Introduction

Acid deposition has many potential impacts on our environment. Acid deposition can effect fauna, flora, soil properties, human health, and the economy. The effects on fauna can be either direct or indirect. Fish and macroinvertebrates can experience reduced respiration and reproductive rates. As an important food base, the reduction of fish and macroinvertebrates can impact organisms that depend on them. Food webs that support wildlife often begin in the stream (Nebel 1990). Fish populations may suffer if they are dependent on the macroinvertebrates. When the fish suffer, the birds that depend on them for a food source also suffer. "Naturalists report in the areas of the Adirondacks where the lakes no longer support fish, there is a total absence of loons and other waterfowl”(Nebel 1990).

Flora is also affected by acid deposition. Above ground, the cuticles of the plants are damaged. Cuticle damage decreases the amount of water the plant can retain. The bark may also be damaged from acid deposition. Below the ground the root hairs are damaged. Essential nutrients are leached from the soil, which can cause damage to the plant. Plants and forests are more susceptible to diseases, fungal infections, drought, and insects because of the damaged cuticle, bark, root hairs, and lack of sufficient nutrients. It is difficult to show how a plant or forest is damaged by acid deposition because the effects of acid deposition are hidden by natural causes such as insect infestation, drought damage, and diseases.

The buffering capacity of the soil is affected by acid deposition. As acids are added, natural buffers in the soil are exhausted. Over time the buffering capacity may decrease to the point where nutrients and toxins in the form of metals are leached out of soil. These toxins such as aluminum, lead, mercury, and magnesium are deposited in streams, lakes, aquifers, and even drinking water.

Human health is also at a great risk. Acid deposition in the form of dry particles and gases are irritants to the human respiratory system. The young, elderly, and people with respiratory diseases are the most susceptible. “The World Health Organization estimates about 1.25 billion urban dwellers –almost one of every five people on Earth- are being exposed to health hazards from air pollutants that may cause acid deposition. The Congressional Office of Technology Assessment estimates that 50,000 premature deaths occur in the United States each year from respiratory or cardiac problems caused or aggravated by current air pollution levels. The American Lung Association estimates that up to 12,000 Americans die each year as a result of air pollution. Much of this air pollution is related to acid deposition.”(Miller 1977).

The environment and human health are not the only things hurt by acid deposition; our wallets also feel the effects. Acid deposition can erode and damage monuments, buildings, and statues. Paint on automobiles and houses become faded and deteriorated, and automobiles may rust. It costs more to repair the damage to monuments and structures than it does to prevent these damages or to reduce emissions of acid deposition causing pollutants. It costs money to repair lakes and streams. Limestone is added to acidified lakes and streams, a process known as liming. However, liming is only a “Band-Aid” approach; one has to keep adding more limestone. The costs never end. As acid deposition changes our soil properties, our drinking water sources are contaminated and must be filtered. The cost of health care today is enormous; the money spent on respiratory problems caused by air pollutants that may lead to acid deposition is speculated to be nearly $150 billion per year (EPA and American Lung Association).

The burning of fossil fuels such as coal, oil, gasoline, and natural gas, is the number one cause of acid pollutants. The combination of wet and dry acidic pollutants that fall back to earth is referred to as acid deposition. Coal generated power plants are the leading producer of sulfur dioxide, whereas forms of transportation such as automobiles, airplanes, and trains are the leading producers of nitrogen oxides (EPA 1990).

Acid deposition is formed when emissions of sulfur (S) and nitrogen oxides (NO_x or NO and NO_2) react with oxygen (O_2) to produce sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) (see Equation 1).

Equation 1 - Formation of Sulfur Dioxide and Nitrogen Oxides

$$S + O_2 \rightarrow SO_2 \text{ and}$$

$$N + O_2 \rightarrow 2NO_2\ ,\ \ N_2 + O_2 \rightarrow 2NO$$

$$\text{and}\quad 2NO + O_2 \rightarrow 2NO_2$$

The sulfur dioxide (SO_2) can then react with oxygen (O_2) again to form sulfur trioxide (SO_3)(see Equation 2).

Equation 2 - Formation of Sulfur Trioxide

$$2SO_2 + O_2 \rightarrow 2SO_3$$

Once in the atmosphere, the sulfur trioxide and nitrogen oxides can react with water to form sulfuric acid (H_2SO_4) and nitric acid ($2HNO_3$) (see Equation 3).

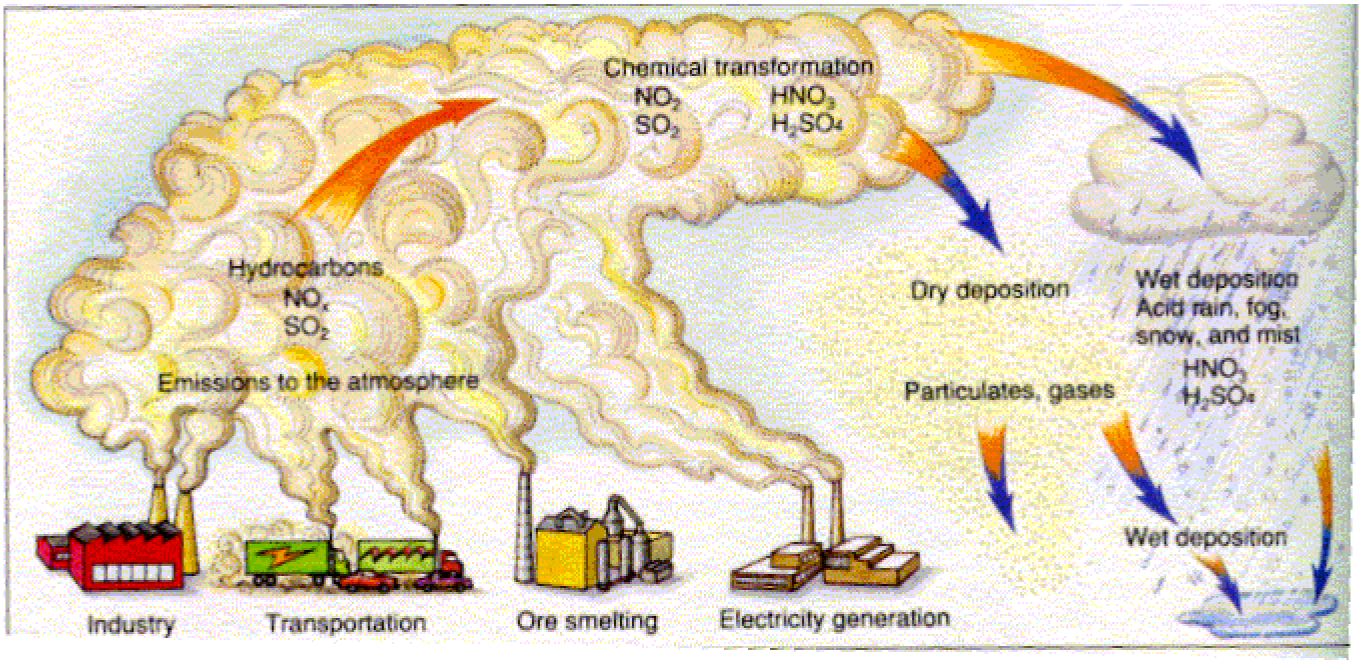
Equation 3 - Formation of Sulfuric acid and Nitric acid

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

The formation of acid deposition is shown in Diagram 1. Some forms of wet deposition are rain, sleet, hail, and snow. However, not all of the acidic pollutants combine with atmospheric water; some remain in dry form and fall to the earth. Fog and dry air particles are some forms of dry deposition (See Diagram 1).

Diagram-1 Acid Deposition Diagram



We are studying four characteristics of water quality that could be affected. They are pH, alkalinity, sulfate concentration, and nitrate concentration. If acid deposition is having an impact, the pH and alkalinity levels would be expected to decrease, while the levels of sulfates and nitrates would be expected to increase. The pH may not decrease immediately due to the alkalinity or buffering capacity, so we tested alkalinity (Burkett 1999a).

Testing alkalinity can be a better way to test for acid deposition because alkalinity will decrease before pH decreases. After neutralizing an acid, the buffer will be exhausted. We tested sulfate (SO_4) and nitrate (NO_3) levels because they are components of sulfuric acid (H_2SO_4) and nitric acid (HNO_3), respectively.

Hardness can be another indication of acid deposition. Hardness is measured for several reasons. As acid deposition increases, the hardness level may rise due to the metals being released into the stream, indicating buffering is taking place (Burkett 1999a).

We tested the level of dissolved oxygen and temperature because if a rise in temperature or drop in dissolved oxygen occurs, the number of benthic macroinvertebrates may decrease. A drop in dissolved oxygen or temperature is not directly caused by acid deposition. There is an inverse relationship between dissolved oxygen and temperature; as temperature rises there is a decrease in dissolved oxygen. Dissolved oxygen is very important to aquatic life. A dissolved oxygen reading of 6 ppm is best to support life for benthic macroinvertebrates. Due to the relationship between dissolved oxygen and benthic macroinvertebrates we are monitoring dissolved oxygen to determine if it is the cause of changes in the benthic macroinvertebrate population.

