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Article

Effect of Fertilizer on Water Quality of Creeks over Time

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SUMMARY

Many people use fertilizer for commercial use, but are unaware of its harmful impacts. The main two ingredients in fertilizer are phosphorus and nitrogen, which are present in fertilizers through compounds such as ammonium phosphate and nitrate. Excess nitrates are dangerous as high nitrate levels in drinking water can cause infants to develop illnesses. In this experiment, we studied the effects of fertilizer on the water quality of Saratoga Creek over time. For 4 days, we measured the total dissolved solids (TDS), pH, and nitrate levels of eight creekwater samples after three fertilizer treatments of 0.5 tsp, 1 tsp, and 1.5 tsp were added. Results showed that fertilizer had a significant effect on all 3 indicators, with TDS levels substantially exceeding the 500 ppm level suggested in the "U.S. Secondary Maximum Contaminant Levels" (SMCLs) and nitrate concentrations surpassing the 10 ppm standard in drinking water set by the EPA. TDS concentrations for the 3 fertilizer treatments at 4 days exceeded the standard by around 6, 12, and 20 times respectively, while pH levels dropped below the acceptable range of 6.5-8.5. Nitrate levels spiked at two days, then gradually returned to their original levels. Although TDS does not pose as great a health risk, high nitrate levels in water can have damaging effects on people's health if consumed, and low pH levels can contaminate the habitats of aquatic species. Therefore, we suggest that people limit their fertilizer use to protect the environment and their peers.

INTRODUCTION

Millions of people use fertilizer in their farms and backyards to increase their crop yield or enhance the growth of their plants. However, improper use of fertilizer combined with runoff can contaminate the groundwater of streams and creeks and degrade their water quality. Nutrients in fertilizer could cause nutrient buildups in streams, lakes, and rivers, stimulating the unwanted growth of algae and other aquatic plants (1, 2). Furthermore, the nutrient enrichment could lead to reduced dissolved oxygen concentrations; without sufficient dissolved oxygen, fish and other aquatic species could suffocate (2).

Fertilizer is primarily made up of two nutrients: nitrogen and phosphorus (3). Although phosphorus is mainly responsible for algal blooms in surface waters and can cause an excessive amount of nutrients (4), its low solubility renders the loss of phosphates in water insignificant, especially in comparison to quantities released by industrial wastes (1). On the other hand, nitrogen is highly soluble and can leach down through the soil and contaminate groundwater (1, 3). The U.S. Public Health Service set the limit for nitrate levels in domestic water supplies to be 10 parts per million (ppm) (5). High nitrate levels in drinking water can cause babies to develop methemoglobinemia, a disorder which interferes with oxygen intake in the circulatory system (2, 3, 6).

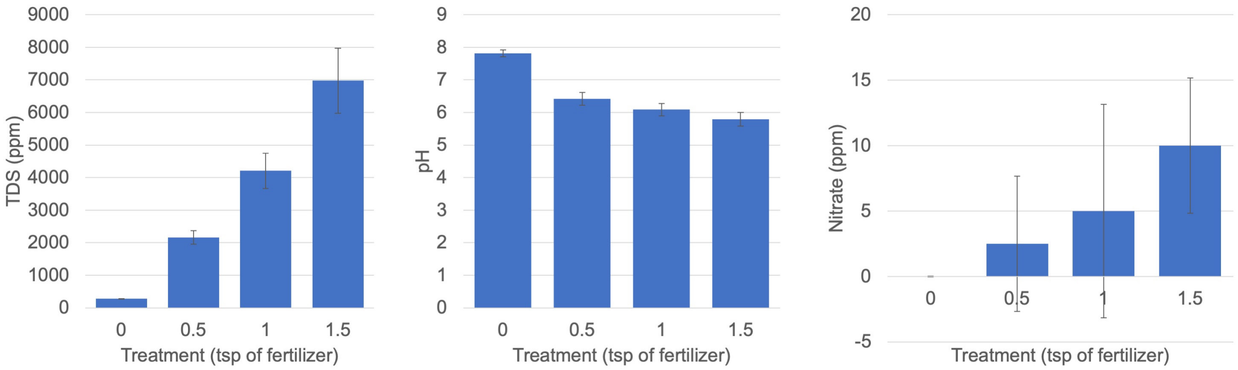
The addition of fertilizer can also drastically change the pH of water, making it drop below the acceptable level of 6.5-8.5. Waters of low pH could leach toxic metals, including iron, manganese, copper, lead, and zinc; create damage to metal piping; and have a bitter taste (8). Many species of fish and aquatic life are also sensitive to changes in water temperature and composition and could be harmed due to acidification (8). Total dissolved solids (TDS) are also an important indicator of water quality. The U.S. guideline for TDS is 500 ppm, and high levels of dissolved solids can stain household supplies, corrode pipes, and cause a metallic taste (8). Similar to low pH, increased TDS levels may suggest that harmful metals like bromide, sulfate, and iron are present in the water (8).

