The Relationship Between Sulfur Dioxide and Nitrogen Oxide air Pollutants and the Acidity of Rainwater

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THE GLOBE PROGRAM

Global Learning and Observations to Benefit the Environment

Abstract

- The purpose of this experiment was to investigate the relationship between air pollution & the pH of rainwater.
- Acid rain forms when air pollutants, such as sulfur dioxide (SO_2) & nitrogen oxides (NO_x), react with water in the atmosphere to produce acidic compounds, which can harm ecosystems, corrode buildings, & affect human health. Understanding the factors that influence rainwater acidity is important for assessing the environmental impacts of air pollution.
- Rainwater samples were collected across a variety of dates with varying levels of air pollution, & the samples' pH levels were measured using pH paper. Seventeen total trials were conducted over different precipitation events, including snow & rain, to ensure sufficient data for analysis.
- Purpose: Study was to determine whether increased air pollution levels increase the acidity in local rainwater.
- Our specific, testable hypothesis was: If rainwater is collected during periods of higher air pollution (measured in μg/m³) then the pH of the rainwater will be lower (more acidic) than rainwater collected during periods of lower air pollution. The results concluded show that precipitation samples collected during times of higher levels of air pollution were measured at a higher acidity. The findings suggest that air pollutants (sulfur dioxide & nitrogen oxides), contribute to the formation of increased acidity in rain by reacting with atmospheric moisture. This experiment shows the relationship between air pollution & the pH of rain, & especially highlights the environmental impacts of air pollution.

Research Question

Asking Questions

- Explains why this is an important question and of scientific interest
- Involves an aspect of Earth's environment about a local or global issue
- Considers ideas that previous investigations did not address
- Reflects in-depth knowledge of the content area
- Question is clearly stated
- Are answerable through scientific research appropriate to the scope of the report (i.e., scientifically testable)

Introduction

Content Knowledge

Scientists across the globe study the relationship between air pollutants such as sulfur dioxide and nitrogen oxides and the pH of rainwater. Rainwater can be affected by substances present in the atmosphere, including pollutants from human activities, and one way scientists measure these effects is by using pH, a scale determining how acidic or basic a substance is. Normal rainwater is slightly acidic, with a pH of around 5.6; however, when rainwater becomes more acidic, it can have harmful effects on forests and aquatic ecosystems and can reduce biodiversity. For example, acid rain has been shown to damage fish populations by lowering lake pH and mobilizing toxic metals such as aluminum. Air pollution mainly comes from human activities such as cars, factories, and power plants that release gases into the atmosphere. Pollutants like sulfur dioxide and nitrogen oxides are produced by burning fossil fuels and react with water in the air to form acids, which lower rainwater pH and result in acidic rain. To understand this relationship, it's important to examine how pollution sources directly influence atmospheric chemistry. Studying the relationship between air pollution and rainwater pH helps scientists understand environmental impacts, which is why this project investigates how pollutants such as sulfur dioxide and nitrogen oxides affect rainwater pH.

If rainwater is collected from an area with a higher Air Quality Index, then the pH of the precipitation will be more acidic than water from a low-pollution area because the sulfur dioxide and nitrogen oxides from vehicles would react with water vapor in the atmosphere to form weak sulfuric and nitric acids.

Research Methods

Planning Investigations

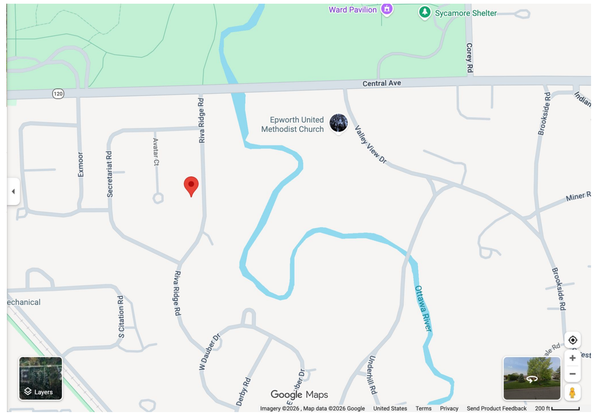
Describes the planning process

- Materials used to conduct our experiment include seventeen Bacnunn pH Test Strips (with a detection range of 4.5-9), one RACETOP Clear Disposable Plastic Cup, reused for all trials, sterile disposable latex gloves, and an online spreadsheet to data recording.
- The Bacnunn pH strips with a 4.5-9 range were selected since it can accurately detect acidity near normal rainwater pH (5.6).
- Air pollution data was accessed using the PurpleAir and AirNow websites.
- Precipitation Samples were collected at this consistent site: 41.674755, -83.661342, in the city of Toledo, Ohio.

