A PRELIMINARY INVESTIGATION OF ACID PRECIPITATION IN METRO NORTHERN NEW JERSEY

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ABSTRACT: Based upon air pollutants from both industrial activity and high vehicle exhaust emissions, the Northern New Jersey region is at risk from damage due to acid rain. A cause-effect relationship has been commonly known to exist between nitrogen oxide and sulfur dioxide; the by-products of industrial activity and auto exhaust emissions, and acid rain. This preliminary investigation statistically compared analytical results of rainwater pH and conductivity, analyzed for dissolved solids, to determine if a relationship exists between rainwater pH and conductivity (dissolved solids) at a local scale. The results of this preliminary investigation show that acid rain does occur in Northern New Jersey (rainwater pH <5.0). A significant statistical correlation between rainwater pH and rainwater conductivity (dissolved solids) analysis was realized by this investigation. Highest rainwater conductivity (dissolved solids) was detected over the city center. It is suggested that concentrated anthropogenically produced airborne dust containing calcium, emanating from roadways and combustion sources, nearest the city center may serve to neutralize acid rain by increasing rainwater pH. In this regard, sea salts may also neutralize acid rain in marine environments.

INTRODUCTION

Studies on the cause-effect relationship between acid deposition and air pollution have previously been conducted around the world. Causal links between air pollution and rainwater acidification have been examined in Wales, United Kingdom (Reynolds, 1999), along with links between sulfur emissions and acid deposition and the possible neutralizing effects of dust containing calcium on acid rain in China (Larssen and Carmichael, 1999). In addition, Reynolds et al. (2000), discussed possible neutralizing effects of sea salts on seemingly expected acidic soil zones within the United Kingdom located downwind of SO_2 sources. Numerous studies on the detrimental effects to property from acid deposition have also been conducted, specifically the deterioration of concrete structures in Asia (Okochi et al., 2000), bronze structures and seemingly resistant stone and marble structures in and around Philadelphia (Dolske, 1995; Meierding, 1993; Meakin., et al 1992,). Recently, studies suggesting links between air pollutant emissions and acid deposition have been conducted within the United States (Butler et al., 2000). Moreover, the transport of acid deposition by various weather fronts has been studied in Taiwan (Chang et al., 1999). Currently a lack of information exists on the relationship between air pollution and acid deposition and its transport by weather fronts in the Northern New Jersey area. Furthermore, data from a spatially high-density precipitation sampling procedure is uncommon in the literature.

The Northern New Jersey region is one of the most urbanized and highly populated areas of the United States. Therefore, acid deposition and its geographic distribution across Northern New Jersey are of interest to environmentalists, the regulatory community, and the public at large. Both the heavily industrial areas of Northern New Jersey, together with concentrated auto exhaust emissions make this region a potential region at risk from the effects of acid deposition. The potential impacts of acid deposition pose a threat to the viability of Northern New Jersey's water bodies, vegetation, property, and may pose serious adverse health effects to one of the most populated areas of the world. Nationally, efforts have been made to reduce the emissions of

pollutants into the atmosphere from point sources and automobiles, which are believed to be major contributors to the acid rain problem (Federal Clean Air Act, 1990 Amendments).

Chemically, pure water will yield a pH (+ hydrogen ion) value of 7.0 standard units (s.u.), while normal rainwater pH values exists within the range of pH 5.0 – 5.6 s.u. This is due to the natural reaction with carbon dioxide in the atmosphere. The presence of CO_2 in the atmosphere increases the acidity of water to a pH of 5 with the formation of bicarbonate in $CO_2+H_2O \rightarrow HCO_3 + H$, and a weak carbonic acid in H_2CO_3 (Thompson, 1999).

However, the presence of airborne pollutants, mainly sulfur dioxide and nitrogen oxides, together with other photo-chemically active constituents, such as those commonly found in the urban atmosphere, tend to further increase the acidity levels of rainwater. These pollutants react with gaseous water in clouds to form sulfuric acid and nitric acid (Godish, 1997).

This preliminary investigation statistically correlated rainwater analytical results for pH and conductivity (dissolved solids) to determine if a relationship exists between rainwater pH and conductivity (dissolved solids) at a local scale. Ambient air quality data collected on November 2, 1999 by the New Jersey Department of Environmental Protection (NJDEP) in the study area were also examined for any possible relationship between air quality and the precipitation analysis. Meteorological data were also recorded and investigated to determine the impacts of winds and rainfall intensity. This is the initial report on results from a more comprehensive work in progress.

