Title: The Effects of PM_{10} on Rainwater pH in Kingsburg, CA Over 2022-2023

Authors: Leyann AbdelFattah, Nicolette Fierro, and Devyn Sasai (Kingsburg High School in Kingsburg, California)
Advisor: Leigh-Ann Olsen

Abstract:
In Kingsburg, the rainfall had been trending more alkaline in its pH readings according to previous pH measurements of the rain. In the Central Valley, there are high levels of particulate matter due to the agricultural makeup of the region. The particles in the air are PM_{10}, which are particles of dust from natural or anthropogenic sites, pollen, and pieces of bacteria and fungal spores (California Air Resources Board). The dust and spores in the atmosphere may cause harm to human health through polluting the air and causing Valley Fever from coccidioidomycosis spores from the soil being inhaled (California Department of Public Health). When some of these particulates get into the rain, they can cause the pH to become more alkaline. This is different from other regions in California, which tend to have more acidic rainfall. In our investigation, we collected data from each rain event in Kingsburg from November 2022 to March 2023, as well as the pH of the rainwater collected.. Along with that, we collected soil from areas nearby in both Kingsburg and Selma for pH testing. The pH of both the soil and rainwater we collected tended to trend more alkaline, which showed that there was a correlation between particles originating from the soil and the pH of the rain.

Research Question:

- What causes the precipitation in the Central Valley to measure at a higher pH (more basic) than the pH of precipitation elsewhere?
- Do the soil particles that become particulate matter affect the pH of the precipitation in the Central Valley?

The study was conducted due to our GLOBE Advisor and previous GLOBE participants noticing that the pH of the rain with other past projects measured more alkaline in pH than the average pH of rainwater, which is usually around 5.0-5.5. This pH average of the rainfall was not the same as the pH collected in Kingsburg. We also decided to create a baseline of the pH of the rainwater in Kingsburg, as no other GLOBE participants had created reliable pH measurements of the rainfall in Kingsburg.

Hypothesis: Due to the great amount of agricultural occupations in Kingsburg, California, the top soil is often broken and tilled, causing particulate matter (PM_{10}) to be released into the air. This particulate matter is combined with rainwater when there is precipitation, causing the pH of the rainwater to be altered. Since the average pH of rainwater in many areas is more acidic compared to the pH of the rainwater in Kingsburg, California, the particulate matter from the soil could be causing the pH of the rainwater to be more basic than expected.

Investigation Plan: We made sure to clean the rain gauge after each rainfall collection to ensure the most accurate reading possible. The rainwater was also measured soon after rainfall. We calibrated the pH meter every 2-3 measurements to maintain accuracy to the best of

our ability, although this could be improved in the future by calibrating it before each reading. We took four soil samples around the Kingsburg area to measure the pH of the soil.

In order to gather the pH of the rainwater in Kingsburg, California and the particulates in the air, we collected the water from rain events and gathered data on the soil in the area.

1. From October 2022 through March 2023, the rain events in Kingsburg, California were recorded through the collection of the rainwater. The rain gauge on Kingsburg High School's campus collected the rainwater.
2. After each rain event, the pH of the rainwater was taken using GLOBE Protocol. The pH of the rainwater was also submitted into the GLOBE website and was recorded in our own spreadsheet.
3. Soil samples from around Kingsburg were also gathered. Using GLOBE Protocols for soil pH, the pH of Kingsburg soil from different locations was analyzed and placed into our own spreadsheet.
4. The data of the soil pH, PM_{10} measurements in the atmosphere, rainwater pH, and the amount of rainfall for each rain event was placed into graphs and spreadsheets to be compared and analyzed.

Research Methods: After we measured the rainwater in the gauge, we poured it into a beaker and followed the GLOBE Precipitation protocols. We then poured salt onto the salt circle size that corresponded to the amount of rainwater we collected. We dumped this salt into the beaker and incorporated it by mixing with a spoon. This solution was then evenly split into two beakers. We took the pH of the solution split between the beakers a total of 3 times; twice for one beaker and once for the other. The pH readings that we recorded were then averaged and we recorded the final pH in our rainwater data spreadsheet. This is part of GLOBE Protocol because the rainwater in areas may be so pure that the pH meter cannot read its pH. The salt should not alter the pH, but allow conductivity so the meter can read the pH properly.

Our collection of rainwater used a rain gauge that was fenced in so no students were able to tamper with the gauge or the water. The rain gauge had a funnel at the top of it to allow water to ease into the tube. The gauge is positioned at a higher level than recommended by the GLOBE protocol, which may have affected the amount of rain collected. However, this is necessary so that it is not accessible to students.

