The Relationship Between pH, Phosphate, and Algae Levels in the Soil

Research Report by:

Colleen Gardina, Whitney McClees, & Lauren Sless

ABSTRACT

Anomalies were noticed for soil algae and pH levels during a soil biota survey in the backwoods of Roland Park Country School. Site 1 had unusually high levels of algae for such a shady and dry area, while Site 4 had a much lower algae count, in spite of additional moisture and sunlight (ideal conditions for algae to thrive). It is known that pH levels in soil have an inverse relationship with phosphate levels in soil and that phosphate is a key nutrient for algae. Therefore, we hypothesized that the unusually high levels of algae in site 1 are due to the low pH values in that site and the corresponding high phosphorous levels. We tested soil samples for algae, pH and phosphate in 12 different spots in both sites. We failed to observe the expected relationship between pH and phosphate, but did observe the expected relationship between phosphate and algae. Therefore, our hypothesis was incorrect and we decided that our next step for our research was to test the water in the site because we now suspect runoff from the surrounding campus may be the source of the discrepancy between pH and phosphate.

INTRODUCTION

Algae, specifically the terrestrial algae we studied in our investigation of the woodlands on the Roland Park Country School campus, are widely known to thrive in moist environments with a large amount of sunlight. In addition, algae especially populate wet soils, such as silt and clay, and in shallow, freshwater areas (Dodge and Shubert, 1996). However, after performing a soil biota survey of the woodlands, we found that Site 1 (39.35794º N; 076.63977º W), the site with the driest and shadiest environment, contained statistically significantly higher algae levels (2.5 / mm^2) than Site 4 (39.35733º N; 076.63840º W), a flat, muddy area with very little tree cover, that contained 0.91 / mm^2 [$p = 0.019$] (ESSRE Microclimate Database, 2006).

This anomaly puzzled us; therefore, we performed additional research in the literature in order to attempt to explain why this natural relationship might be disrupted in these two sites. We discovered that, in addition to the amounts of water and sunlight in an ecosystem, the pH and phosphate levels can both indirectly and directly affect the quantity of algae in any environment as well. In fact, Jarvis (2005) states that ecosystems with low, acidic pH levels have higher phosphate levels in the soil. These higher phosphate levels can cause higher algae levels because phosphate is a nutrient that algae need to live and grow (Jarvis, 2005). Phosphate is a critical component of nucleic acids (Raven and Johnson, 1991), and therefore with higher phosphate concentrations, the algae will be able to reproduce more (Pote, 2003).

When we returned to the results of our biota survey, we found that our data actually corresponded with Jarvis's (2005) assertion that pH could affect the size of an algae population. A lower pH should correspond to a significantly higher quantity of algae in the soil, and, in fact, Site 1, with the higher algae count, had an average pH level of 5.7, whereas in Site 4, the pH level was 6.5 (ESSRE Microclimate Database, 2006). Given that the differences between both average algae levels and average pH levels between the two sites were statistically significant ($p = 0.019$; $p = 0.005$, respectively), we decided that this difference in pH possibly explains the anomalous algae numbers in Site 1 because the lower pH may have made more phosphate available to the algae for nutritional purposes.

