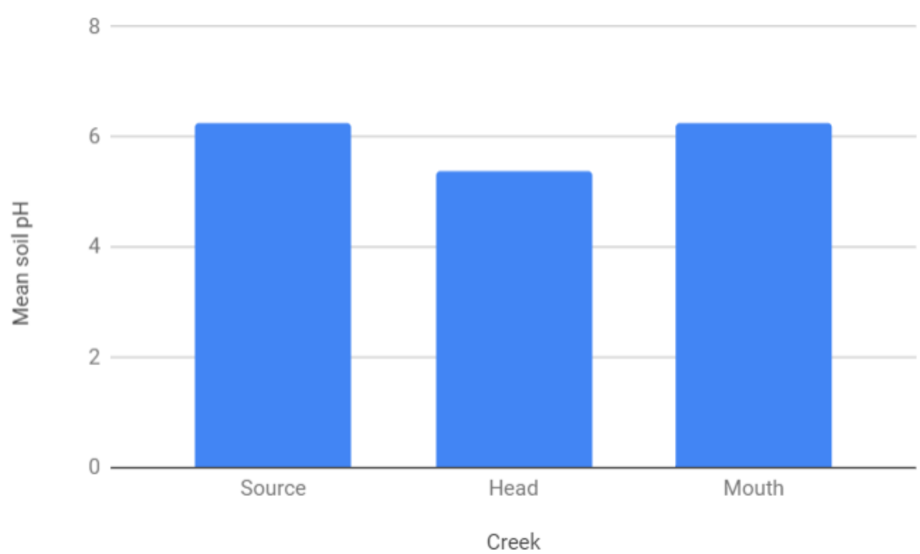

Figure 11. The mean soil pH (significant p-value) at the source, head and mouth of the creek.

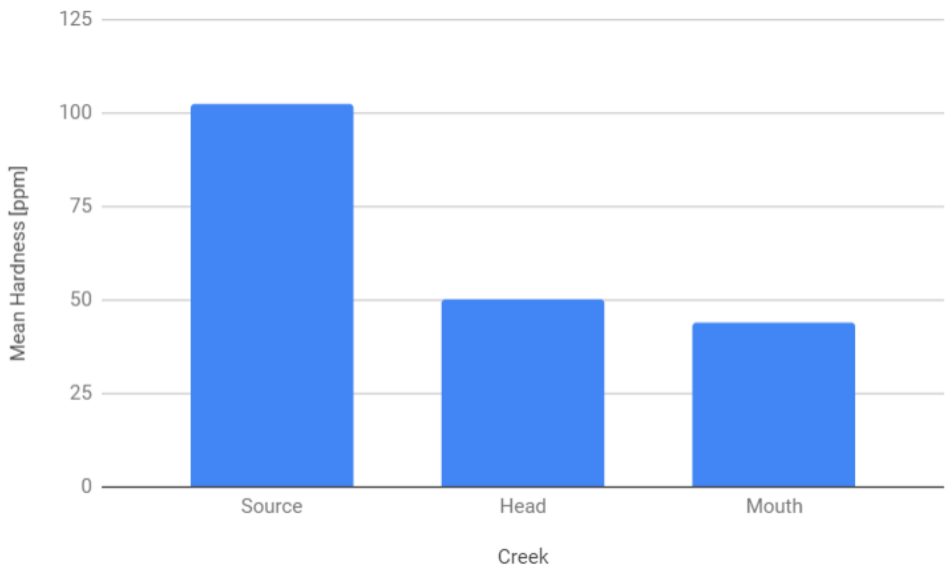

Figure 12. The mean concentration of total hardness (significant p-value) at the source, head and mouth of the creek