To measure the pH of the soil, we used GLOBE protocols to ensure that our measurements were accurate. We collected the top 10 centimeters of soil from our sites in our collection cans. The soil was left to dry in the drying oven for over a week. The soil was then individually tested by sifting the soil to ensure no other debris was in the soil. Each soil site had 40 grams of soil massed three times. Soil measurements were placed into three different beakers with 40 mL of distilled water. Each beaker was stirred continuously for 30 seconds and stirred for a total of five times with a wait time of 3 minutes between each stir. The pH of the beakers were measured and the average of the pH were recorded. We also collected PM_{10} measurements that were

taken from the Hanford weather station, as this was the nearest site at which we could find data from (it is located about 18 miles southwest of Kingsburg).

To answer our initial question, we used the particulate matter (PM_{10}) as our independent variable and the pH of the rainwater as the dependent variable.

GLOBE Data:
Figure #1:

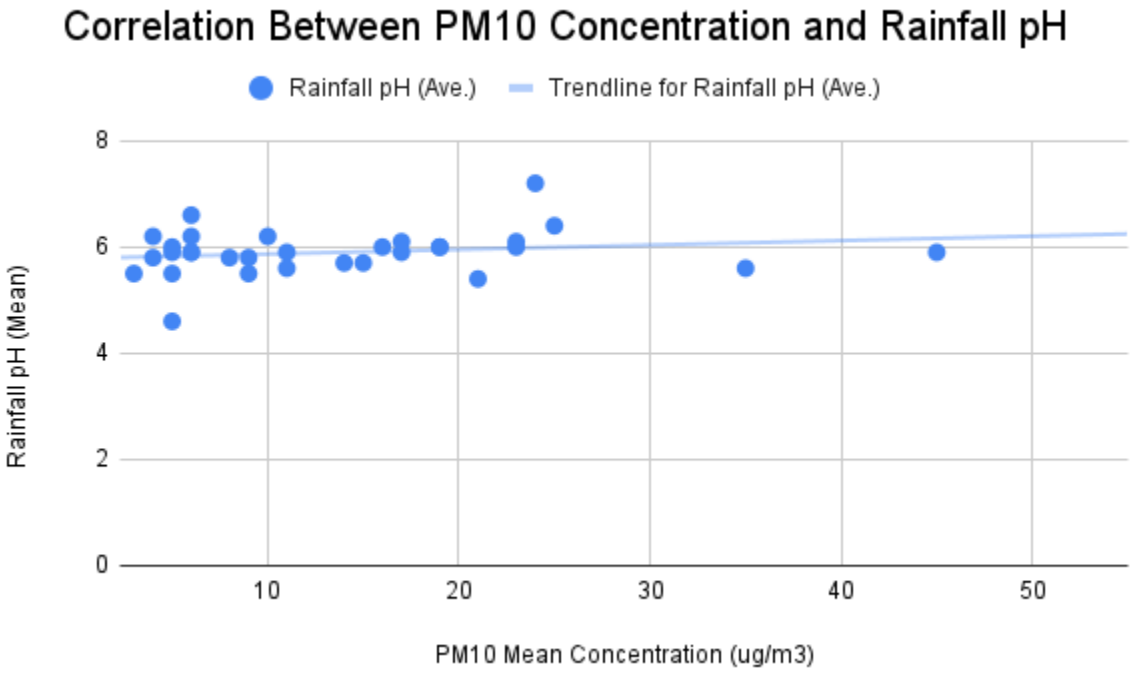
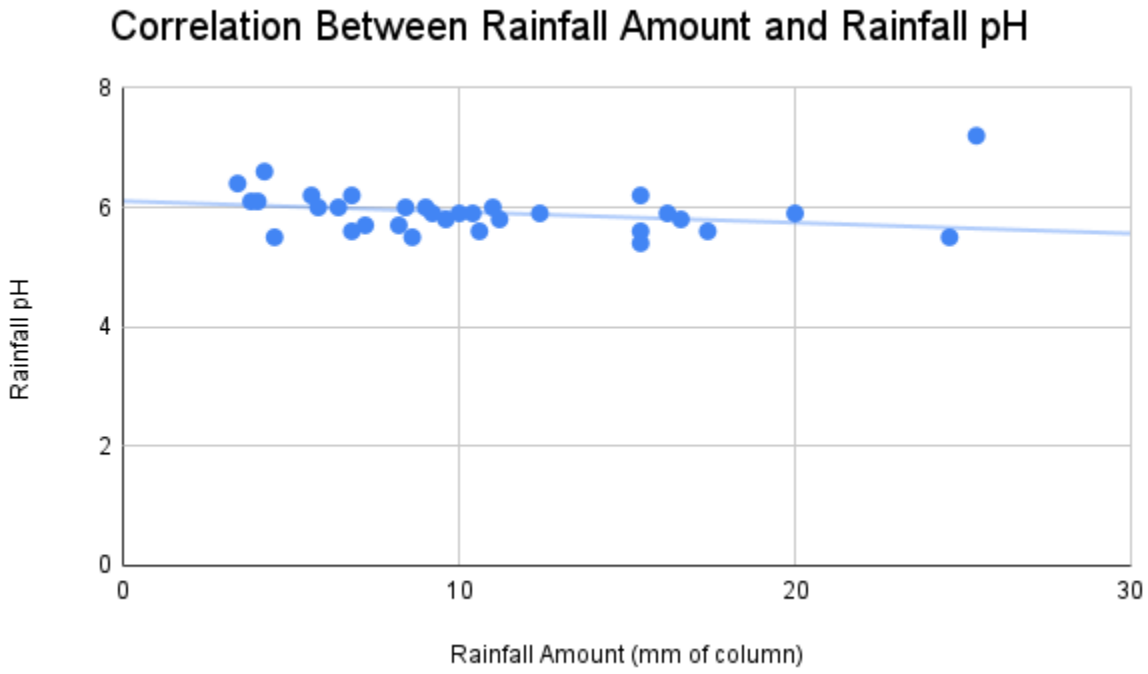