METHODOLOGY

Synoptic Weather Scenario

Early on November 2, 1999, a cyclonic weather system began its march up the Atlantic coast and entered into the Northern New Jersey metropolitan area from the south with initial light rain occurring in the southern-most sector of this study region and eventually extending northward. By

12:00 p.m. local time on the same date, all of the study area was experiencing moderate rain. Wind speed and direction were monitored from local internet weather reporting stations on an hourly frequency. Local weather stations reported winds primarily from the east and southeast during the duration of the weather cyclone over the Northern New Jersey metro area. According to local weather reporting stations, the November 2, 1999 precipitation in the form of showers and rain lasted until approximately 22:00 eastern standard time for an approximate duration of ten hours.

Sampling Procedures

Beginning on or about 12:00 noon on November 2, 1999, 25 sample jars were placed across the Northern New Jersey and metropolitan study area in an attempt to collect rainwater for chemical analysis of pH and conductivity, analyzed for dissolved solids. Rainwater samples were collected in 250 milliliter, factory clean and sealed neoprene sample container jars. A funnel was placed over the top of the open rainwater sample container jars to allow for better sample collection. Each sample container jar was securely placed outside on the ground surface just prior to the above mentioned rain event. Rainwater sampler container jars were carefully located away from any overhead drips such as trees, rooflines, etc. Prior to setting each sample jar for collection, the location and exact time that sampling commenced was recorded on each bottle by each sampler. At the cessation of sampling, the funnel was removed, the jar was sealed, and the exact time that the sampling ended was again recorded upon each jar by the sampler.

Potential contamination from dry deposition was determined to be minimal based upon sampling times just prior or simultaneous with the commencement of precipitation at that location. However, some errors did occur during sample collection. For instance, sample #5 was contaminated during the study, and sample #9 lacked sufficient volume to be analyzed and therefore both were not included within the initial analysis.

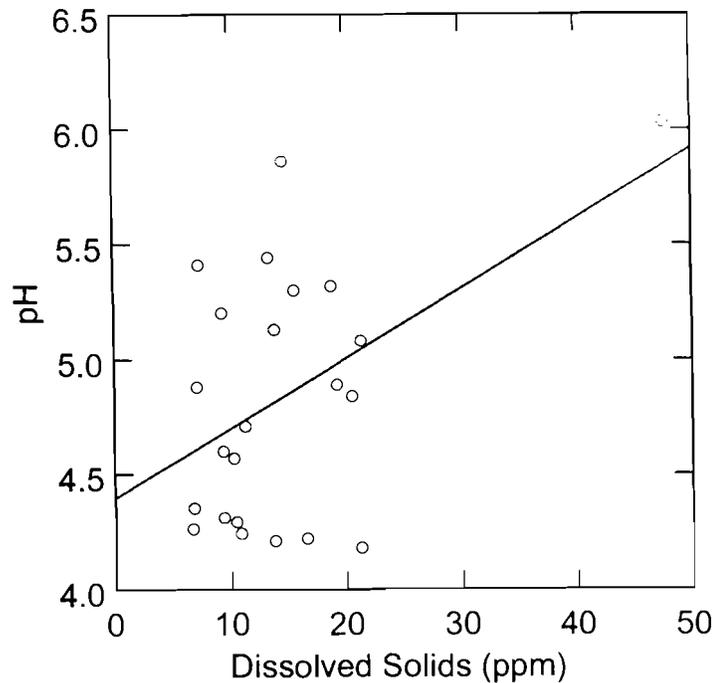## pH as a function of Dissolved Solids

Figure 1. Statistical regression analysis results between rainwater pH and rainwater conductivity analyzed for dissolved solids.

RESULTS

On November 3, 1999 at 10:00 pm, some sample jars were uncovered and analyzed for pH and conductivity (dissolved solids). 12 sample jars were analyzed on November 12, 1999 due to the delays encountered with the mailing of some sample containers to the lab. Chemical analysis for rainwater pH was conducted utilizing an Oakton model WD-35615-60 hand-held pH meter calibrated to a 3 point method of pH to 4, 7, 10 standard units (s.u.). In an attempt to recover accurate pH analysis, each sample was analyzed three (3) separate times on November 3, 1999 at @10:00 p.m. The 13 remaining samples were analyzed on November 12, 1999, along with the first samples for the second time. There was some deterioration in pH values after the 9-day interval, but the later analysis was consistent and proportional to the initial analysis. Data for pH reported here are based on the second analysis.