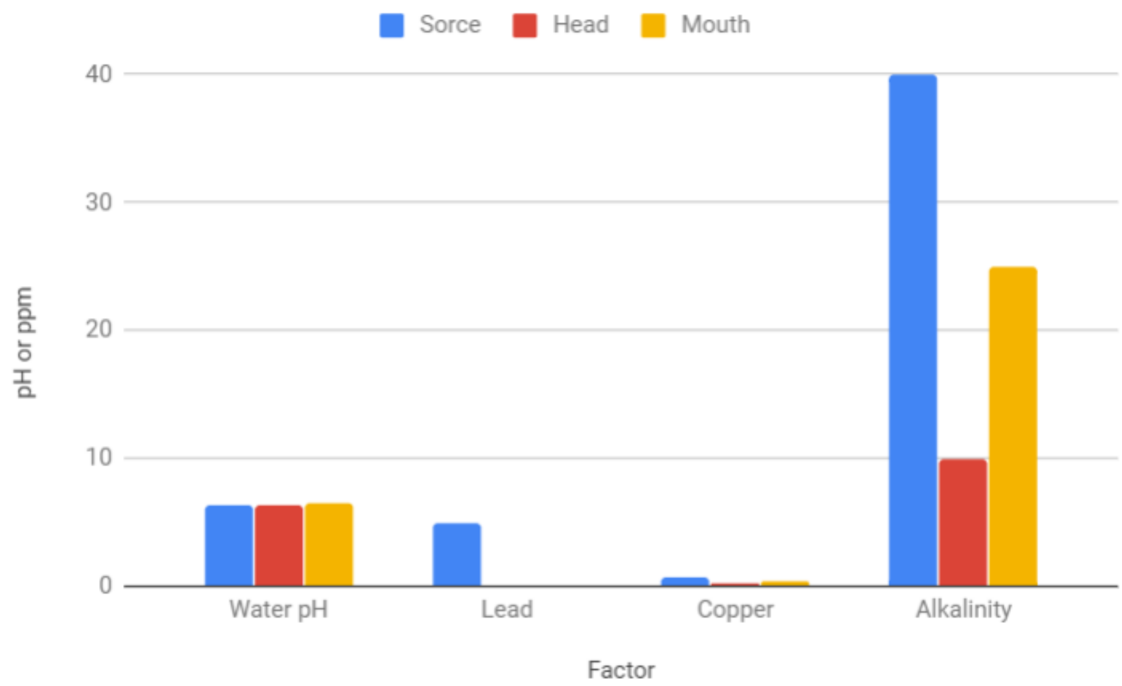

Figure 13. The mean concentration of each factor (non significant p-values) at the source, head and mouth of the creek

Any groups with means of 0 (nitrate, chlorine, nitrites, and iron) were not analyzed using ANOVA due to violation of the ANOVA assertion that none of the group means can be 0. The only result from the ANOVA analysis that were significant were total hardness and soil pH. The F-values for total hardness and soil pH were 9.0450 and 5.444 and the corresponding p-values were 0.00702 and 0.0281, respectively.

In terms of soil pH, the source of the creek was significantly different from both the source and mouth of the creek. In addition, the source of the creek had a water hardness concentration that was significantly different from both the source and mouth of the creek.

Correlation tests for the variables chlorine, nitrites and iron was not conducted because all measured values were 0 and therefore would not show a correlation with soil pH. The only result from the correlation test that was significant was the correlation between nitrates and soil pH with a correlation coefficient of 0.740 and a p-value of 0.00594. The significance level for all tests used an alpha value of 0.05.

DISCUSSION

Based on our previous study, we determined that the soil pH of the head of the creek to be lower than the soil pH at the mouth of the creek. Therefore, we predicted that soils with low pH correlates with an increase in heavy metal leaching as more acidic soils increase the mobilization of heavy metals (Calmano et al. 1993). According to our results, there was no significant correlation between soil pH and heavy metal (Copper, Iron, Lead, and Chlorine) concentration in Salish Creek, unlike what was predicted. However, we found that nitrate had a significant positive correlation with soil pH. This suggests that anionic nutrients such as nitrate have a higher tendency to mobilize in more alkaline environments. Stevens et al., (1998) echo this statement finding soils with high pHs tend towards production of more nitrogenous compounds, which can runoff into local water sources. The soil at the mouth of the creek could contain more of these nitrogenous compounds in comparison to the other sites (due in part to the higher soil pH), and this could be an interesting prediction for further study. Regardless, the concentration of nitrates is not concerning. Some fish exhibit stunted growth in high nitrate water (Monsees et al., 2016) but the concentration is significantly higher than any of the sites.