The water quality of streams is also influenced by the different soil properties. Carbonate-based soils have a very high buffering capacity. Limestone (calcium carbonate) is the most widespread natural buffer (Nebel 1990). When acidic water is mixed with limestone, excess hydrogen ions react to produce soluble calcium, carbon dioxide, and water (see equation 4). This is how carbonate-based soils neutralize acidic water.

Equation 4-Buffering reaction

$$CaCO_3 + 2H^+ \rightarrow Ca^{+1} + CO_2 + H_2O$$

After the acidic water is filtered through the soil, the pH of the water is close to neutral (Nebel 1990). Soils that are not carbonate-based have a lower buffering capacity than limestone. Sandstone and shale soils are not as capable of absorbing the hydrogen ions; therefore, they are not good buffers.

Another way to determine the buffering capacity in a certain area is to test the thickness of the soil. Thicker soil has a higher buffering capacity. Mountainous areas usually have thin soils, while flat plains usually have thicker soils. Because western Maryland is a mountainous region with mostly thin sandstone and shale soils, the streams we are testing are more vulnerable to acid deposition.

Acid deposition is a problem that affects many organisms. Organisms such as benthic macroinvertebrates are sensitive to physical and chemical changes and are therefore likely to be affected by acid deposition (Mitchell and Stapp 1996). Fish are also affected by acid deposition in streams. One way fish are affected is by the free aluminum that is leached out of the streambeds and deposited into the water. Aluminum and other toxic metals such as lead are very lethal to aquatic organisms. They cause mucous to be secreted in the organism's gills and make it hard for them to breathe.

In acidified aquatic ecosystems rapid die-off rates of almost all aquatic organisms result from the failure to reproduce or from the direct impacts of acids (Nebel 1990). In more severe cases of acid pollution, acid deposition can leach calcium out of the watershed; fish and other organisms can develop skeletal deformations from lack of calcium. The young organisms are more vulnerable to the effects of acid deposition. The acidified water can also change the reproduction rates of aquatic organisms by limiting hatch success or by killing the organisms before they reach reproductive age (Burkett 1999).

We are collecting benthic macroinvertebrates for our study because they are good biological indicators (Burkett 1999). These macroinvertebrates are easily found, caught and identified to order. They are also found in nearly every stream. Some are more sensitive to particular disturbances than others. For instance, the caddisfly, the hellgrammite, and the mayfly are very sensitive to disturbances in stream water quality; dragonflies, sowbugs, and crayfish are not as sensitive; some macroinvertebrates such as blackflies, midges, and leeches, are tolerant of nearly any disturbances in water quality (Burkett 1999).

The AES Warrior Run power plant, a coal-generated power plant, will begin operation in October 1999. The purpose of conducting this study in western Maryland is to determine if the emissions from AES Warrior Run power plant will affect the local stream water quality or the streams' benthic macroinvertebrate community.

Coal-generated power plants have many ways to reduce the amounts of sulfates and nitrates emitted into the atmosphere. The method used by AES Warrior Run is fluidized-bed combustion. Fluidized-bed combustion is the process by which crushed limestone is combined and burned with powdered coal. This method helps reduce emissions because the limestone acts as a buffer. Methods employed by other plants to reduce emissions involve scrubbers in the smokestacks, burning low sulfur coal, removing sulfur from coal, and decreasing combustion temperature (EPA 1977). Scrubbers are found in smokestacks where limestone is mixed with water and sprayed within the smokestack (EPA 1990). Sulfur is removed from coal by washing it before the coal is burned. Decreasing combustion temperature reduces emissions of nitrogen oxides (EPA 1977).

We hypothesize that the AES Warrior Run power plant will not cause a statistically significant change in stream chemistry or the benthic macroinvertebrate community.

Methods

The Regional Math Science Center is testing streams in western Maryland. The sampling sites included Sideling Hill, Flintstone Creek, Evitt`s Creek, Mill Run, Murley Branch, Fifteen Mile Creek, and Poplar Lick. Poplar Lick was our control site, because it is upwind from the power plant and is less likely to be affected by emissions from the power plant. Therefore, if Poplar Lick`s stream chemistry or macroinvertebrate populations change, it indicates that the power plant may not be responsible for changes that may occur at our other sample sites and other factors must be considered. All other streams were downwind from the power plant. Winds may blow the emissions from the AES Warrior Run power plant in their direction. These streams were selected because they have similar characteristics such as size, flow, accessibility, and are not affected by acid mine damage. Stream sampling was performed Tuesday and Thursday mornings from mid-June to the end of July in 1998 and 1999. Three research groups tested stream chemistry and three groups tested benthic macroinvertebrates at each site.

The stream chemistry tests were performed with LaMotte test kits. LaMotte test kits have a reputation of ease of use, portability, and low cost with sufficient accuracy. The stream parameters tested were pH, alkalinity, nitrates, sulfates, dissolved oxygen, total hardness, calcium hardness, magnesium hardness, and temperature. Additional stream water samples were taken to the Appalachian Laboratory for analysis of pH, alkalinity, nitrates, and sulfates. We took samples to the laboratory to see how accurate the LaMotte test kits were. We also tested pH with the Oaktron pH Testr 3. The pH probe was calibrated weekly with pH standard solutions of pH 4, 7, and 10.

The chemical tests were performed in a pool area upstream of the macroinvertebrate collection zone so the water chemistry was less likely to be affected by our sampling. Since pH is based on a logarithmic scale, we could not simply average the pH data. Instead, we calculated the hydrogen ion concentration for the pH values and then averaged the hydrogen ion concentrations. These values are converted back to pH to provide a more accurate average pH.

Samples of macroinvertebrates were taken from a one-meter square riffle area using a D-net. We rubbed the rocks off in the riffle area to remove any macroinvertebrates and collected a kick sample. We were sampling for diversity and the abundance of the macroinvertebrates: therefore, we recorded the number of individuals belonging to each order identified.

When we tested the soil pH, we used the LaMotte test kit and collected soil samples with a soil auger. Each chemistry group obtained their own soil sample away from the flood plain and performed the pH test for a total of at least three samples per site.

Collected data was organized and analyzed using Microsoft Excel. Graphs and statistical tests were used to analyze the data that was collected. All statistical tests were performed at 95% confidence level.

Column graphs were used to compare the 1998 values for pH, alkalinity, dissolved oxygen, sulfate, nitrate, and total hardness to the 1999 values. T-tests were performed for all stream averages for pH, alkalinity, dissolved oxygen, sulfates, nitrates, and total hardness.

Using a column graph, we compared the summed averages of sulfates and nitrates for 1998 to 1999. Another column graph was used to compare the combined sulfate and nitrate levels for the control site (Poplar Lick) for 1998 and 1999.

Scattergrams of the average temperature versus average dissolved oxygen for 1998 and 1999 were constructed. Correlation coefficients were used to compare the two data sets. A column graph was constructed to show the change in temperature between 1998 and 1999 for each sampling site.

After recording the 1999 pH data, the values were compared to the pH data from 1998. The column graph used to represent our data compares the stream pH readings from each test site for the 1998 and 1999 testing seasons. We performed a t-test to see if there was any statistical difference between the 1998 and 1999 data.

A column graph was used to compare the difference between dissolved oxygen levels from 1998 to 1999. A t-test was used to compare the data statistically.

We utilized column graphs to compare the Appalachian Laboratory results to Hach and LaMotte test kit results. Column graphs were used to visually determine any differences between each set of data.

Chi-square tests statistically determine whether any differences on the bar graphs are significant. If a difference is detected, then we will look to other test kit choices for future investigations.

We constructed graphs comparing pH levels as measured by the Appalachian Laboratory, the Hach test kits, and the LaMotte test kits. We performed a Chi-square test on the pH probe data versus the Hach kit data and the pH probe data versus the Laboratory data for pH. We also compared alkalinity results for each test method. We performed Chi-square tests after seeing differences in the graph. The last tests we performed were on sulfates and nitrates. We constructed column graphs comparing Appalachian Laboratory results and LaMotte test kit results for sulfates and nitrates. We then performed t-tests to determine if any differences were significant. Hach test kits were not used to measure sulfates and nitrates.

We used a scatter plot with a trendline to show the relationship between average alkalinity and stream pH for each test site. A correlation coefficient was calculated to indicate the strength of the relationship. A column graph shows the relationship that the average alkalinity has with the pH at each stream.

An X-Y scatterplot with a trendline was also constructed to illustrate the relationship between the average soil pH and stream pH for all test sites. The correlation coefficient was calculated to determine if there was a relationship between the two variables. A bar graph was used to compare the average soil and stream pH at each site for 1999.