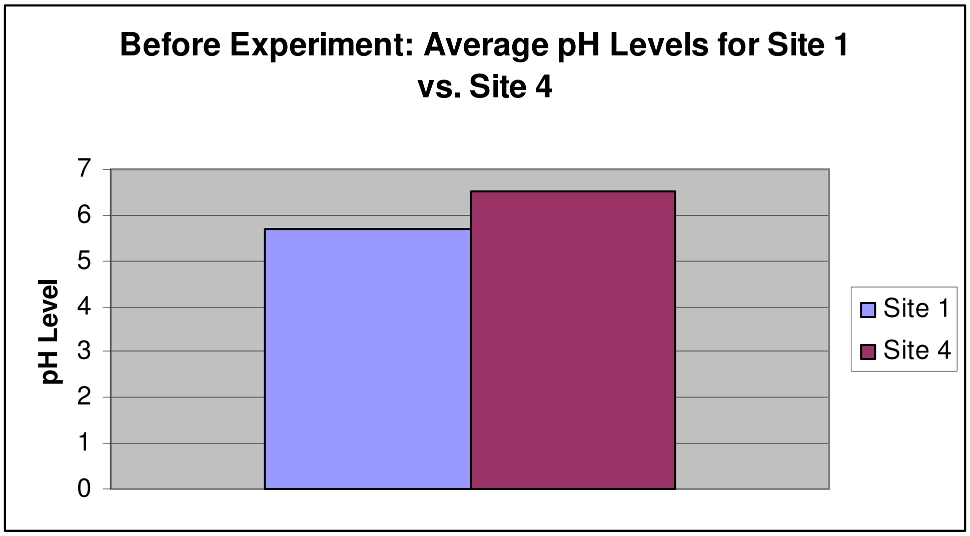
Therefore, we designed an experiment to test the hypothesis that the lower pH level in the Site 1 ecosystem leads to the higher phosphate levels that could account for the higher algae levels in that site. In order to confirm our hypothesis, we examined Sites 1 and 4 for algae, phosphate, and pH levels.

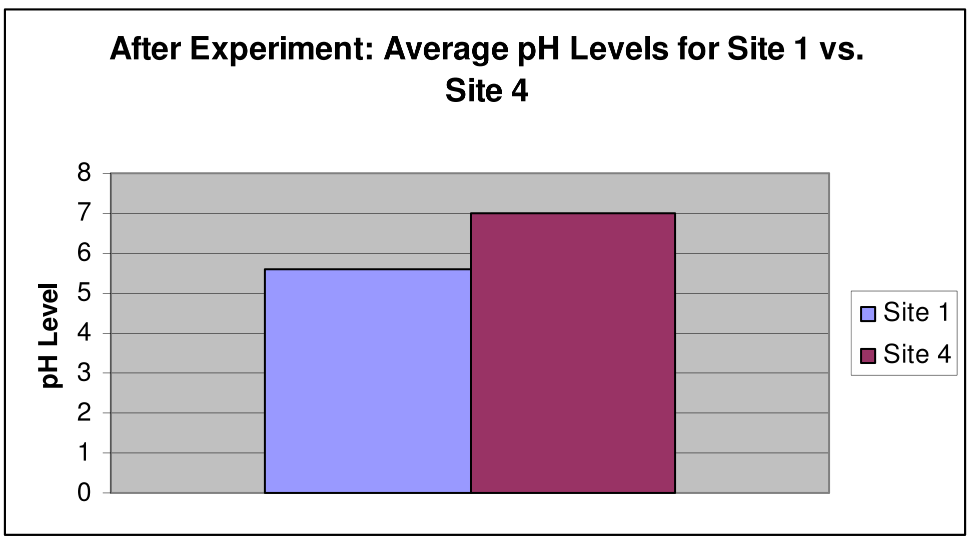
METHODS

24 glass microscope slides were marked with a line 1.5 cm from one end. 24 slides were then taken outside to be cultured for algae. For three consecutive days, 3 slides per day were inserted each day in each quadrat in site one (39.35794^{o} N; 076.63977^{o} W) and site four (39.35733^{o} N; 076.63840^{o} W) in the woodlands on the Roland Park Country School campus. They were inserted 6 cm in the ground, leaving 1.5 cm out of the ground, exposed to sunlight (Pipe and Cullimore, 1980). The slides were allowed to sit for five consecutive days from their day of insertion. After five days, each day's collection of slides was carefully removed from the soil, and excess soil was cleaned from the slides with distilled water. Then, a column of soil, 6 cm long by 2.3 cm in diameter, was removed from the exact spot where the slide was taken out of the ground using a soil core. Then, the algae were observed at a power of 40x using a compound light microscope. Five fields of view were observed and the algae was counted for each field of view. The five algae counts were averaged together and the average was divided by 17.3 mm^2 to determine the number of algae per mm^2 (ESSRE Soil Ecology Protocols, 2003). Concurrently, pH and phosphate tests were performed on each corresponding soil sample, using the LaMotte STH-14 Series soil test kit. The amount of phosphate was measured in parts per million.