Even with the significant decrease in soil pH observed from the mouth of the creek to the upper sites (source and upper creek sites), there was no measured increase in heavy metal presence in the water. This could be due to a multitude of factors, namely that there is little industrial presence in this area. More industrialized areas of Vancouver, especially those with high volumes of traffic have been shown to have more contaminants in their soils (Oka et al. 2014). With the lack of local construction and traffic even near the lower site, there could be little to no presence of metals or contaminants in the surrounding soils, and therefore no leaching into the stream. In addition, Salish Creek is currently under restoration efforts with the mouth of the creek already being fully restored. Restoration efforts included cleaning the surrounding environment which may have minimized the amount of heavy metals present for contamination (Ho, 2018). Soil quality assessments could be an area of future study, not regarding salmon health so much as forest health. Bedrock and soil composition analysis could potentially shine light on the apparent lack of mobile metal ions.

Our results also indicate that total water hardness and soil pH significantly differ between the three creek sites. This echos our similar finding in our previous study regarding soil pH. High levels of hardness can be beneficial, as higher levels can buffer pH and protect from the effects of metal toxicity (Laurén & McDonald, 1986). Specifically, water hardness inhibits biotoxicity of copper ions in water. Our findings did show small levels of copper present in the water, but in combination with the observed water hardness the copper should be of no danger to life in the stream. Varying levels of water hardness could become problematic if there are appreciable levels of other heavy metals in the water. Unfortunately, with hardness lowest at the spawning site and higher in the upper sites it would likely not prevent toxicity if metals were present in the water of the spawning site.

With no other significance found for factors at each site, and no other correlations present, there are no indicators that toxins and compounds in the water of Salish Creek could impact the health of spawning salmon in the restored mouth of the creek.

Limitations

The 9 in 1 water test kit strips used in this experiment had limited resolution. A color coded chart was provided with the kit which was used to read off the values indicated on the used strip based on the color change observed after dipping the strip in the water. There were two big limitations with the test strips. First of all, the color change that was observed was subjective and the lighting of the environment could have affected the readings. The colors provided in the color coded chart were not on a continuous spectrum. Instead, they were discrete blocks with discrete values. For example, the reading of lead went up by increments of 20 ppm which restricts our measurements to set values by the 9 in 1 water test kit. This introduced another source of error as most of the readings of each variable were approximate values and could actually be higher or lower than recorded. As a result, deciding on what color was observed on the strip was subjective and potentially introduced uncertainty. Additionally, the lighting of the environment was different at all of the three sites and could have introduced error when reading off the colors on the strip.

If this experiment were to be done again, each strip should be put under a constant light source to prevent unnecessary error, and strips with smaller increments should be used. If possible, more advanced titration or lab based equipment could be used to determine water quality and presence of compounds.

It was difficult to access the true middle site of Salish Creek as the terrain was treacherous. Therefore, we were unable to gather data from the true (relative to distance) middle of the creek which could have introduced bias. Without data on the exact middle part of the creek we were unable to get the full distribution of soil pH along the length of Salish Creek, instead opting for the head, approximate middle, and the restored spawning area at the mouth of the creek. For future studies, a true middle site along Salish Creek should be used to measure the soil pH and the corresponding variables measured in this experiment to get the full outlook on the interaction between soil pH and potential waterborne toxins. However, with the mouth of the creek restoration and the aim to use only this area for spawning, the significance of this design limitation is minimal.