Rainwater samples were also analyzed for conductivity utilizing an Oakton model WD-35607-30 hand held conductivity meter. Each sample container jar was stirred prior to conducting analysis, to prevent sedimentation. Analysis for conductivity was conducted once on November 3, 1999 for 12 samples and again on November 12, 1999 for all 25 samples. Data for conductivity (dissolved solids) reported here are based on the November 12, 1999 analysis.

Statistical Analysis

This preliminary investigation statistically compared 23 rainwater pH samples with rainwater sample conductivity (dissolved solids) results utilizing regression analysis. The result of this

points. Total rainwater volume collected in all rainwater sample container jars averaged 80.5 ml, during an average total sampling time of 8.85 hours. The mean pH value was calculated as 4.88 with a standard deviation of 0.556. The mean conductivity (dissolved solids) was calculated as 14.18 ppm.
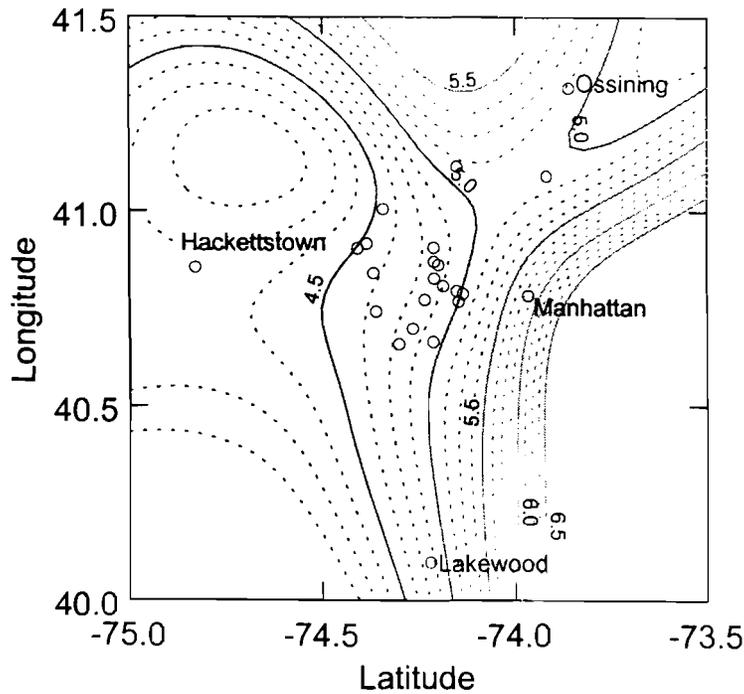
Acid Rain Distribution in Study Area

Figure 2. Study area geographic distribution of sample rainwater pH results.

regression analysis revealed that the relationship between sample rainwater pH results (dependent variable) and sample conductivity results (independent variable) were significant with R-squared = 0.225, (adjusted R-squared of 0.188), with P=0.022. However, the regression is probably influenced by the high pH/high conductivity outlier (Manhattan). This is graphically displayed in Figure 1.

The results were averaged and plotted at their relative corresponding latitude and longitude

Geographic Relation

Sample rainwater pH results revealed that acid deposition increased westward across Northern New Jersey and away from Manhattan. Figure 2 details this increasing acid deposition gradient across the study area from east to west, from a pH >6.0 s.u. collected in Manhattan to a pH of 4.5 s.u. over North-Western New Jersey (Hackettstown). In addition,

Figure 3 denotes the geographic distribution of dissolved solids, as measured by conductivity. It reveals that the highest conductivity (dissolved solids) value were found in Manhattan (>50 parts per million, ppm). Figure 3 also shows that conductivity (dissolved solids) decrease in a westerly direction over Northern New Jersey, where a value of 4 ppm was recorded in Central-Northern New Jersey. It should be noted that both Figure 2 and 3 are graphic representations based upon this investigation's limited amount of data and contain probable errors.

