Justin Barry
Enviornmental Chemistry
Dr. Hermanson
PIM #2

Determining Why pH Levels Vary From The Western and Eastern United States

Introduction

In many locations across the United States, pH levels from precipitation have been recorded for several decades. The rise in acidic precipitation has been a concern because of detrimental effects to the ecology. Acid rain causes destruction to our waterways, animals, and animal habitat *(1)*. The history of acid rain has changed over the past 50 years with increasing anthropogenic affects on the atmosphere. Data has been gathered from four different sites around the U.S. where the pH of precipitation has been recorded for more than 10 years. The highest and lowest pH measurements are listed and a discussion of varying pH values from the western and eastern United States is included.

Data

The pH of natural rain is 5.6 *(2)*. Many sites in eastern U.S. have an average pH below 5.6 due to acid rain and several sites in western U.S. have an average pH slightly above 5.6, due to other factors that will be discussed. The National Atmospheric Deposition Program/National Trends Network has posted pH precipitation values for dozens of U.S. sites. As seen in Figure 1 and Figure 2, the pH values for the multiples sites has decreased from 1994 to 2003 *(3)*. Furthermore, the pH values for the western U.S. are slightly higher than the natural pH of rainfall, 5.6 *(2)*.

Figure 1

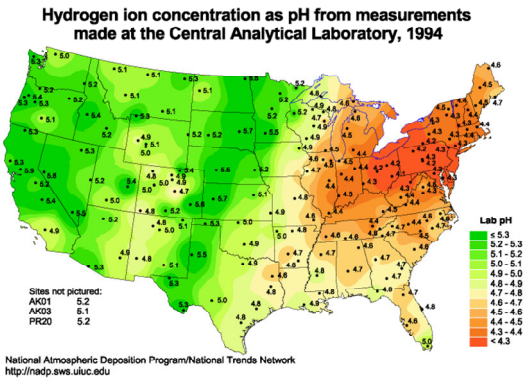
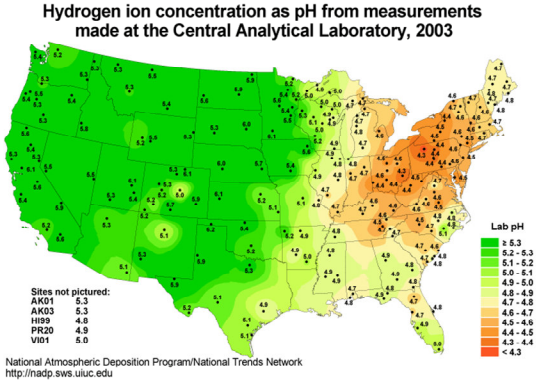


Figure 2



Site CA88, Davis, CA has the highest recorded pH at 6.1 and VW18, Pearsons, VW, has one of the lowest pH at 4.3. It is well known that the eastern U.S. is plagued with many coal burning, sulfur emitting power plants that discharge large amounts of CO_2 and SO_2 (See Figure 3) into the atmosphere. This simple fact alone can easily account for the low pH of precipitation in the region surrounding Pearsons, VW. Comparing the west coast Baird notes that "…nitrate rather than sulfate is the predominant anion because more pollution results initially from nitrogen oxides than from sulfur dioxides" *(2)*. The more difficult question is why the western U.S. has pH values for precipitation that exceed the natural levels of rain. The trend from the west coast to the east coast of the U.S. appears to be a decrease in levels of pH precipitation. This data seems to dispute an increase in car emissions in the western U.S. and a reduction in sulfur emissions from coal burning power plants. Moreover, if the polluted, acidic air was transported long distances, one would think that then entire U.S. would have a low pH in precipitation, not just the eastern U.S. The data in Figure 2 indicates otherwise.

Figure 3

CO_2 reaction that contributes to acid rain:

$CO_2(g) + H_2O(l) \longrightarrow H + (aq) + HCO_3^-(aq)$

SO2 reaction that contributes to acid rain:

$SO_2(g) + 0.5\ O_2(g) \longrightarrow SO_3(g)$ (explosive!)

$SO_3\ (g) + H_2O(l) \longrightarrow H_2SO_4\ (aq)$ (stable)

Information on Sites

Pearsons, WV is a town of approximately 7900 people (Site WV18). Settled in the late 1700's, the county had railroad pass through the town by the late 1800's because of the lucrative timber and coal industry. By 1911 over 2.2 million tons of coal per year was being mined from the county surrounding Pearsons, WV *(4)*. The town still has an industrial feel to this day. Figure 4 indicates the pH of precipitation.

Davis, CA is located northeast of San Francisco (Site CA88). Home to University of California-Davis Campus, the city is surrounded by highly populated urban centers. Over 60,000 people reside in Davis *(5)*. Figure 5 indicates the pH of precipitation.

Organ Pipe Cactus National Monument is located in southern Arizona, Pima County (Site AZ06). This arid location is several hours west of Tuscan, AZ. Figure 6 indicates the pH of precipitation.

The last site is the Aurora Research Farm located in Cayuga County, NY (Site NY08). This rural county is located next to the Finger Lakes of New York. Figure 7 indicates the pH of precipitation.