RESULTS

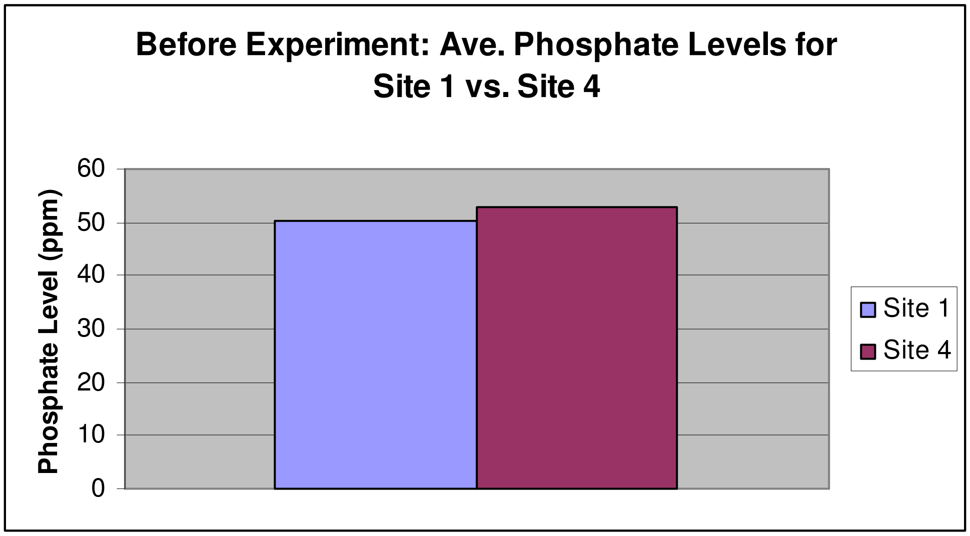
pH

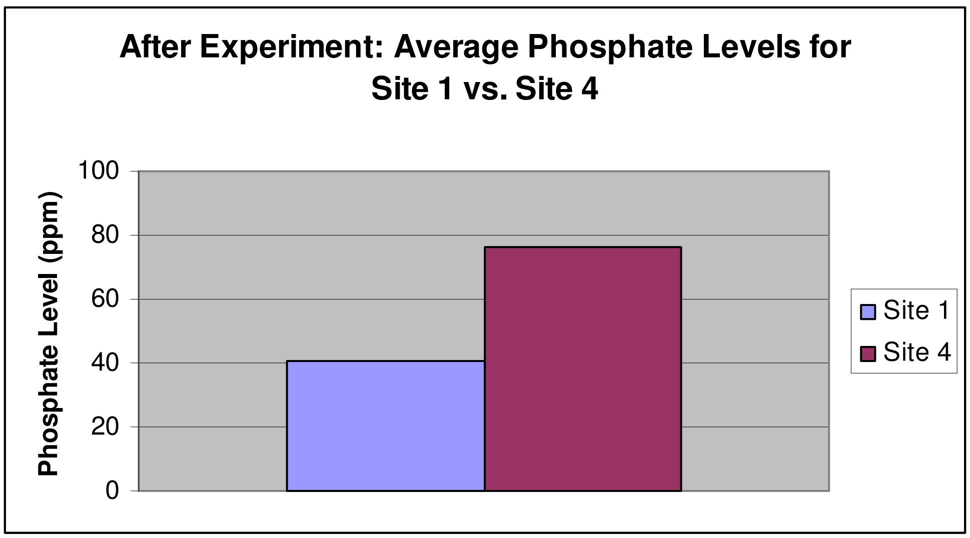




In the two graphs pictured above, it is clear that the difference between the soil pH in Site 1 and Site 4 became more pronounced, with the pH in Site 1 decreasing from 5.7 to 5.6 and the pH in Site 4 increasing from 6.5 to 7.0. The p-values between the before and after graphs went from $p = 0.005$ to $p = 0.00$, respectively. This shows that both times the pH tests were performed on the soil in these two sites, a significant difference was found to exist between the two sites.