A final limitation lies with our data analysis. Nitrate, chlorine, nitrites, and iron all had at least one group mean equal to zero. This disallows ANOVA and forces analysis with less powerful tests. All variables with a group mean of zero showed no significance between the creek sites. With Iron, Chlorine, and Nitrites showing no presence at all, these were entirely discounted when doing significance testing and no correlation tests were performed.

CONCLUSION

Without further in-depth water and soil assays being conducted, all data points towards the restored mouth of the creek site being free from potential heavy metal and compound contamination. There were no appreciable levels of toxins measured at any of the sites, and it is likely that the significant water hardness found would be able to protect against small increases in contaminants. In summary, the waters of Salish Creek appear to be healthy for spawning salmon to return to, and restoration efforts did not introduce any unwanted contamination to the stream.

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REFERENCES

Blake, L., & Goulding, K. W. T. (2002). Effects of atmospheric deposition, soil pH and acidification on heavy metal contents in soils and vegetation of semi-natural ecosystems at Rothamsted Experimental Station, UK. *Plant and soil*, *240*(2), 235-251.

Calmano, W., Hong, J., & Förstner, U. (1993). Binding and mobilization of heavy metals in contaminated sediments affected by pH and redox potential. *Water science and technology*, *28*(8-9), 223-235.

Ho, K. (2018, September 12). Salish Creek restoration project intended to rehabilitate fish habitat. The Ubyssey, pp 12.

Hocking, M. D., & Reynolds, J. D. (2011). Impacts of Salmon on Riparian Plant Diversity. *Science,331*(6024), 1609-1612.

Laurén, D. J., & McDonald, D. G. (1986). Influence of water hardness, pH, and alkalinity on the mechanisms of copper toxicity in juvenile rainbow trout, Salmo gairdneri. *Canadian Journal of Fisheries and Aquatic Sciences*, *43*(8), 1488-1496.

Mico, C., Recatala, L., Peris, M., & Sanchez, J. (2006). Assessing heavy metal sources in agricultural soils of an European Mediterranean area by multivariate analysis. *Chemosphere, 65*(5), 863-872.

Monsees, H., Klatt, L., Kloas, W., & Wuertz, S. (2017). Chronic exposure to nitrate significantly reduces growth and affects the health status of juvenile Nile tilapia (Oreochromis niloticus L.) in recirculating aquaculture systems. *Aquaculture Research*, *48*(7), 3482-3492.Moore, J. W., Schindler, D. E., & Scheuerell, M. D. (2004). Disturbance of freshwater habitats by anadromous salmon in Alaska. *Oecologia*, *139*(2), 298-308.

Morgan, J. D., & Iwama, G. K. (1991). Effects of salinity on growth, metabolism, and ion regulation in juvenile rainbow and steelhead trout (Oncorhynchus mykiss) and fall chinook salmon (Oncorhynchus tshawytscha). *Canadian Journal of Fisheries and Aquatic Sciences*, *48*(11), 2083-2094.

Noakes, D. J., Beamish, R. J., & Kent, M. L. (2000). On the decline of Pacific salmon and speculative links to salmon farming in British Columbia. *Aquaculture*, *183*(3-4), 363-386.

Oka, G. A., Thomas, L., & Lavkulich, L. M. (2014). Soil assessment for urban agriculture: A Vancouver case study. *Journal of soil science and plant nutrition*, *14*(3), 657-669.

Regish, A. M., Kelly, J. T., O'Dea, M. F., & McCormick, S. D. (2018). Sensitivity of Na /K - ATPase isoforms to acid and aluminum explains differential effects on Atlantic salmon osmoregulation in fresh water and seawater. *Canada J. Fish Aquatic Science*, 75, 1319-1328.

Sheng, J., Wang, X., Gong, P., Tian, L., & Yao, T. (2012). Heavy metals of the Tibetan top soils: Level, source, spatial distribution, temporal variation and risk assessment. *Environ. Sci. Pollut. Res., 19*(8), 3362-3370.