We combined sulfate and nitrate data and compared them to the pH using a scatterplot with a trendline and a correlation coefficient to determine if there is a relationship between the two chemical parameters. To analyze our data for combined nitrates and sulfates, we added the mean nitrate and sulfate values for each site.

In order to compare macroinvertebrate data from 1998 to 1999, we totaled the number at macroinvertebrates at each site and divided it by the total number of square meters tested. This calculation was performed because there were different number of groups testing from year to year and from site to site.

A column graph was chosen to compare the total number of sensitive macroinvertebrates per square meter for 1998 and 1999. A t-test was performed to determine if there was a significant difference between years.

We performed a Shannon-Weiner Index of Diversity for orders of macroinvertebrates for 1998 versus 1999. We also performed a t-test to determine if there was a significant difference in the Shannon-Weiner Indices

A scatter plot with a trend line was constructed to determine if there is a relationship between the number of macros collected on each test day to the number of days between testing. This is done to see if enough time is allowed for the population to recover from disturbances. A correlation coefficient will be calculated to determine the strength of any relationship.

A column graph was constructed to compare the macros per square meter at Poplar Lick and Sideling Hill (sites sampled the first week) when there was a greater number of inexperienced students.

A scatter plot between sulfate levels in the stream and the number of macroinvertebrates collected per square meter was constructed and a best-fit line was added. A correlation coefficient was used to determine the strength of the relationship. The graph may be used to show if sulfates may have contributed to the change in the number of macroinvertebrates per square meter.

An XY scatterplot with a trendline was constructed to show if a relationship exists between average nitrate concentrations and the average number of benthic macroinvertebrates per square meter. A correlation coefficient was calculated to show the strength of the relationship between the nitrate levels and the number of benthic macroinvertebrates.

We constructed a graph to compare the levels of combined nitrates and sulfates to the number of sensitive benthic macroinvertebrates per square meter. Of the benthic macroinvertebrates collected, we will include those that are the most sensitive to acid deposition in our graph. We chose to use a scatterplot with a trend line to represent our data. We calculated a correlation coefficient to test the strength of the relationship between the sulfates and nitrates and the benthic macroinvertebrate populations.

Results

As can be seen in Figures 1.1 through 1.8, the dissolved oxygen for all the streams has diminished but, not significantly. Nitrate concentrations for Mill Run, Evitt's Creek, Sideling Hill, and Poplar Lick have increased, while the nitrate values for Flintstone Creek, 15-Mile Creek, and Murley Branch have gone down. Sulfates levels have risen at Mill Run, Evitt's Creek, Sidling Hill, and Poplar Lick and have dropped at Flintstone Creek, 15-Mile Creek, and Murley Branch. Alkalinity has risen for all sites except for Mill Run and Murley Branch. Also, total hardness has risen for all sites except for Mill Run which decreased and Sideling Hill where it remained the same. Although graphs show differences between 1998 and 1999 data, t-tests revealed that there is no significant difference between the data.

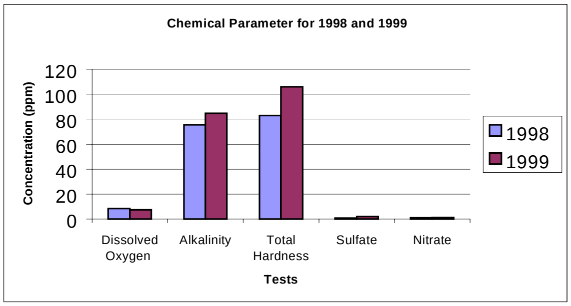


Figure 1.1

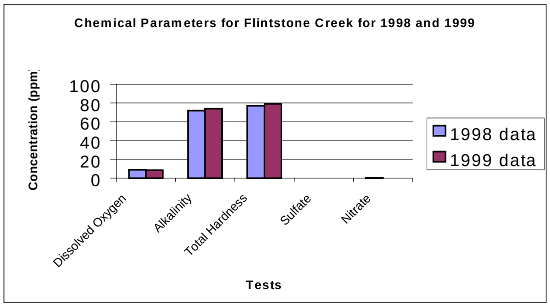


Figure 1.2

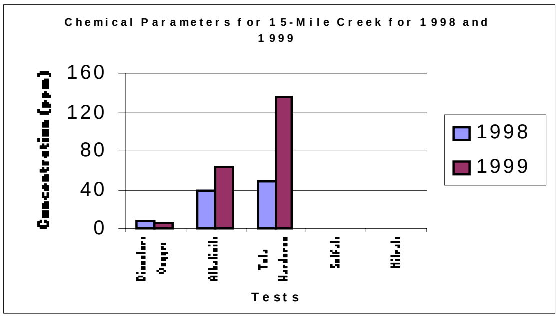


Figure 1.3

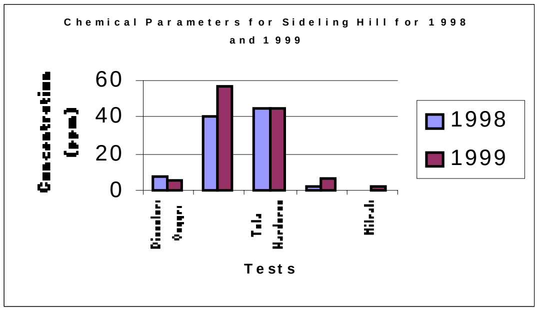


Figure 1.4

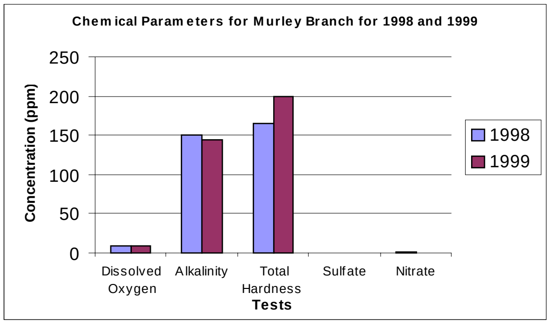


Figure 1.5

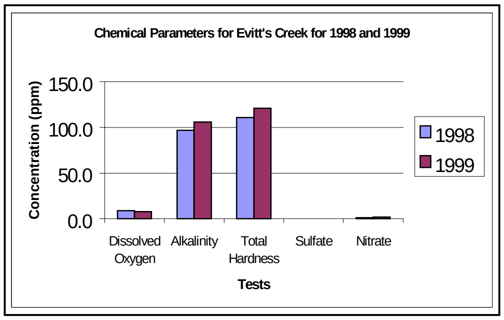


Figure 1.6

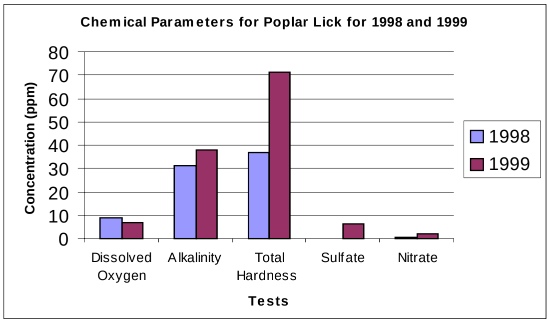


Figure 1.7

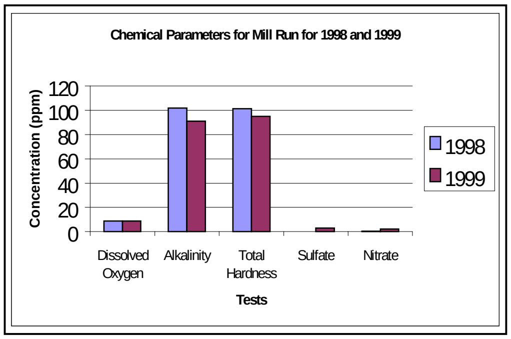
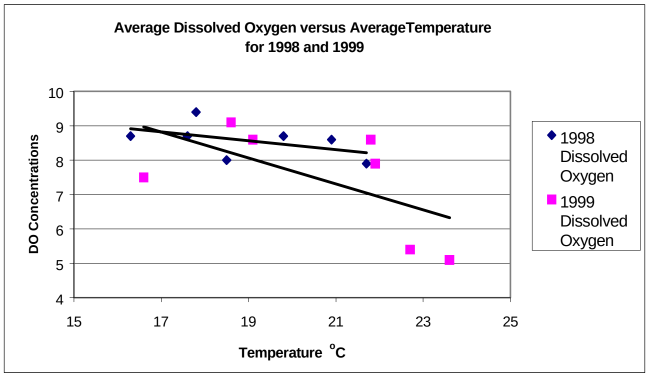


Figure 1.8

(Amber)

The scattergram, Average Dissolved Oxygen versus Average Temperature for 1998 and 1999, (Figure 3.1) shows that as the temperature rises, the dissolved oxygen decreases. This trend is illustrated in the data collected for both years. Also, the correlation coefficient shows that there was stronger relationship between the temperature and dissolved oxygen in 1999 than in 1998 (Appendix 3.1); the correlation for 1998 is -0.47 and the correlation for 1999 reads is -0.60.