Figure 4

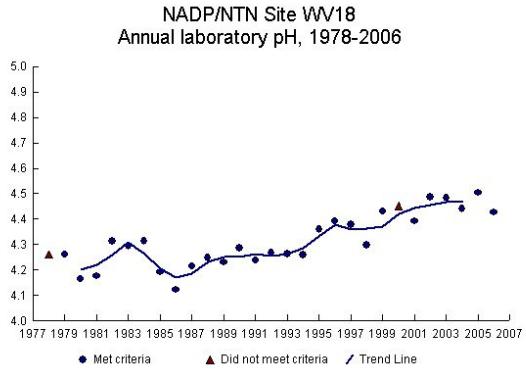


Figure 5

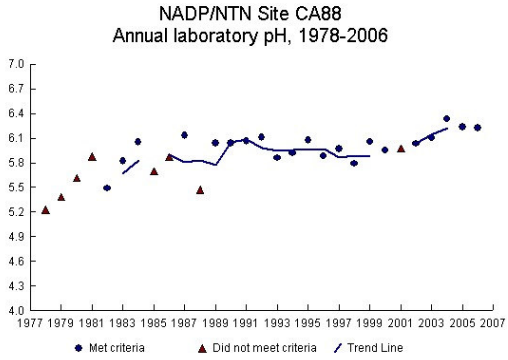


Figure 6

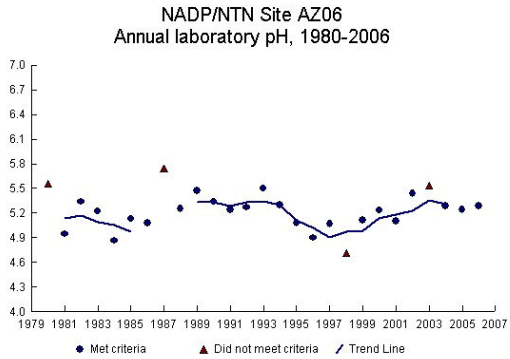
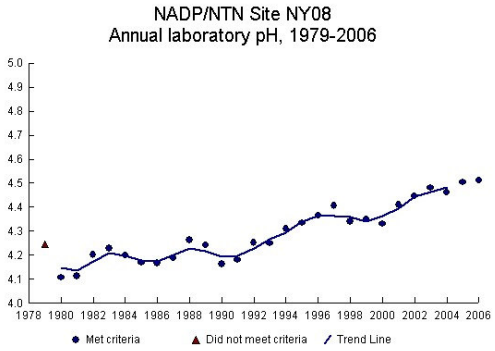


Figure 7



Analysis of Data

After searching the literature on acid rain in the western part of the U.S., particulate matter in the atmosphere plays a significant role in the pH of precipitation *(6)*. Grantz et al, notes that there is substantially more particulate matter in the atmosphere in the western U.S. than in the eastern U.S. *(7)*. Particulate matter is more easily suspended in arid conditions. Particulate matter, between five and 15 micro-meters, is very effective in reacting with precipitation *(6)*. Soil-derived components, organic materials, sulfate ions, nitrate, and ammonium are the major constituents of suspended airborne particulate matter in the western U.S. *(1)*. The suspended particles, originating as particles from the ground or from anthropogenic sources, neutralize the acidity of rain *(2)*. One such neutralization is described below:

$$H^+ + CO_3^- \longrightarrow HCO_3^-$$

Carbonate ion, located in soils can be picked up by the wind and converted to a bicarbonate ion. Most of the western part of California and the majority of western U.S. contains alkaline soils *(2)*. Atmospheric acid rain species H_2SO_4 and HNO_3 are neutralized to raise the overall pH precipitation of the western U.S. The trend in the pH data can be explained by this neutralization effect. Moving eastward the trend indicates a decrease in pH. Even the "…neutralization of

acidity by ammonia gas released into the air from livestock and from the use of fertilizers, and by carbonate ion suspended in air from the dust raised by faming activities…" are the main reason why precipitation over the central U.S. is not acidic *(2)* Continuing east, many coal burning power plants and low soil alkalinity in the Appalachian Mountains can explain a further decrease in pH levels. It is also important to note that the pH values for each of the four sites decreases going from the western to eastern U.S.

Conclusion

Acid rain has been a problem for many decades across the U.S. The pH for rain has been increasing for most locations across the U.S. In some locations, particularly in the western part of the country, the pH is higher the natural rainfall, 5.6. Four sites were chosen to compare the trend in pH for precipitation in the U.S. Overall the pH of precipitation decreases from the western to the eastern U.S.. This particulate matter originates in the alkaline-based soils. After becoming suspended in the air, it neutralizes acid rain produced by highly populated western cities. In some cases, like Davis, CA, the pH of precipitation can exceed natural rainfall pH values.

Literature Cited

(1.) Derrick, M.R.; Moyers, J.L.; Yarborough, K.A.; and Warren, M. *Water, Air, and Soil Pollution,* Springer: Netherlands, 1984; pp 171-181.

(2.) Baird, C; Cann, M. *Environmental Chemistry,* Freeman: New York, 2005; p 93.

(3.) National Atmospheric Deposition Program/National Trends Network: http://nadp.sws.uiuc.edu/sites/ntnmap.asp (accessed July 11, 2007)

(4.) West Virginia Rails-To-Trails Council: http://www.wvrtc.org/trails/tucker_history.html (accessed July 11, 2007)

(5.) U.S. Census: http://quickfacts.census.gov/qfd/states/06/0618100.html (accessed July 11, 2007)

(6.) Esplin, G.J. *British Columbia Research Council,* Page: London, 1987; pp1-9.

(7.) Kulp, J.L. *Regulation*. http://www.cato.org/pubs/regulation/reg13n1-kulp.html (accessed July 11, 2007)

(8.) Grantz, D.A.; Garner, J.H.B.; Johnson, D.W. Environmental International. 2003, 29, 213-239.