Smith, S. R. (1994). Effect of soil pH on availability to crops of metals in sewage sludge-treated soils. I. Nickel, copper and zinc uptake and toxicity to ryegrass. *Environmental Pollution*, *85*(3), 321-327.

Stevens, R. J., Laughlin, R. J., & Malone, J. P. (1998). Soil pH affects the processes reducing nitrate to nitrous oxide and di-nitrogen. *Soil Biology and Biochemistry*, *30*(8-9), 1119-1126.

Zhang, T., Li, X., Lu, Y., Wu, C., Fang, T., Liu, P., ... & Liang, W. (2013). Acute toxicity of heavy metals to Tetrahymena in an in vitro experiment and envelope damage study. *Bulletin of environmental contamination and toxicology*, *91*(1), 62-68.

Zheng, S. A., Zheng, X., & Chen, C. (2012). Leaching behavior of heavy metals and transformation of their speciation in polluted soil receiving simulated acid rain. *PloS one*, *7*(11), e49664.

APPENDIX

	24.6m	17.1m	9.2m	28.1m
Water pH	6.4	6.4	6.4	6.4
Lead (ppm)	20	0	0	0
Chlorine	0	0	0	0
Nitrite	0	0	0	0
Nitrate	10	10	10	10
Copper	1	0.5	0.5	0.5
Iron	0	0	0	0
Soil pH	6	6.5	6.5	6
Hardness	120	50	120	120
Alkalinity	40	40	40	40

Table 1. Source of the Creek Data Table

	1.5m	15.4m	23.5m	29.6m
Water pH	6.4	6.4	6.4	6.4
Lead (ppm)	0	0	0	0
Chlorine	0	0	0	0
Nitrite	0	0	0	0
Nitrate	0	0	0	0
Copper	0	0.5	0.5	0
Iron	0	0	0	0
Soil pH	5	5.5	5.5	5.5
Hardness	50	50	50	50
Alkalinity	0	0	0	40

Table 2. Head of the Creek Data Table

	18.5m	2.1m	6.2m	23m
Water pH	6.4	6.4	6.4	6.8
Lead (ppm)	0	0	0	0
Chlorine	0	0	0	0
Nitrite	0	0	0	0
Nitrate	10	10	10	10
Copper	0.5	0.5	0.5	0
Iron	0	0	0	0
Soil pH	6.5	5.5	6	7
Hardness	50	25	50	50
Alkalinity	20	40	40	0

Table 3. Mouth of the Creek Data Table

	Site	Water pH	Soil pH
Site	1		
Water pH	0.36927447	1	
Soil pH	0	0.5634004	1

Figure 14. Correlation Analysis between water pH and soil pH at each of the three creek sites.

	Site	Lead	Soil pH
Site	1		
Lead	-0.3692745	1	
Soil pH	0	0.02253602	1

Figure 15. Correlation Analysis between lead and soil pH at each of the three creek sites.

	Site	Nitrate	Soil pH
Site	1		
Nitrate	-1.923E-17	1	
Soil pH	0	0.73992299	1

Figure 16. Correlation Analysis between nitrate and soil pH at each of the three creek sites.

	Site	Copper	Soil pH
Site	1		
Copper	-0.3692745	1	
Soil pH	0	0.11268008	1

Figure 17. Correlation Analysis between copper and soil pH at each of the three creek sites.

	Site	Total Hardness	Soil pH
Site	1		
Total Hardness	-0.7439416	1	
Soil pH	0	0.25598512	1

Figure 18. Correlation Analysis between total hardness and soil pH at each of the three creek sites.