Figure 3.1



The column graph, Average Temperature for 1998 versus Average Temperature for 1999, (Figure 3.2) shows that there was an increase in temperature at each of the seven sampling sites.

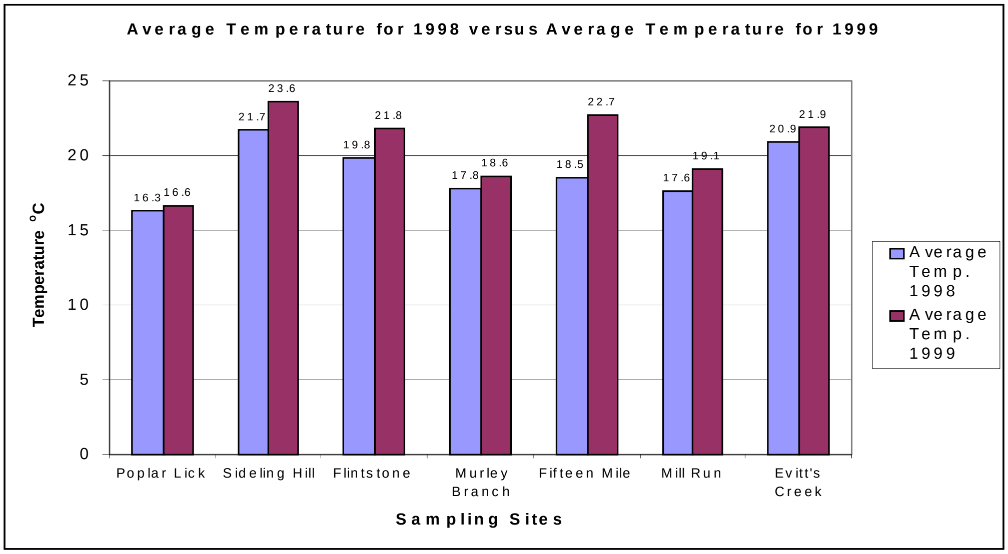


Figure 3.2

The following graph (Figure 4.1) represents the stream pH from 1998 versus 1999. The values for each site are very similar for both years. The calculated t-value was 0.98. This value falls between the expected value of 2.16 and –2.16, for a 95% confidence level and 12 degrees of freedom, indicating that there is no statistical difference between the 1998 and 1999 data.

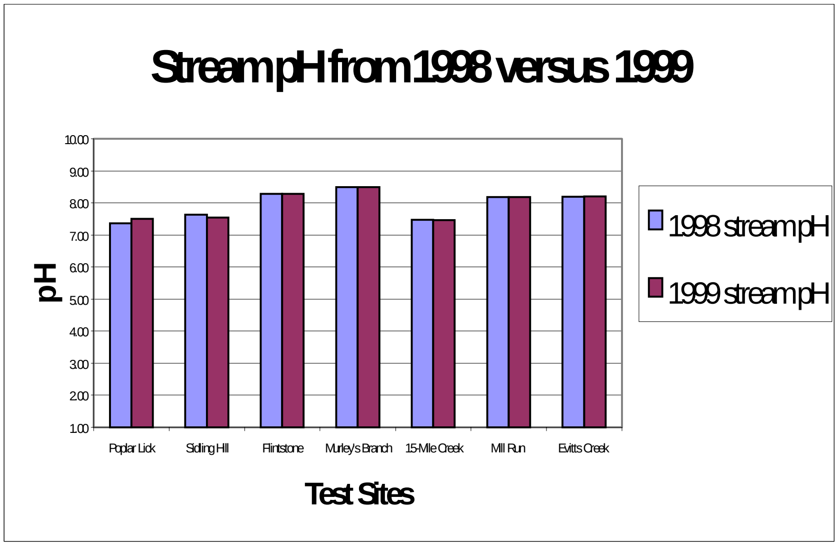


Figure 4.1

Figure 5.1, comparing the dissolved oxygen data from 1998 to 1999, shows that dissolved oxygen levels were relatively similar at all test sites for both years. Our calculated t-value was .10398 with 12 degrees of freedom at a 95% confidence level. The calculated t-value was lower than the expected value. Therefore, there is no significant difference in the dissolved oxygen levels between the years of 1998 and 1999.

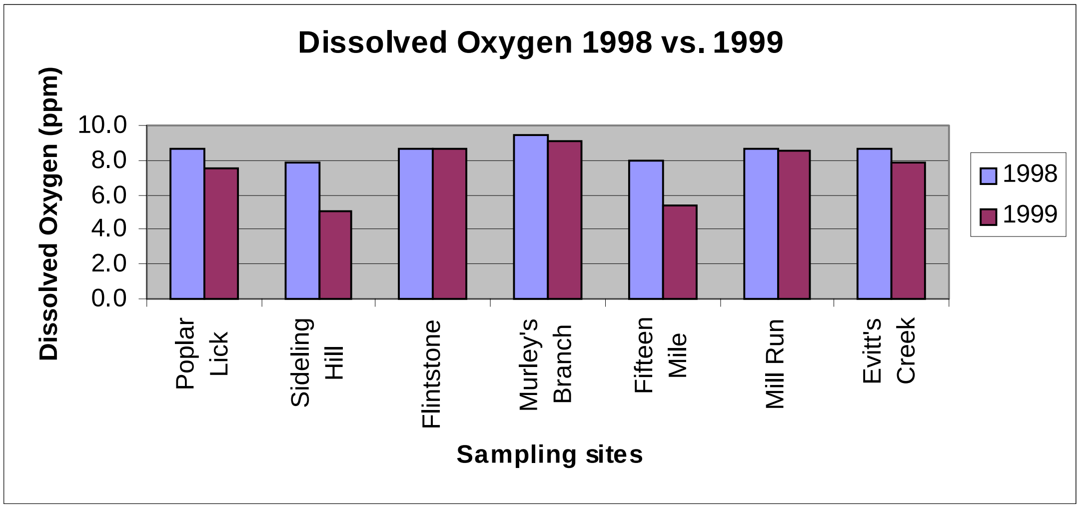
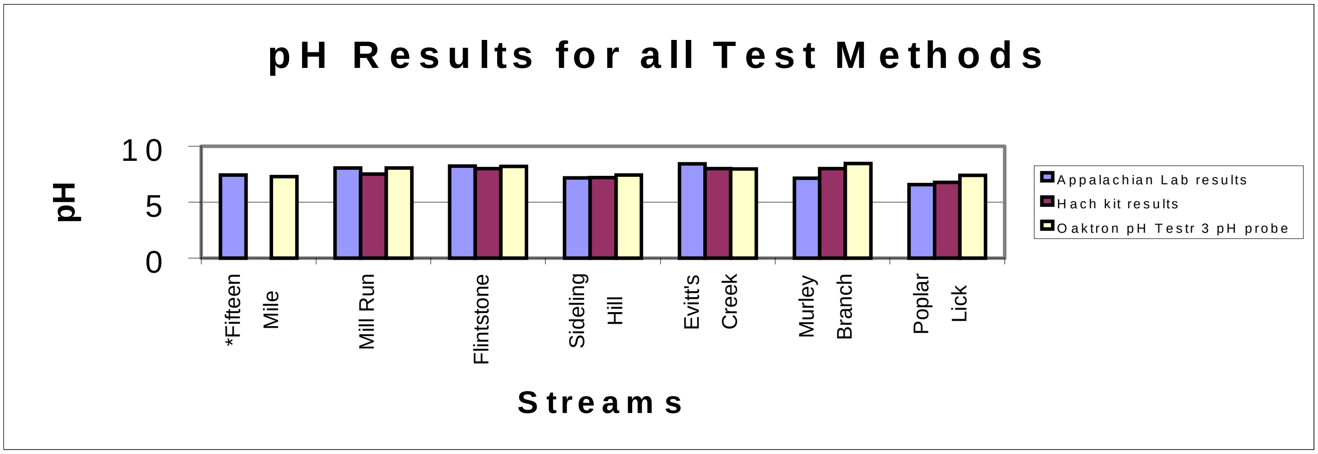


Figure 5.1

According to Figure 6.1, there seems to be minor differences between the pH measured at each site by the Appalachian Laboratory, the Hach test kits, and the Oaktron pH Testr 3 pH probe. After performing Chi-square tests, it was found that there is no significant difference between the Oaktron pH Testr 3 pH probe and the Hach test kit measurements for pH (X^2=0.1281, d.f.= 5, 95% confidence interval). A Chi-square test also showed that there is no significant difference between the pH measurements from the Oaktron pH Testr 3 pH probe and the Appalachian Laboratory (X^2=0.3380, d.f.= 6, 95% confidence interval).