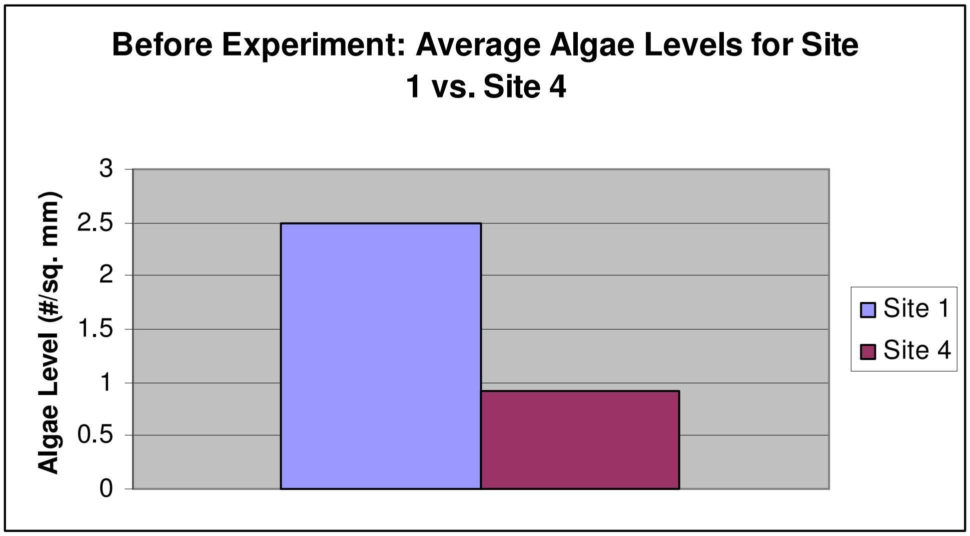
Phosphate

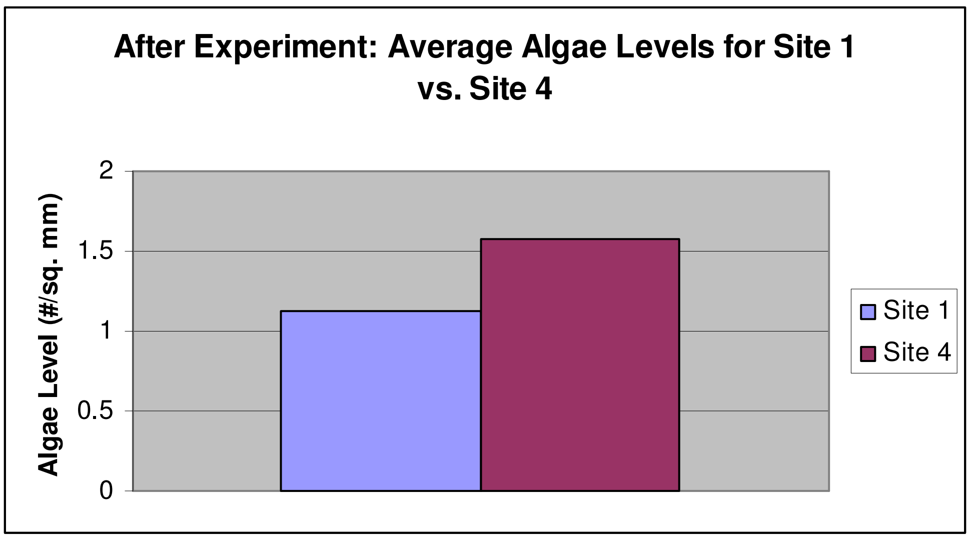




Phosphate experienced a different change than pH. As can be seen in the two phosphate graphs above, the relationship between the phosphate levels in Site 1 and Site 4 changed drastically. In the graph of the data taken before we performed our experiment, it is clear that the difference in phosphate levels in the soils of these two sites was insignificant ($p = 0.85$). However, in the graph illustrating our post-experiment findings, we can see that there is now a considerable difference between the amount of phosphate in the soils of the two sites (the levels went from a difference of 2.5 ppm to a difference of 35.35 ppm). There is, in fact, now a significant difference between the two sites in this case, with a p-value of 0.01.

Algae





As the last two graphs show, algae levels in the soils of the two sites changed significantly in a pattern that corresponds to the pattern of change in phosphate levels. Between the start and end of our experiment, a drastic change occurred in the algae levels in Site 1 and Site 4. In fact, where there was once a statistically significantly lower level of algae in Site 4 ($p = 0.02$), there are now abundant amounts of algae in Site 4 ($p = 0.31$).

DISCUSSION

Our findings contradict our hypothesis. We predicted that the original differences in pH in the soil between site 1 and site 4 would account for differences in the levels of phosphate in the soil that would account for the observed difference in algae density. However, the soil pH in site 1 in fact became slightly more acidic (decreasing from 5.7 to 5.6), while the soil pH in site 4 became more basic (increasing from 6.5 to 7). This made the difference between the two sites even more significant because the p-values went from 0.005 to 0.00. Meanwhile though, the amount of phosphate in the soil in site 1 actually went down from 50.42 ppm to 40.9 ppm and these changes in the amount of phosphate actually increased from 52.92 ppm to 76.25 ppm ($p = 0.01$). Therefore, our data displayed the exact opposite of the known relationship between pH and phosphate in soils (Jarvis, 2005). In fact, we observed a direct linear correlation (r^2= 24.686%) rather than the usual inverse relationship.