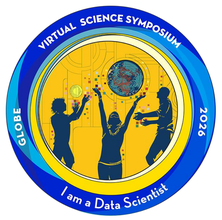
Carrying Out Investigations

Describes what happened

- Gather all materials needed. (The same collection location and cup were used for all trials to ensure control variables. While it's actively precipitating, put the plastic cup outside to collect water for 10 minutes
- Collect the cup, put the pH paper into plastic cup for approximately 2 seconds whilst wearing sterile latex gloves
- Compare pH paper to pH list after 15 seconds under natural daylight, record pH number measured from the rainwater.
- Wash hands immediately using soap and water.
- This procedure was repeated for a total of 17 trials. The GLOBE procedure we used pH in the Hydrosphere, and precipitation in the atmosphere.



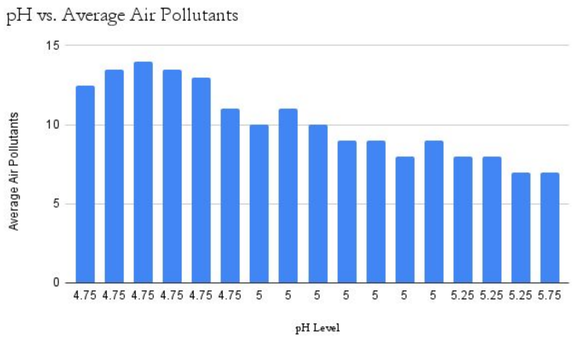
GLOBE Badges



Results

Analyzing Data

The pH values will be recorded for each trial and entered into the data table. The average pH of the rainwater sample will be calculated and compared to the normal rainwater pH, which is 5.6. A common trend that we saw with our graph is that there is a common relationship between the air pollution going downwards, and so does the pH. The pH rarely varies and stays pretty consistent around that 5 pH range, while the air pollution has a wider range. Our hypothesis stated that if rainwater is collected from an area with a higher Air Quality Index, then the pH of the precipitation will be more acidic than water from a low-pollution area because the sulfur dioxide and nitrogen oxides from vehicles would react with water vapor in the atmosphere to form weak sulfuric and nitric acids. Our experiment accurately reflects what we should test to prove or disprove our hypothesis because we tested the level of air pollutants, such as sulfur dioxide and nitrogen dioxide, in relation to the pH of the rainwater at the same time, in the same area.



Site location	Time	Date	Average
41.67, -83.68	7:00 AM	11/9	12.5
41.67, -83.70	9:00 PM	11/21	13.5
41.67, -83.71	11:00 PM	11/25	14
41.67, -83.72	9:00 AM	11/26	13.5
41.67, -83.73	1:00 PM	11/30	13
41.67, -83.77	10:00 AM	12/19	11
41.67, -83.66	2:00 PM	11/7	10
41.67, -83.67	8:00 PM	11/8	11
41.67, -83.69	2:00 PM	11/18	10
41.67, -83.74	12:00 PM	12/9	9
41.67, -83.75	3:00 PM	12/10	9
41.67, -83.76	7:00 PM	12/18	8
41.67, -83.66	9:00 PM	12/26	9
41.67, -83.78	7:00 AM	12/23	8
41.67, -83.79	2:00 PM	12/25	8
41.67, -83.66	4:00 PM	12/28	7
41.67, -83.66	1:09 PM	12/29	7

ph	airpollution (airnow) (μg/m³)	airpollution (purpleair) (μg/m³)
4.75	13	12
4.75	14	13
4.75	14	14
4.75	13	14
4.75	13	13
4.75	11	11
5	10	10
5	11	11
5	10	10
5	9	9
5	9	9
5	8	8
5	9	9
5.25	8	8
5.25	8	8
5.25	7	7
5.75	7	7

Discussion

Interpreting Data

The purpose of this investigation was to determine if there was a relationship between air pollution levels and rainwater pH. Our hypothesis stated that higher levels of air pollution would result in lower pH of the rainwater, making the rain more acidic. The results showed that there was an inverse relationship between air pollutants that were higher, around 12-14 μg/m³, and the pH of the rainwater was lower, around 5.0 pH. When the air pollution decreased, the pH of rainwater increased, reaching at the highest of 5.75. This trend suggested to us that air pollution is more likely to produce acidic rainwater. These results aligned with other studies on this relationship, which show that air pollutants like sulfur dioxide and nitrogen oxides contribute to lower pH levels in rain. Similar research has also demonstrated that areas with higher pollution experiences more acidic rain due to these pollutants. The results supported our hypothesis. The data matched the original hypothesis that an increase in air pollution would correspond with lower pH of rainwater. A scientific explanation for these results is that air pollutants released from factories and vehicles react with water vapor in the atmosphere which results in sulfuric and nitric acids. These acids lower the pH of rainwater. When air pollution levels are lower, there are fewer acidic compounds in the atmosphere, leading to a higher pH. Some errors in our experiment could be limited data points, different weather conditions, and inaccuracies in our pH measurements. Improvements we may do in the future could be collecting samples of rainwater over a longer period of time. Overall, the experiment tested the hypothesis because it compared air pollution levels to rainwater of pH over time. The data showed a trend that supported the hypothesis.