Figure #2:



Data Summary:

Figure #1: The pH of rainwater in Kingsburg, California and the mean PM_{10} concentration is displayed. The trendline shown suggests that as there is an increased amount of PM_{10}, the pH of the rainwater increases as well, shifting the rainwater pH more alkaline.

Figure #2: The graph displays the amount of rainfall and its correlation to the mean pH of the rain. The trendline suggests that as the amount of rainfall increases, the mean pH of the rainfall decreases. The outlier on the graph occurred on 3/10/23 with a pH of 7.2, which leans more alkaline compared to the average rainfall pH.

** The average for particulate matter was 16.09 micrograms per cubic meter (ug/m^3)

Soil Collection Site (of the Calgro-Coarse-Loam soil):

Soil Collection Site Description: This site was around half a mile southeast of Kingsburg High School. It had a very flat surface, some vegetation, and a mixture of different colored soils. Data from USDA-NCSS soil surveys for the region shows that the soil from this specific site is composed mostly of Calgro Coarse-Loam (UC Davis Website). pH testing of the soil samples taken from this site revealed that the samples were more basic, with an average pH of 8.4.

Data Analysis:

The data shows that the pH of one of the soil closest to the school (Calgro Coarse-Loam), was especially alkaline. This is due to the presence of calcium carbonate in the soil, as this compound causes the soil pH to become more basic (USDA Website). The soil site that contained the Calgro-Coarse Loam was closest to the location where most of our rainwater data was collected, which means that most of the particulate matter observed within the rain gauge could be coming from this source. These basic particulates and the basic pH observed within much of the rain that we collected correlate with each other, as the wind picks up dust from the surrounding soil that mixes with the rain and gets in the rain gauge we used. Not only was this soil site close to the location we collected our rain data from, but the direction of it from the site supports the idea that much of the particulate matter was composed of this especially basic soil. We collected our rainwater data at school, which is southeast from the soil site. Many of the heavy wind events that we experienced showed winds that were blowing from the southeast, meaning that much of the particulate matter came from the direction of the alkaline soil site. Along with that, these events showed winds at speeds up to 13 mph, meaning that more particulate matter was blown and combined with the rain. When this particulate matter mixes with the rainfall, it affects the pH of the water through a neutralization reaction where the pH is shifting away from being acidic and towards being more alkaline. This reaction occurs when the calcium carbonate in the dust combines with the rainwater. Since rainwater is already slightly acidic, it allows the calcium carbonate to become more soluble and to break into Ca^{2+} and CO_3^{2-} ions. Ca^{2+} ions then combine with OH^- ions from the H_2O molecule to form $Ca(OH)_2$, which is a basic compound. This compound is aqueous, so when it dissolves in the rainwater, the Ca^{2+} and OH^- ions that are basic in pH cause the overall pH of the rainfall to shift towards being more alkaline.