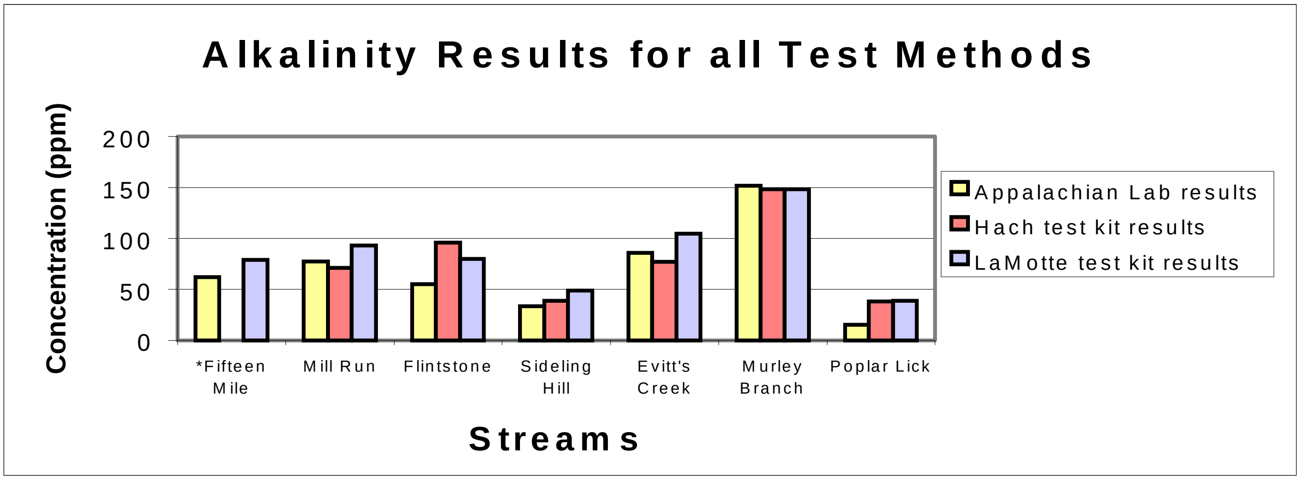


*pH was not measured with the Hach kits at Fifteen Mile

Figure 6.1

Figure 6.2 shows some differences in alkalinity measurements between the different tests. The greatest difference occurred at Flintstone Creek between the Appalachian Laboratory results and the Hach test kit results. There is about a 40 ppm difference between the two results. In general, the largest differences for each stream are between the Appalachian Laboratory results and the LaMotte test kit results. Chi-square tests show that the LaMotte results are significantly different from the Hach results (X^2= 17.9374, d.f.= 5, 95% confidence interval) and the Appalachian Laboratory results

(*X2*=36.9513, d.f.= 6, 95% confidence level) for alkalinity measurements. We then performed a Chi-square test comparing the Hach test kits to the Appalachian Laboratory results to determine if we should utilize the Hach kits for our study. The Hach testing method also showed a significant difference (X^2=33.4298, d.f.= 5, 95% confidence interval) from the Appalachian Laboratory results for alkalinity.

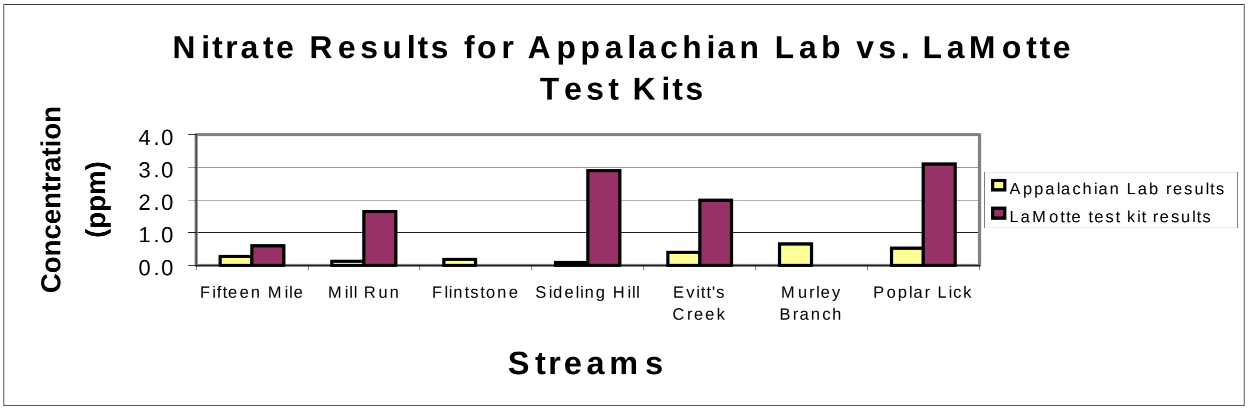


*Alkalinity was not measured with the Hach kits at Fifteen Mile

Figure 6.2

We found that there was no significant difference between the nitrate results from the Appalachian Laboratory and the LaMotte test kits, although the graph shows small differences (refer to Figure 6.3).

Figure 6.3



The graph comparing sulfate results from the Appalachian Laboratory and the LaMotte test kits seem to show a great difference between the results found by the Laboratory and the LaMotte test kit (refer to Figure 6.4). The Appalachian Laboratory found the sulfate at Murley Branch was 32 ppm and the LaMotte test kits found zero for the sulfate level. The LaMotte test kits found the sulfate level to be zero ppm at Fifteen Mile, Flintstone, Sideling Hill, and Murley Branch while the Appalachian Laboratory found values greater than zero for each stream. However, when we performed t-tests on the sulfate results for Appalachian Laboratory versus LaMotte test kits, we see that there is no statistically significant difference (X^2=0.0016, d.f.= 12, 95% confidence interval) between the two sets of results.

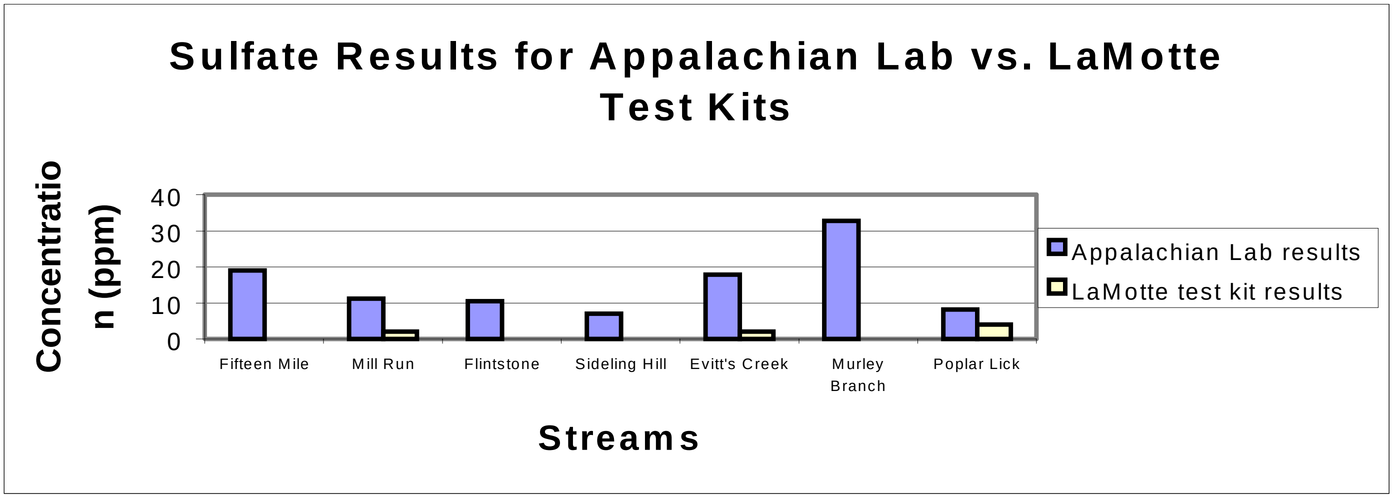


Figure 6.4

Figure 7.1 shows that when the pH increases, alkalinity increases. We also can conclude with a correlation coefficient of 0.80 that there is a strong positive relationship between the alkalinity and the pH of the test sites.

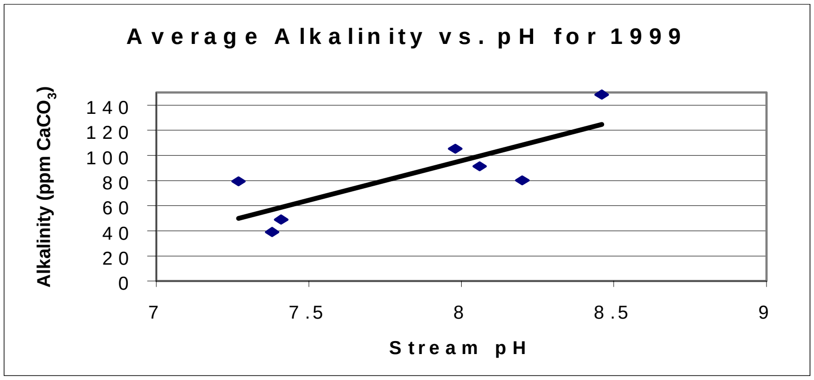


Figure 7.1

According to Figure 7.2, Murley Branch has a very high buffering capacity. Flintstone Creek, Fifteen Mile Creek, Mill Run, and Evitt's Creek have good buffering capacities. Poplar Lick and Sideling Hill have very low buffering capacities even though they have near neutral pH values.