	Site	Alkalinity	Soil pH
Site	1		
Alkalinity	-0.3312946	1	
Soil pH	0	0.18196367	1

Figure 19. Correlation Analysis between alkalinity and soil pH at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	1800	900	3.522	0.0742
Residuals	9	2300	255.6		

Figure 20. One way anova: Alkalinity at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	8329	4165	9.045	0.00702*
Residuals	9	4144	460		

Figure 21. One way anova: Total Hardness at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	2.042	1.0208	5.444	0.0282*
Residuals	9	1.688	0.1875		

Figure 22. One way anova: Soil pH at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	1800	900	3.522	0.0742
Residuals	9	2300	255.6		

Figure 23. One way anova: Alkalinity~Soil pH at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	0.02667	0.01333	1	0.405
Residuals	9	0.12000	0.01333		

Figure 24. One way anova: Water pH at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	66.7	33.33	1	0.405
Residuals	9	300	33.33		

Figure 25. One way anova: Lead at each of the three creek sites.

	Df	Sum Sq	Mean Sq	F value	P value
Site	2	0.2917	0.14583	2.1	0.178
Residuals	9	0.6250	0.06944		

Figure 26. One way anova: Copper at each of the three creek sites.

Creek	P-value
Mouth - Source	1.000
Head - Source	0.045*
Head - Mouth	0.045*

Figure 27. TukeyHSD on Soil pH at at the source, head and mouth of the creek. * represents significance for p-values less than 0.05.

Creek	P-value
Mouth - Source	0.0095*
Head - Source	0.0177*
Head - Mouth	0.9116

Figure 28. TukeyHSD on Hardness at the source, head and mouth of the creek. * represents significance for p-values less than 0.05.

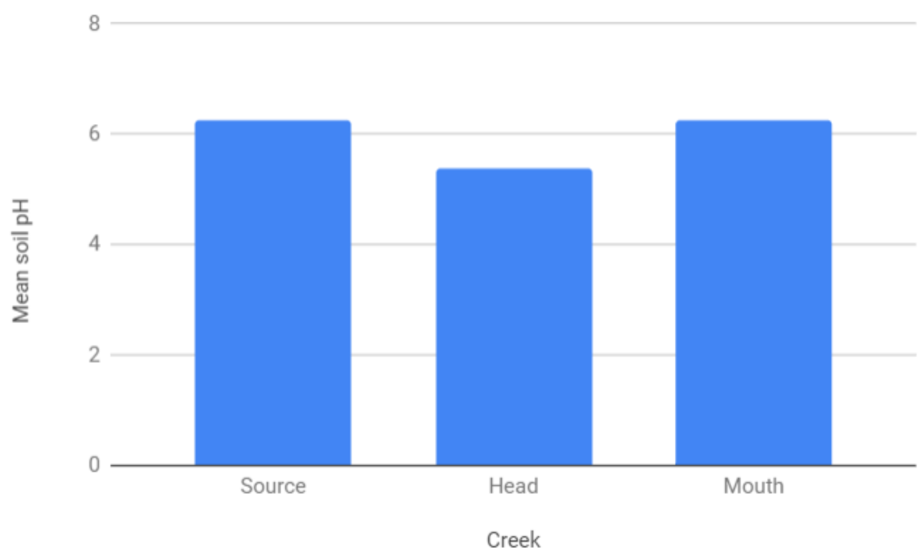

Figure 29. The mean soil pH (significant p-value) at the source, head and mouth of the creek.