To better comprehend the effects of fertilizer on water quality in creeks over time, we studied the changes in nitrate, TDS, and pH levels in water samples we collected from Saratoga Creek, a local creek in the Bay Area, after the addition of fertilizer. We hypothesize that as the amount of fertilizer in the creek increases, the water quality of Saratoga Creek will decrease. Data from our experiment illustrates that after the addition of fertilizer, the TDS and nitrate levels increased past the acceptable level in drinking water, while the pH levels decreased drastically, as the water turned acidic. Over time, the TDS levels continued to climb; however, the nitrate and pH levels began to gradually return to their original levels with the nitrate concentration decreasing and the pH increasing. As a result, this experiment reveals that continual use of fertilizer degrades the water quality of creeks, rendering it dangerous for aquatic species to live in and for human consumption.

RESULTS

This experiment was conducted to study the effect of fertilizer on the water quality of creeks. Data was collected by measuring the change in TDS, pH, and nitrate levels of water samples from Saratoga Creek over a period of 4 days after the addition of 3 different fertilizer treatments: 0.5 tsp, 1 tsp, and 1.5 tsp. Each treatment was applied to two samples of creek water, and there were also two samples that were given no fertilizer that acted as control samples for this experiment.

As expected, the two control samples that had no fertilizer



A B C

Figure 1. Mean TDS, pH, and Nitrate vs. Fertilizer Treatment. (**A**) Mean TDS vs. Fertilizer Treatment. Fertilizer treatments significantly increased the Total Dissolved Solids (TDS) of Saratoga Creek (*p*=7.77E-16). (**B**) Mean pH vs. Fertilizer Treatment. Fertilizer treatments significantly decreased the pH of Saratoga Creek (*p*=2.22E-16). (**C**) Mean Nitrate vs. Fertilizer Treatment. Fertilizer treatments significantly increased the nitrate levels of Saratoga Creek (p=0.003049). The numbers on the bars represent the mean value taken from all eight data points of TDS for the respective treatments—two from each day (0, 0.1, 2, 4). Tukey Post-Hoc values are in **Table 1**.

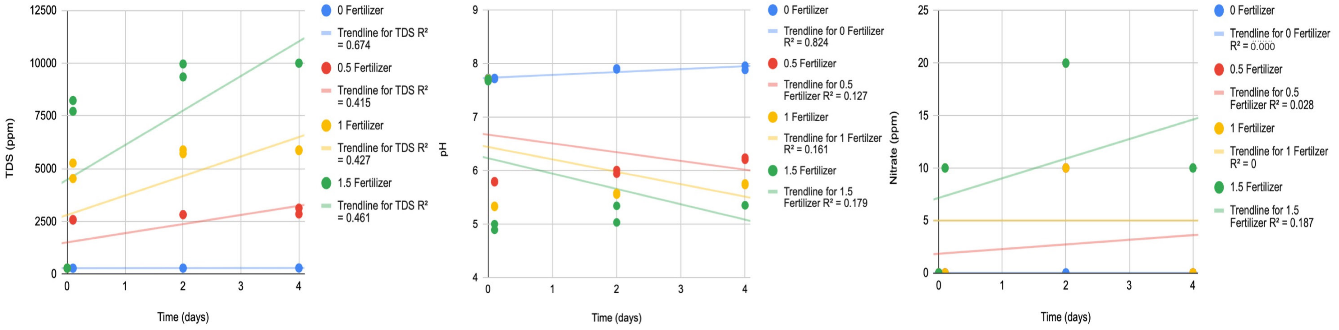


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Figure 2. Change in TDS, pH, and Nitrate over time. (**A**) Change in TDS over time. There is a moderately strong positive association between TDS and time (0 tsp: r^2 = 0.674, 0.5 tsp: r^2 = 0.415, 1 tsp: r^2 = 0.427, 1.5 tsp: r^2 = 0.461). (**B**) Change in pH over time. There is a weak negative association between pH and time (0 tsp: r^2 = 0.824, 0.5 tsp: r^2 = 0.127, 1 tsp: r^2 = 0.161, 1.5 tsp: r^2 = 0.179). (**C**) Change in nitrate over time. There is little to no association between nitrate and time (0 tsp: r^2 = none, 0.5 tsp: r^2 = 0.028, 1 tsp: r^2 = 0, 1.5 tsp: r^2 = 0.187). Each dot represents a recorded single measurement in the experiment, and there were two samples per treatment for each time point.