Air Quality

Ambient air monitoring data (nitrogen oxides and SO_2) from the NJDEP continuous air monitoring network's nine remote stations located in the study area were examined for a possible trend between air quality and the analytical results of this investigation. However, no obvious trend or statistical relationship could be determined at this time. Further study between air quality and

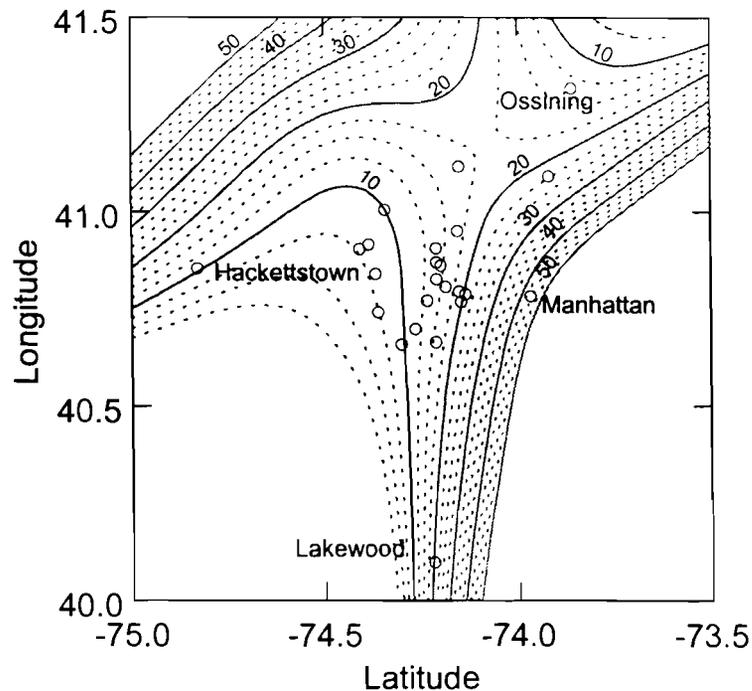# Total Dissolved Solids Distribution in Study Area

Figure 3. Study area geographic distribution of rainwater conductivity results analyzed for dissolved solids.

The isolines of pH and conductivity in Figures 2 and 3 are interrupted by the lack of data outside the map areas shown.

precipitation analysis results in the Northern New Jersey Metro area is ongoing in this regard.

CONCLUSION AND DISCUSSION

A significant statistical correlation between rainwater pH and rainwater conductivity (dissolved solids) was realized in this preliminary investigation. A statistical correlation between pH and conductivity (dissolved solids) indicates that rainwater pH in the Northern New Jersey Metro area is significantly affected by dissolved solids. Based upon the sampling data analyzed, an increase in dissolved solids yields an increase in rainwater pH, as shown in Figure 1. Furthermore, Figure 2 geographically shows a gradient of increasing acid deposition values (east to west) across the study area, with lowest acid deposition rates found in the city center (pH>6.0 s.u.). Similarly, the results of this investigation indicate a decreasing gradient of conductivity (dissolved solids - east to west) across the study area with highest conductivity (dissolved solids) results found in the city center (>50 ppm). Based upon the data obtained, the following are proposed reasons for the above-mentioned results.

- Dust, possibly containing calcium, originating from local and anthropogenic sources such as roads and combustion sources most concentrated nearest the city center (Manhattan, NYC and Newark, NJ) may neutralize acid deposition. The chemical composition of the anthropogenically emitted calcium dust is not known, but it may be a combination of $CaCO_3$, CaO and $CaSO_4$ (Larssen and Carmichael, 2000). In the case of CaO, the weak atmospheric sulfuric acid formed from the interaction of sulfur dioxide and rainwater may be neutralized according to the following reaction: CaO + $H_2SO_4 \rightarrow Ca^{2+} + H_2O + SO_4^{2-}$ (Larssen and Carmichael, 2000; Godish, 1997).

- Based upon the proximity to the Atlantic Ocean, airborne sea salts may serve to neutralize acid rain especially in this marine environment (Reynolds et al., 2000; Godish, 1997).

- Increasing rainwater acidification found in the western section of northern New Jersey reflect a large regional-scale pattern (Godish, 1997) The study area exists on the fringe of high nitrogen oxides and sulfur dioxides emanating from the upper Ohio valley, and transported long-range by westerly prevailing winds (Godish, 1997).

The potential threats to human health, the environment, and structural deterioration from acid deposition require additional analysis of precipitation under different meteorological conditions in order to determine whether calcium and/or sea salts nearest this city center may pose in modified acid deposition.

ACKNOWLEDGEMENTS

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