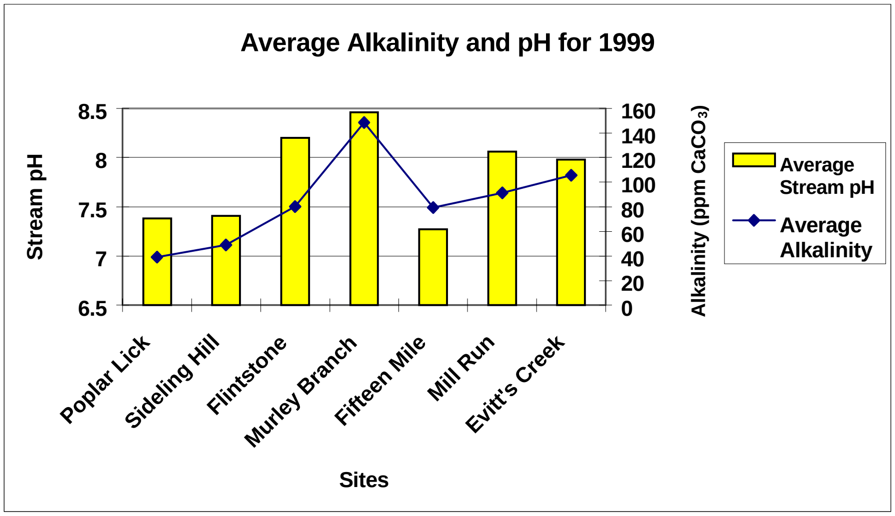


Figure 7.2

As seen below, Figure 8.1 shows that as the soil pH rises, the stream pH rises as well. The correlation coefficient between stream pH and soil pH is 0.89. The soil pH compared to the stream pH at each site is shown in Figure 8.2. This graph shows that the stream pH is much higher than the soil pH for all of the test sites.

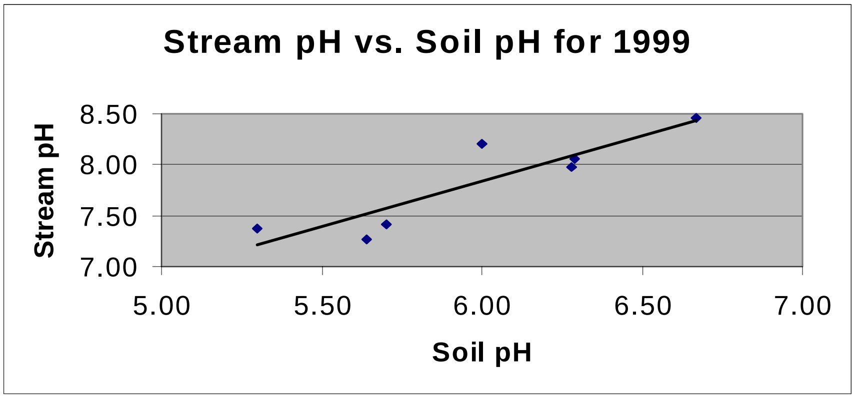


Figure 8.1

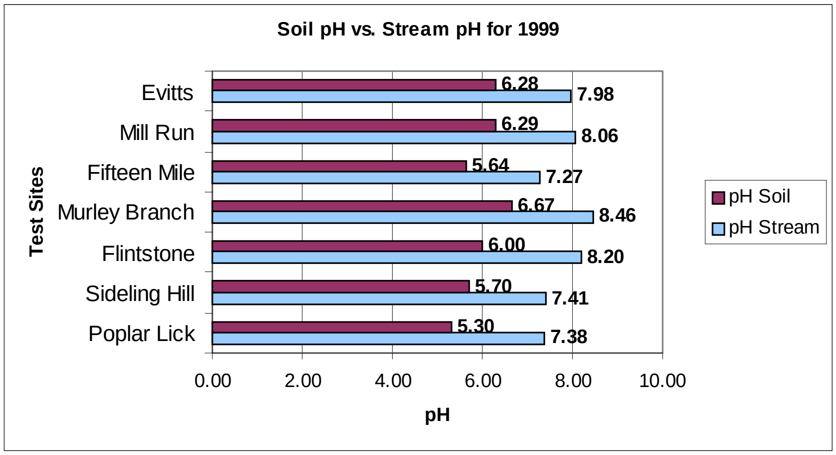


Figure 8.2

The relationship between the combined sulfate and nitrate values and the stream pH is shown in Figure 9.1. From the data collected, we received the following results: our highest combined sulfate/nitrate value was 9.11 ppm, with a pH value of 7.51; the lowest combined sulfate/nitrate value was 0 ppm, with a pH of 8.46. The correlation coefficient was -0.52, indicating that there is a slight relationship between the combined nitrate and sulfate values and the pH.

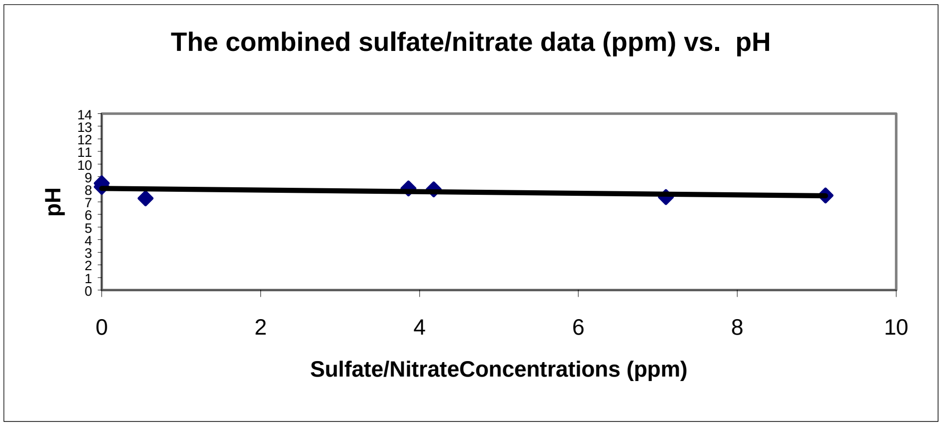


Figure 9.1

As illustrated in Figure 10.1, there was a difference between sensitive macroinvertebrate abundance from 1998 and 1999. The number of sensitive macroinvertebrates has decreased from 1998 to 1999 by approximately 15 macroinvertebrates per square meter. However, after performing a t-test, we found that there is no significant difference in sensitive macroinvertebrate abundance per square meter for 1998 and 1999.

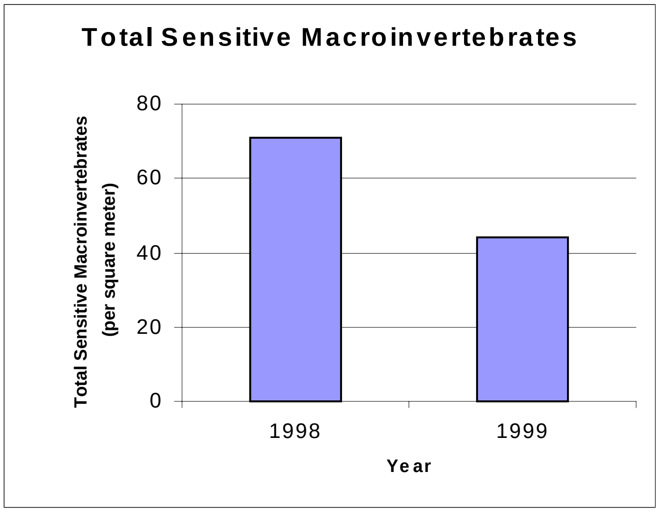


Figure 10.1

Figure 11.1 shows the Shannon Weiner Indices for 1998 and 1999. Those indices changed little between the two years. The largest change occurred at Flintstone Creek.

The index increased approximately 0.6, and the smallest change occurred at Sideling Hill where the index decreased approximately 0.1. We performed a t-test to compare the indices shown in the graph. The test indicated that no significant difference occurred in Shannon-Weiner diversity indices between 1998 and 1999 (at 12 degrees of freedom and a 95% confidence level).