The outlier shown in Figure #2 from 3/10/23 had a pH of 7.2, 25.4 mm of rain, and a PM_{10} of 24. The average PM of the other days collected in our data was 16.09. Since the PM_{10} was much higher than the other days of measurement, more PM_{10} was dissolved into the rainwater. The increased amount of PM_{10} and the increased amount of rainfall did not follow the trendline of the increased amount of rainfall leading to a decrease in the pH. This is a result of there being more PM_{10} in the air and in the rainwater, so the PM_{10} was more concentrated in the rainfall.

Figure #2 has a downward trendline between the rainfall and the pH of the rainwater. As the amount of rainwater increased, the pH of the rainwater decreased. As more rainwater fell, the PM_{10} in the air became not as prevalent in the collection of water's pH as it was in the smaller amounts of rainwater's pH. Figure #1's trendline is increasing as there is a higher PM_{10} concentration, there is a higher (more alkaline) pH of the rainwater. Since Figure #1 has a correlation of more PM_{10} and a more basic pH of the rainwater, when there is a great amount of

rainwater, the PM_{10} seems to become diluted and not as effective towards the rainwater's pH. This causes the pH of the rainwater to be more acidic (have a lower pH) in comparison to the pH of rainwater when there was not as much rainfall.

Conclusion:

After a careful analysis of the data and research collected, it can be concluded that PM_{10} in the Central Valley has an impact on the rainwater pH. Despite there being a correlation between the rainfall pH and PM_{10} in the atmosphere, it wasn't as strong as we had expected it to be. This is because of the high amount of rain and frequent rain events that occurred this year, which may have caused the results of the investigation to be different than they would be otherwise. It is for this reason that Kingsburg High School students should continue to research this phenomenon further in future years, as this will help to understand the magnitude at which the pH is being affected by the PM_{10}.

Not only does the particulate matter in this region affect the pH of the rain, but it also harms the health of those who live in the Central Valley. The presence of particulate matter is prevalent due to the high volume of agriculture that takes place within the valley. Agriculture-related practices such as the high volume of tractor activity, harvesting, and tilling of the soil creates particles that contribute to air pollution. Along with that, activity from cars creates added dust in the air by picking it up from the road. Cars are a primary method of transportation for many in the Valley, meaning that this generates even more PM_{10} in the air. It is because of this heavy presence of air pollution that people in this region are prone to asthma and other health issues. Breathing in PM_{10} for extended periods of time can result in lung cancer and death according to the California Air Resources Board. Older people, young children, and asthmatics are at very high risk for poor health conditions due to repeatedly inhaling PM_{10}. This kind of air pollution can also lead to Valley Fever, which is caused by the inhalation of dust that contains fungal spores (California Department of Public Health). The amount of Valley fever cases has been increasing, possibly as a result of the California drought leaving the land dry and susceptible to wind carrying the fungal spores to more people.

In the future, a possible research opportunity would be to measure our PM_{10} at Kingsburg High School instead of using the data collected from the site at Hanford. With our own research closer to our site, we will be able to find more accurate readings of PM_{10} on certain days, the time of day when there is the most PM_{10}, and the PM_{10} measurements at certain times during the year. Another possible research opportunity would be to test the soil further. We could perform a soil texture test to decipher the amounts of clay, silt, and sand that is within the soil. Dust in the air is mainly composed of clay and silt, so by conducting soil texture tests, we would be able to understand if our environment has a majority of clay and silt in the soil that would cause it to be suspended in the atmosphere (Geophysical Fluid Dynamics Laboratory). The mineral dust can be caused by natural and anthropogenic activities, and may harm human health through poor air quality and causing the development of health issues (Geophysical Fluid Dynamics Laboratory).

Limitations/Sources of Error: One source of error was that a portion of the soil samples was touched with bare hands, which could have led to a slight change of the soil pH due to contact

with natural oils from human skin. A possible improvement for a similar future project would be to collect a broader range of soil samples from throughout the area.

Another possible error we made while collecting our rainwater was not being able to immediately measure the pH of the water after rainfall. This could have allowed other particulates in the air to enter the water and alter the pH. The reason for our late collection of rainwater was due to the rainfall happening on a weekend, not allowing us to come to school and measure the water's pH.

The data for our particulate matter was sourced through an EPA website that lists outdoor air quality data from different sites located around the country. To get the data for our research, we chose a site in Hanford (30 kilometers southwest from our base at Kingsburg High School). Although this was the nearest site we could find to our location, it was not as close as we would have liked, and an improvement for a future similar project would be to find a way to measure PM10 concentrations closer to our actual location.

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