This presents the question of what is causing the abnormal relationship between pH and phosphate levels in the soil at site 1 and site 4, especially because the expected relationship between phosphate and algae was observed (r^2=38.472). A possible explanation for the unusual and unexpected disturbance of the relationship between pH and phosphate could be the fact that on the days immediately preceding our collecting of data, a very heavy rainstorm had occurred. According to Busman *et al* (2002), the freshwater stream running through site 4 could have been flooded with excess phosphate from the hill located near site 4 that is heavily fertilized. This excess phosphate could account for the sudden increase in algae in site 4, while the excess water could account for the increase in pH. For further research, we could test phosphate levels in the stream to see if the stream is flooded with phosphate.

Bibliography

Busman, L., Lamb, J., Randall, G., Rehm, G., and Schmitt, M. (2002) The Nature of Phosphorus in Soils. Available Online http://www.extension.umn.edu/distribution/cropsystems/DC6795.html.

Dodge, J. and Shubert, L. (1996) Algae. Methods for the Examination of Organismal Diversity in Soils and Sediments. Pg. 67-78.

ESSRE (2006) Microclimate Databases. Available Online https://faculty.rpcs.org/brockda/ESSRE%20Microclimate%20Survey.htm.

ESSRE (2003) Soil Ecology Protocols. Available Online https://faculty.rpcs.org/brockda/ESSRE%20Protocols.htm.

Jarvis, B. (2005) Phosphorus Effect on pH. Available Online http://www.raingardens.com/forum/index.cgi?noframes;read=10167.

Pipe, A.E. and Cullimore, D.R. (1980) An implanted slide technique for examining the effects of the herbicide Diuron on soil algae. *Bulletin of Environmental Contamination and Toxicology* 24, 306-312.

Pote, D. (2003) Does Initial Soil P Level Affect Water-Extractable Soil P Response to Applied P? Available Online http://www.ars.usda.gov/research/publications/publications.htm?SEQ_NO_115=129563.

Raven, P. and Johnson, G. (1991) Understanding Biology Second Edition. pg. 58-60