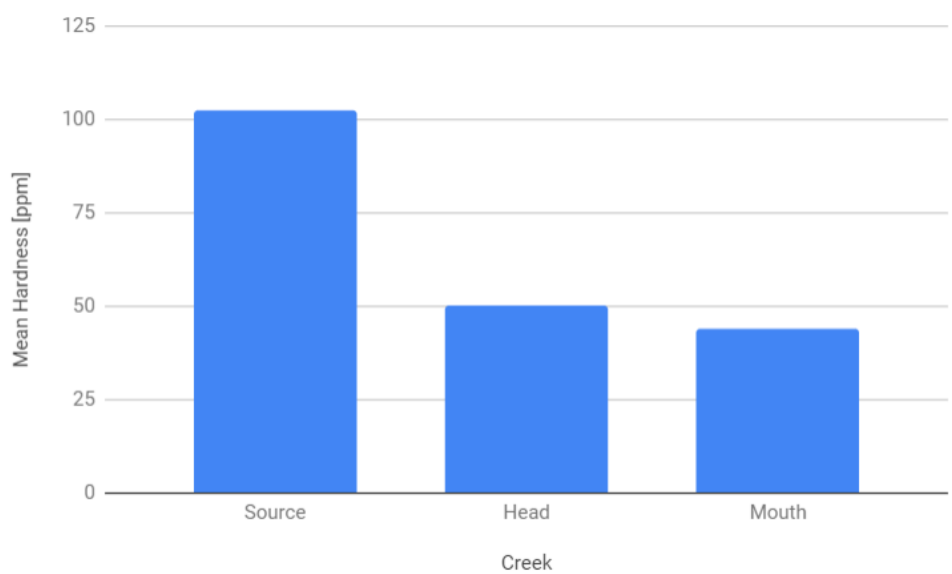

Figure 30. The mean concentration of total hardness (significant p-value) at the source, head and mouth of the creek

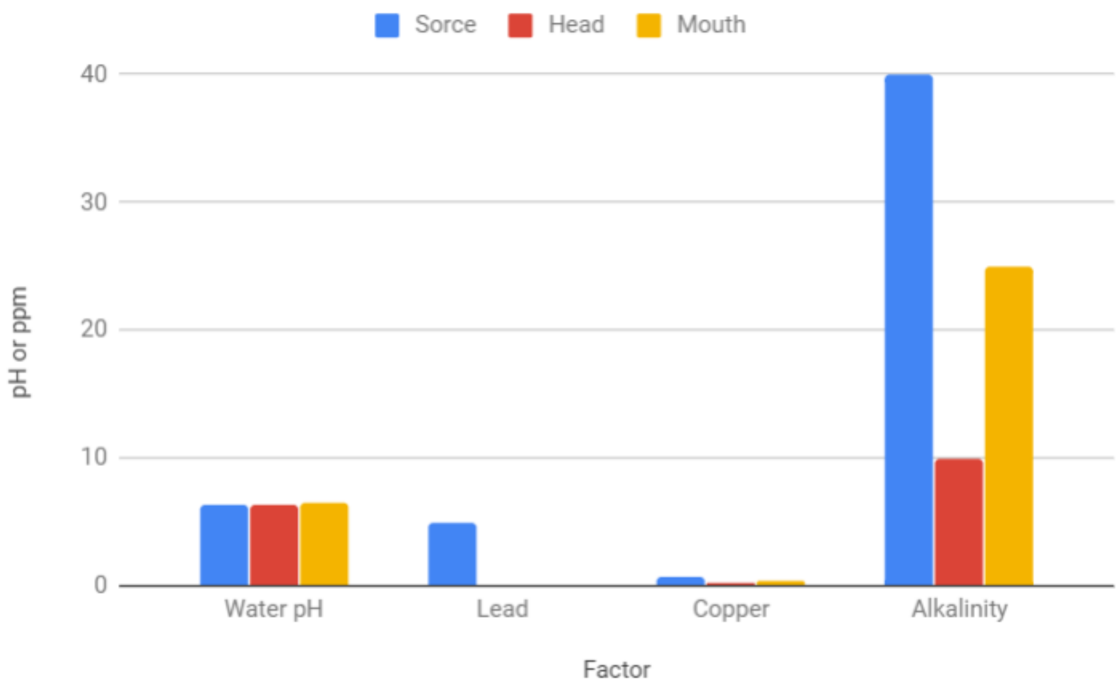

Figure 31. The mean concentration of factor (non significant p-values) at the source, head and mouth of the creek