added to the water solution remained at approximately the same levels with the nitrate concentrations, staying constant at 0 ppm and the TDS and pH levels slightly increasing. Bar graphs and a one-way ANOVA test were used to compare the effect of fertilizer dosage on the concentration of TDS, pH, and nitrate levels (**Figure 1A, 1B, 1C**). The ANOVA test demonstrated fertilizer had a significant effect on all three indicators: TDS (*p*<0.000001), pH (*p*<0.000001), and nitrate (*p*=0.00305).

Linear regression tests also revealed that there was a moderately strong, positive relationship between time and TDS (**Figure 2A**, **Table 1**). No value was recorded on the fourth day for TDS, because the number exceeded the maximum limit of 9,990 ppm in the TDS meter. Time vs. pH and time vs. nitrate both have a weak relationship (**Figure 2B**, **Figure 2C**, **Table 1**). Nitrate levels spiked on the second day, with levels for all three fertilizer treatments increasing by 10 ppm, and gradually returned to their original levels by the fourth day (**Figure 2C**).

DISCUSSION

The main goal of this experiment was to study the effect of fertilizer on water quality over time. We hypothesized that as the amount of fertilizer in the creek increased, the water quality of Saratoga Creek would decrease. The drastic increases in TDS and nitrate levels and overall decrease in pH after fertilizer was added supported our hypothesis. After the addition of fertilizer, TDS and nitrate levels exceeded the U.S. guidelines of 500 ppm and 10 ppm, respectively, while the pH dropped below the acceptable range of 6.5-8.5 listed in the Secondary Maximum Contaminant Level for pH (8).

Over the period of four days, TDS levels for all fertilizer treatments increased, with the samples given 1.5 tsp surpassing 9,990 ppm on the fourth day (**Figure 2A**). TDS is the total concentration of dissolved ions (8); therefore, it makes sense that the TDS would increase after the soluble fertilizer dissolved into the water, which adds thousands of ions. The experiment concluded after four days, but we believe that TDS levels would have continued to climb if measured for a longer duration, highlighting the negative impact fertilizer

Comparison	TDS (ppm)	pH	Nitrate (ppm)
0-0.5	*0.00000	*0.00000	0.72037
0-1	*0.00000	*0.00000	0.18458
0-1.5	*0.00000	*0.00000	*0.00221
0.5-1	*0.00000	*0.00161	0.72037
0.5-1.5	*0.00000	*0.00000	*0.02331
1-1.5	*0.00000	*0.00629	0.18458

Table 1. Statistical significance of individual treatments. The Tukey Post-Hoc test p-values from the one-way anova test shows that the majority of the individual treatments were significantly different from the control. Significant combinations are identified with an asterisk (*).

has on water quality.

In this experiment, we used fertilizer to simulate the pollution from commercial activities on bodies of water, and the more fertilizer that we added, the lower the pH dropped (**Figure 1B**). This decrease in pH is most likely caused by the nitrogen and phosphorus, which is abundant in fertilizer (3), since both elements are acidic. Over time, the pH levels slowly began to increase (**Figure 2B**), but they were still substantially lower than where they started. Chemical pollution such as fertilizer causes bodies of water to turn acidic, which could be detrimental to species of fish (7), as the decrease in oxygen levels could cause certain aquatic species to suffocate (2).

Although nitrate levels gradually returned to their original levels by the fourth day (**Figure 2C**), the spike on the second day can be dangerous for aquatic species and human consumption. The levels for both the 1 tsp and 1.5 tsp fertilizer treatments reached 10 ppm or above (**Figure 2C**), passing the threshold of acceptable nitrate levels in water supplies. The decrease in nitrate levels over time can be attributed to denitrification (6), as between measurements, the lid was opened allowing nitrogen to escape through the air. Over time, nitrogen levels could also decrease as a result from uptake by algae and aquatic plants present in the water (6).