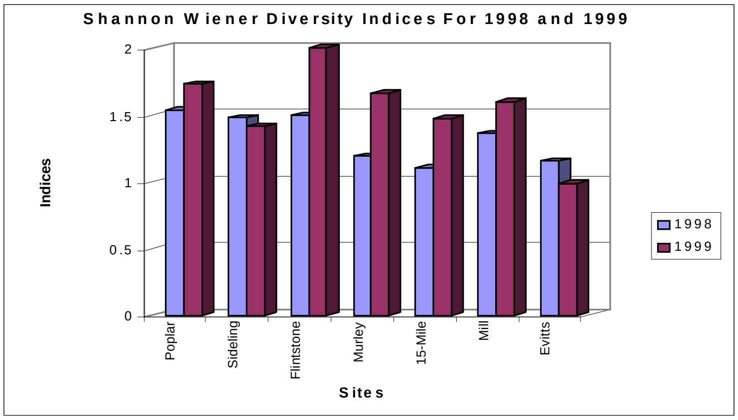


Figure 11.1

The trend line in Figure 12.1 shows that there is weak relationship between the number of macros collected per square meter and the time elapsed between testing. A correlation coefficient of 0.06 indicates that there is no relationship. When reviewing the data, we can see several increases and decreases between the samples, but there is no specific pattern. Additionally, there is no relationship between the number of macros collected per square meter at Sideling Hill and Poplar Lick and the days between testing (Figure 12.2).

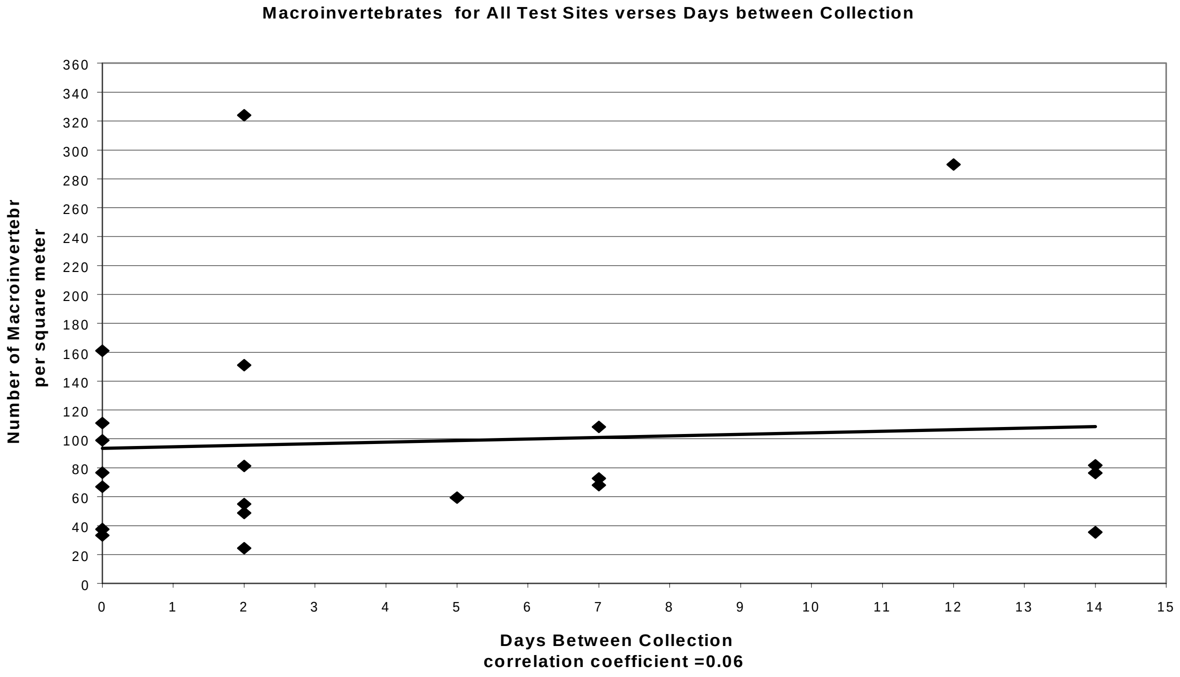


Figure 12.1

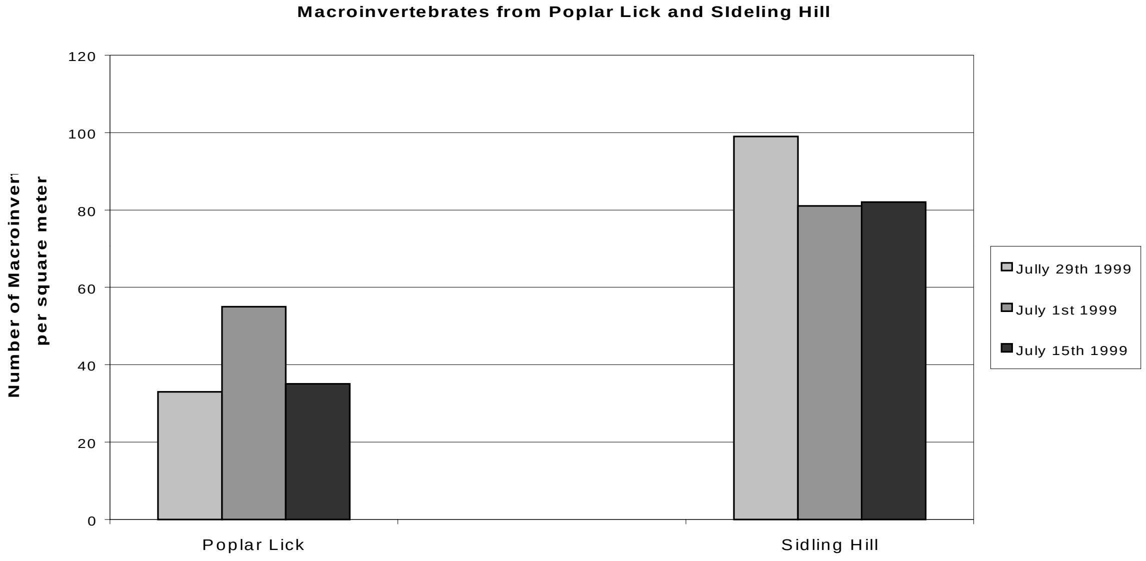


Figure 12.2

The graph (Figure 13.1) shows that the macroinvertebrate counts decline slightly as sulfate levels increase. However, the correlation coefficient of -0.24 indicates that the relationship is nonexistent.

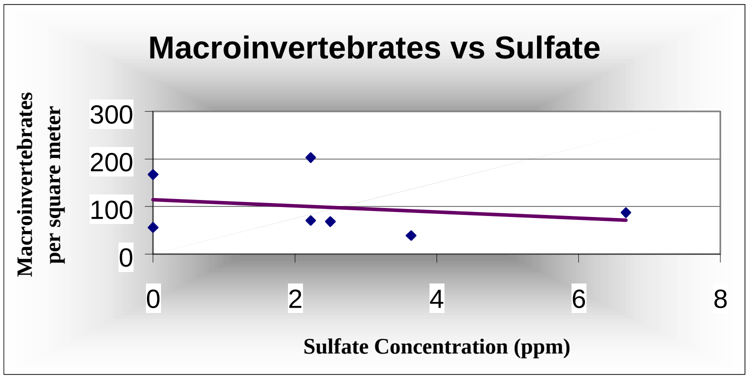


Figure 13.1

Figure 14.1 shows that as the concentration of nitrates increases, the number of benthic macroinvertebrates per square meter decreases slightly. However, the correlation coefficient of -0.17 indicates that a relationship does not exist.

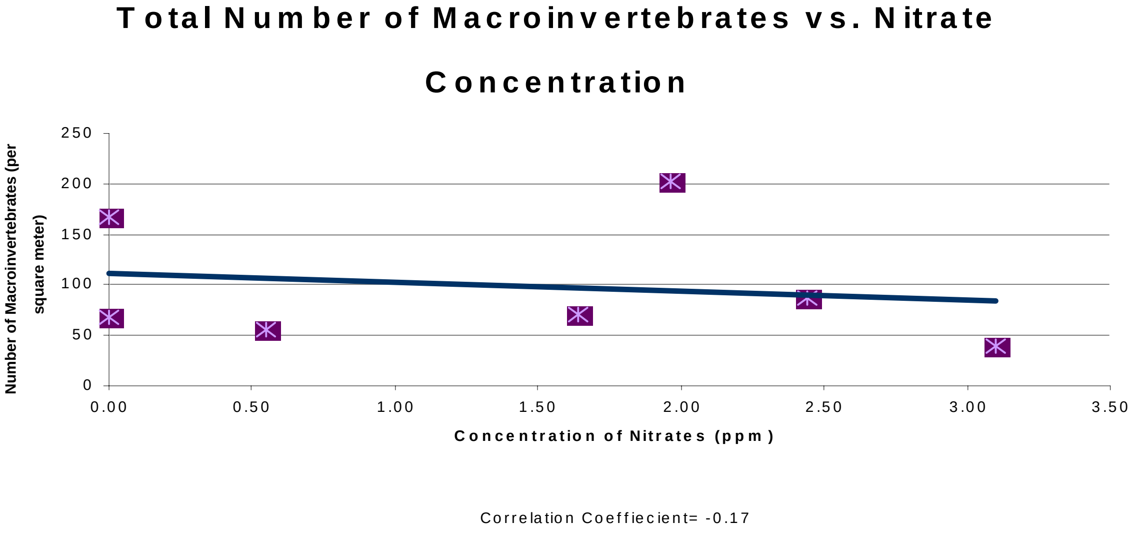


Figure 14.1

Figure 15.1 shows the combined nitrate and sulfate levels at each site compared to the number of sensitive benthic macroinvertebrates per square meter at each site. The graph shows that the number of macroinvertebrates increases as the sulfate and nitrate levels increase. The result of the correlation coefficient test was 0.263. This result shows that there is not a strong relationship.