Conclusions

Drawing Conclusions & Next Steps

Our hypothesis was supported by our experiment. Our data suggests that higher air pollution levels corresponded with lower pH values. A major success of our experiment was the collection of data over multiple datasets and having multiple data points. If we were to conduct this experiment again, we may look into increasing the number of locations we conduct this experiment, as well as spreading it out across several months and seasons of the year. Some areas for further research could be experimenting with different types of pollutants to see which affects rainwater the most, how seasonal changes affect the acidity, and more locations, such as urban and rural areas. This type of research is important because acid rain can impact the ecosystem and water sources. Understanding this relationship can help scientists develop strategies to reduce pollutants and protect the environment.

Bibliography

Burns, D. A., Fenn, M. E., Baron, J. S., Lynch, J. A., & Crosby, B. J. (2011). *National Acid Precipitation Assessment Program reports to Congress: An integrated assessment*. U.S. Geological Survey. https://pubs.usgs.gov/pub/circular/2000/1219

Cheng, J., Zhang, L., Hu, Z., Cathcart, H., Hayden, D., Cole, A., Feng, J., O'Brien, J., Macdonald, A. M., Akerje, J., & Brook, J. R. (2022). Long-term declines in atmospheric nitrogen and sulfur deposition reduce critical loads exceedances at multiple Canadian rural sites, 2000–2018. *Atmospheric Chemistry and Physics*, *22*(21), 14017–14036. https://doi.org/10.5194/acp-22-14017-2022

Greenfelt, P., Engleryd, A., Forsius, M., Hov, Ø., Rodhe, H., & Cowling, E. (2020). Acid rain and air pollution: 50 years of progress in environmental science and policy. *Ambio*, *49*(4), 849–864. https://doi.org/10.1007/s13280-019-01214-8

Kumar, D., Deng, X., & Li, L. (2023). Recovery of river chemistry from acid rain in the Mississippi River Basin under changing anthropogenic pressures. *Science of the Total Environment*, *897*, 165311. https://doi.org/10.1016/j.scitotenv.2023.165311

Lawrence, G. B., Sutherland, J. W., Boylen, C. W., Nierzwicki-Bauer, S. A., Momen, B., Baldigo, B. P., & Simeone, H. A. (2007). Acid rain effects on aluminum mobilization clarified by inclusion of strong organic acids. *Environmental Science & Technology*, *41*(1), 93–98. https://doi.org/10.1021/es061437v

Likens, G. E., Driscoll, C. T., & Buso, D. C. (1996). Long-term effects of acid rain: Response and recovery of a forest ecosystem. *Science*, *272*(5259), 244–246. https://doi.org/10.1126/science.272.5259.244

McHale, M. R., Burns, D. A., Siemion, J., & Kendall, C. (2021). Trends in precipitation chemistry in the United States: Effects of reductions in SO2 and NOx emissions. *Atmospheric Environment*, *247*, 118219. https://doi.org/10.1016/j.atmosenv.2021.118219

National Atmospheric Deposition Program. (2022). *NADP data documentation*. Wisconsin State Laboratory of Hygiene. https://nadp.slh.wisc.edu

PurpleAir. (2022, July 18). *Data attribution*. https://www.2.purpleair.com/pages/attribution

PurpleAir. (2024, April 22). *About the PurpleAir API*. https://community.purpleair.com/t/about-the-purpleair-api/71142

U.S. Environmental Protection Agency. (2020). *AirNow real-time air quality REST API* [Data set]. Data.gov. https://catalog.data.gov/dataset/airnow-real-time-air-quality-rest-api

U.S. Environmental Protection Agency. (n.d.). *AirNow*. https://www.airnow.gov

Weiler, K., Driscoll, C. T., Lynch, J. A., Newcomb, D., & Roy, K. (2012). Long-term recovery of lakes in the Adirondack region of New York following decreases in acidic deposition. *Atmospheric Environment*, *49*, 56–64. https://doi.org/10.1016/j.atmosenv.2011.10.031