Throughout the experiment, there were a few sources of error that may have affected our results. A primary source of error centered around the accuracy and reliability of our measuring instruments. The TDS and pH meter we used are good ways to calculate the TDS and pH as they are affordable (under $20) with an accuracy of +/- 2%. In addition, the 6-in-1 nutrient strips are a cost-efficient way to measure nitrate as they are cheaper than nitrate specific tests but have relatively the same accuracy. However, the nitrate concentrations in the nutrient strips go directly from 0 to 20 ppm. As a result, our estimates could have been slightly inaccurate when calculating nitrate levels. Small dents in the measuring cups could have also caused the amount of fertilizer given to each jar to differ marginally, which could impact the TDS, pH, and nitrate levels. Furthermore, since the TDS meter only measures up to 9,990 ppm, TDS values were unable to be recorded for the fourth day (**Figure 1**), which likely affected the linear regression line for the 1.5 tsp treatment.

This experiment was conducted on freshwater samples from Saratoga Creek, a local creek in the Bay Area; therefore, future experiments could test the effect of fertilizer on saltwater vs. freshwater sources. We used a specific brand of fertilizer, so different types of fertilizer including potassium, nitrogen, and phosphorus-based fertilizers could be tested. Future iterations may be performed over a longer time period than four days to study the long-term effects of fertilizer on water quality. Subsequent experiments can also be improved with additional samples for each treatment in order to have more data points to generate a more robust p-value.

Typically, fertilizer enters bodies of water in two ways. Chemicals can enter the groundwater by rainwater as runoff, or substances can leach through the soil (3). Nitrogen, one of the main nutrients in fertilizer, is highly soluble (3). Until 1966, the area around Saratoga Creek was primarily agricultural land, making it possible for fertilizers to be found in the soils around the creek. Additional work is needed to determine the full impact of different types of fertilizers on water quality, but this study showed that water quality is affected by fertilizer. This could become a major problem for drinking water sources and aquatic wildlife due to an increase in fertilizer usage, especially in commercial agriculture.

METHODS

Sample collection

Eight 12 oz water samples were stored in a house at room temperature over a period of four days to study the effect of fertilizer on water quality. The 12 oz water samples were collected using measuring cups in identical Mason jars from Saratoga Creek in Saratoga, California at 3:30 pm from a section of still water partially covered by shade from trees. The measuring cups helped ensure that an equal amount of creek water was in each of the jars. The jars were then taken to the house and labeled. The TDS, pH, and nitrate levels of the water in each of the eight jars were measured using a Total Dissolved Solids meter, pH meter, and nutrient strips respectively. The HM Digital TDS-3 Handheld TDS meter measures the TDS from 0 to 9,990 ppm, while the SUMGOTT pH meter calculates the pH from 0-14, with a resolution of 0.01 pH. The nutrient strips used (Tetra EasyStrips 6-in-1 Test Strips) measure nitrate, alkalinity, hardness, pH, nitrite, and chlorine, but for this experiment, only the nitrate concentration was recorded.

Fertilizer Distribution

Three different fertilizer treatments would be applied to six jars. Each of the three treatments of 0.5 tsp, 1 tsp, and 1.5 tsp had two replicates and resulted in a fertilizer concentration (grams of fertilizer per 100 milliliters of water solution) of 0.694, 1.389, and 2.083 in the jars respectively. Before fertilizer was added, the TDS, pH, and nitrate levels were measured to ensure that all of the water samples in the eight jars had similar levels to avoid possible confounding variables. Two jars were also not given any fertilizer and acted as the control samples for the duration of the experiment. After the different amounts of fertilizer (Miracle-Gro Water Soluble All Purpose Plant Food) were poured into their respective jars, the lids were put back on, and the jars were gently shaken for fifteen seconds to thoroughly mix the fertilizer into the water. The lids were then taken off, and the TDS, pH, and nitrate levels were measured. Once the measurements were recorded, the jars were stored in a room at room temperature. The measurements were repeated at 2 days and 4 days.

Analysis

In order to determine the fertilizer's effect on water quality over time, the TDS, pH, and nitrate levels for the different fertilizer treatments were recorded in a Google spreadsheet. We used linear regressions on a scatter plot to display the R2 values to study the impact that time had on the individual treatments. In addition, bar graphs were used to visualize the effect the fertilizer treatments had on the mean values of each parameter after zero (0.1 days, 2 days, and 4 days). We ran a one-way ANOVA test between the mean value and fertilizer treatment to calculate the significance of our results. Finally, we conducted Tukey post hoc tests in order to compare the significance between the different treatments (0, 0.5, 1, 1.5) for each of the three indicators. The one-way ANOVA test and Tukey post hoc tests were done on the online Statistics Kingdom platform. All other tests were conducted on Google Sheets.

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