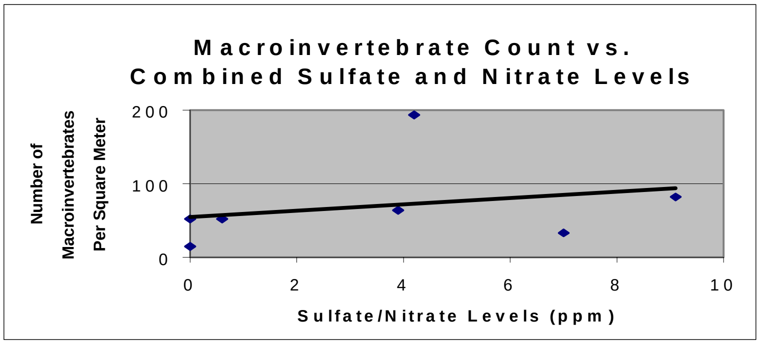


Figure 15.1

Discussion

Water depth, animal and human waste, and dumping chemically imbalance items in the stream could have caused the slight variation observed in the graphs for stream chemical parameter.

(Amber)

Based on the inverse relationship between temperature and dissolved oxygen, we would expect that if there were a change in the temperature, there would also be an inversely proportional change in dissolved oxygen. An earlier column graph also shows there was a decrease in the measured amount of dissolved oxygen observed for each sampling site.

The reason for this comparison was to see if the pH values of the streams were rising, dropping, or remaining relatively the same. This year we expect the readings to be approximately the same as last year.

Therefore, it will provide a base line to see if there is a change after the plant goes online. There are many factors that may have affected the slight variations of observed pH. For example, the samples could have been taken in different areas of the stream. One area of the stream could have a high buffering capacity, making the pH higher.

According to both the t-test and graph, there is no statistically significant difference between dissolved oxygen levels from 1998 to 1999. However, the 1999 dissolved oxygen levels are slightly lower for Sideling Hill, and Fifteen Mile than the 1998 values. The dissolved oxygen could have decreased as a result of low stream flow, fewer riffle areas for the water to mix with atmospheric oxygen, or warmer water temperatures.

We chose the Oaktron pH Testr 3 pH probes in lieu of the LaMotte pH test kits because we found the probe to be more accurate than the kit. The Chi-square tests showed that there were no significant differences between the pH probes and the Hach kits or between the pH probe and the Laboratory results. We did not perform a Chi-square test to determine if there is a significant difference between the Hach kits and the Appalachian Laboratory results because we determined that the probe was accurate for measuring pH.

Due to the inaccuracy of the LaMotte kits for measuring alkalinity, as determined by the Chi-square test, we also performed a Chi-square test comparing the Hach kit data to the Appalachian Laboratory data to determine if they would be more accurate in measuring alkalinity. The LaMotte kit alkalinity tests involved titration and were calorimetric; different shades of color in the test were sometimes hard to view, which could result in accuracies in the test. These differences could also be attributed to human error or different sampling locations at the stream. In the future, we will have to perform the alkalinity tests more carefully, a greater number of times, and perhaps with a different test kit. We cannot, however, determine that the LaMotte kits are inaccurate for measuring alkalinity since the differences could be attributed to human error in performing the test.

The LaMotte test kits are accurate for measuring sulfates and nitrates according to the t-tests comparing the Appalachian Laboratory to the LaMotte kits.

The LaMotte test kits are, except in the case of alkalinity, accurate for conducting our study. In view of the cost, ease of performing the tests, and overall accuracy, they are the best choice for the amount of time and money available for our study. For future investigations, we may look into additional test kits for conducting alkalinity tests. We may also conduct additional tests to completely determine where the error lies in the alkalinity measurements.

Alkalinity is the amount of buffering material in the water; thus it has a relationship with pH. When a stream pH is neutral or basic, one would expect a high

We expected a high correlation between soil pH and stream pH. We also expected the stream pH to be higher than the soil pH due to the soil's ability to act as a buffer to acid deposition. The relationship between soil and stream pH is very high. Therefore, we surmise that the soil is indeed buffering the acid rain.

The relationship between combined sulfate/nitrate and pH was weak, thus predictions about the pH from nitrate/sulfate values using this graph would be very unreliable. The lack of nitric and sulfuric acids in the stream water caused low nitrate and sulfate values. As a result there was no great effect on pH. Many factors other than the acid deposition, such as buffering capacity of the soil and stream water, and other sources of acidity may have affected the pH and the combined nitrate/sulfate levels. Some of the sources affecting stream water quality may be farm runoff, dissolved minerals (e.g. gypsum), and other materials in the streams. Our baseline data shows very little relationship between pH and combined nitrate/sulfate values.

The t-test shows that there is no significant difference between years. We expected this result since we are still collecting baseline data. We could also use this type of graph to compare macroinvertebrate abundance for future years of our study. We would expect to find a difference if the power plant was affecting the streams, or also if there a drop in pH, higher nitrate or sulfate levels from a source other than the power plant, or a disturbed habitat due to antroprogenic factors.

No significant difference occurred in the macroinvertebrate community structure, which may show that the stream environment is relatively stable. This information is useful because it provides us with baseline data for next year.

The inexperience of the younger students does not appear to affect the number of macros collected. Creating a bar graph is the best method we could devise to analyze this. The results also indicate that different time lapses between sampling periods at a particular site do not influence the samples collected for the macroinvertebrate community.

In light of the conclusions there is no need to adjust our testing pattern. Sampling different riffle areas could have caused the variability in the data. Also, some riffle areas may have been sampled more often than others. We are unable to consider this possibility because we did not note which riffle areas were used when collecting. Next year we should mark which riffles were used.

The graph and the linear regression analysis did not present any unexpected findings, as a literature search did not reveal any conclusive evidence of a relationship between sulfate levels and the number of macroinvertebrates.

Other research has stated that there is no direct relationship between nitrates and benthic macroinvertebrates, but excessive nitrates can cause low levels of dissolved oxygen (EPA 1999). Low dissolved oxygen results in lower numbers of macroinvertebrates. If we were to find higher levels of nitrates in the streams, a correlation between macroinvertebrates and nitrates may occur. Because the nitrate levels were very low, it is unlikely that the nitrates affected the dissolved oxygen levels.

It was not expected that the macroinvertebrate populations would increase as the nitrate and sulfate levels increased. A reason for this could be that the alkalinity of the streams neutralized the acids and left the sulfates and nitrates in the water. This would not have an effect on the macroinvertebrates and, therefore, the sulfate and nitrate levels would not be an indicator of the pH or the health of a stream.

To improve the study, each student should learn the methods for all the test kits before going into the field. We could also increase the number of test sites and the number of times we visit the test sites. This change in our procedure would increase our sample size thus giving us a better representation of the water quality. We could also improve our accuracy by having each student perform the same test each field testing day. In addition, we could have a group of students assigned to each site to perform the tests. In these groups, we should have the inexperienced students with the experienced students. Through cooperative learning, peers learn easier and are able to ask question in a way that each of them can understand. By collecting rain samples, we could obtain information on the pH of different areas. Additionally, we could obtain data on wind direction, which will help to determine where the emissions are moving.

A limitation that we have with this research project is that we only have six weeks to teach concepts and to gather and analyze data. Experience is another problem that we have; every year new and inexperienced students join the program. Therefore, every year we have to teach these students how to use the equipment in the field. Another problem is that nature is unable to be controlled and is unpredictable. For instance, in the past two years we have had a drought in Maryland. The drought caused some streams to dwindle to small pools of water. We also can not travel a long distance due to time and lack of manpower. Additionally, we are limited to the number of accessible sites that we are able to use. We are also limited to the use of portable test kits rather than the facilities at the Appalachian Lab, which may be more accurate than the test kits.

Some things that we could do to reduce acid deposition can be done at home. For example, we could conserve energy by turning lights off when we leave a room or not use the heater or air conditioner when they are not needed. Also to reduce acid deposition, people could car pool, walk, or bike ride. They could also choose an alternative power source for their house, such as solar power, wind-generated power, natural gas, geothermal, or even alcohol combustion. These sources can result in fewer emissions of SO_2 and/or NO_x or can cut emissions altogether. Power plants can also help reduce these emissions by burning cleaner types of coal, use fluidized-bed combustion, and by using scrubbers.