A REPORT FROM

The University Hygienic Laboratory

OAKDALE CAMPUS

THE UNIVERSITY OF IOWA
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A STATEWIDE SCREENING FOR ACID RAINFALL

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ABSTRACT

From April through October 1980, a statewide screening for acid rainfall was conducted in Iowa. Ninety-seven National Weather Service observers were provided with pH color-indicating strips and measured and recorded the pH of every precipitation sample. Results of the screening indicate pH values of rainfall ranged from a low of 4.0 to a high of 7.0. The pH values 5.7 and 5.9 were observed most often and represented 66% of the 4,197 values measured. Approximately 80% of the rainfall pH values fell in the 5.7 to 7.0 range and 20% in the acid rainfall range (5.6 or less). Median pH values calculated for the 97 sampling locations ranged from 5.1 to 6.2, with medians of 5.7 and 5.9 occurring most frequently. With the exception of one three-county area, most of the eleven sampling locations demonstrating acid rainfall (median values 5.6 or less) were widely separated and probably represented localized problems. Three adjacent counties located in southeast Iowa had low median pH values and this area is recommended for future study.

ACKNOWLEDGMENTS

We would like to especially acknowledge the help and cooperation of all the participating National Weather Service observers without whom this study could not have been conducted.

INTRODUCTION

For Iowa, an intensely agricultural state, the need for precipitation to initiate and sustain plant growth and to replenish streams, lakes and ground water supplies is ever present. Much concern has been expressed in the last few years regarding precipitation and changes in its acidity (pH). Pure rainwater in equilibrium with carbon dioxide has a pH value of 5.65. Recent reviews (1,2) of available data indicate that precipitation in a large region of North America is well below 5.65 (rain with a pH below 5.6 is considered acidic rain). The increasing acidity of rainfall is believed to be the result of the accumulation of certain acids in the atmosphere. These acids are produced by reactions between sulfur and nitrogen oxides, which arise primarily from the combustion of fossil fuels. Originally, acid rainfall was found in the eastern and northeastern portions of the United States, which are highly industrialized areas utilizing fossil fuels to a relatively high degree. Recent information, however, indicates that "acid precipitation has spread measurably southward and westward in the United States." (1) Researchers in Minnesota have observed acid rainfall (3) and are concerned about potential damage to both terrestial and aquatic ecosystems. The Minnesota Legislature, recognizing the extent and severity of the acid rain problem, passed a bill designated to identify, control and abate acid rain. In Iowa very little is known about acid rainfall. Tabatabai, at Iowa State University, has conducted research on the nutrient content and pH of samples of rainfall from seven locations around the state. He found that the average pH value of rainfall and snowmelt samples was about 6 (3,4). In an effort to expand and improve on the limited data base, the University Hygienic Laboratory conducted a statewide screening for acid rainfall.

MATERIALS AND METHODS

The National Weather Service maintains a voluntary group of observers throughout Iowa to record daily temperature and precipitation. Upon obtaining approval from the National Weather Service, an informational mailing was sent to over 150 observers, requesting their assistance in determining rainfall pH. Over 125 positive responses were received, from which 120 were selected and provided with the necessary instructions and materials. The approximate locations of all participating observers are shown in Figure 1. The study began in April and continued through October 1980.

In order to obtain as much statewide information as possible, utilize non-scientific personnel, and measure pH as soon as possible following precipitation, pH color-indicator sticks were used to determine the rain pH. The pH-indicator sticks (colorpHast indicator sticks, MCIB Manufacturing Chemicals, Inc., Cincinnati, Ohio[1]) covered a range from 4.0 to 7.0 with a 0.2 sensitivity from 5.3 to 5.9 and a 0.3 to 0.5 sensitivity on all other readings. Color codes were established for the pH values 4.0, 4.4, 4.76, 5.0, 5.3, 5.5, 5.7, 5.9, 6.2, 6.5 and 7.0. A pH reading was obtained by immersing the stick in rain water, which then developed a color that was compared to a standard color chart with associated pH values. The pH values and rainfall amounts were recorded on data sheets and returned when the study was completed.

[1]Mention of manufacturer or trade names does not constitute endorsement for use by the University Hygienic Laboratory.

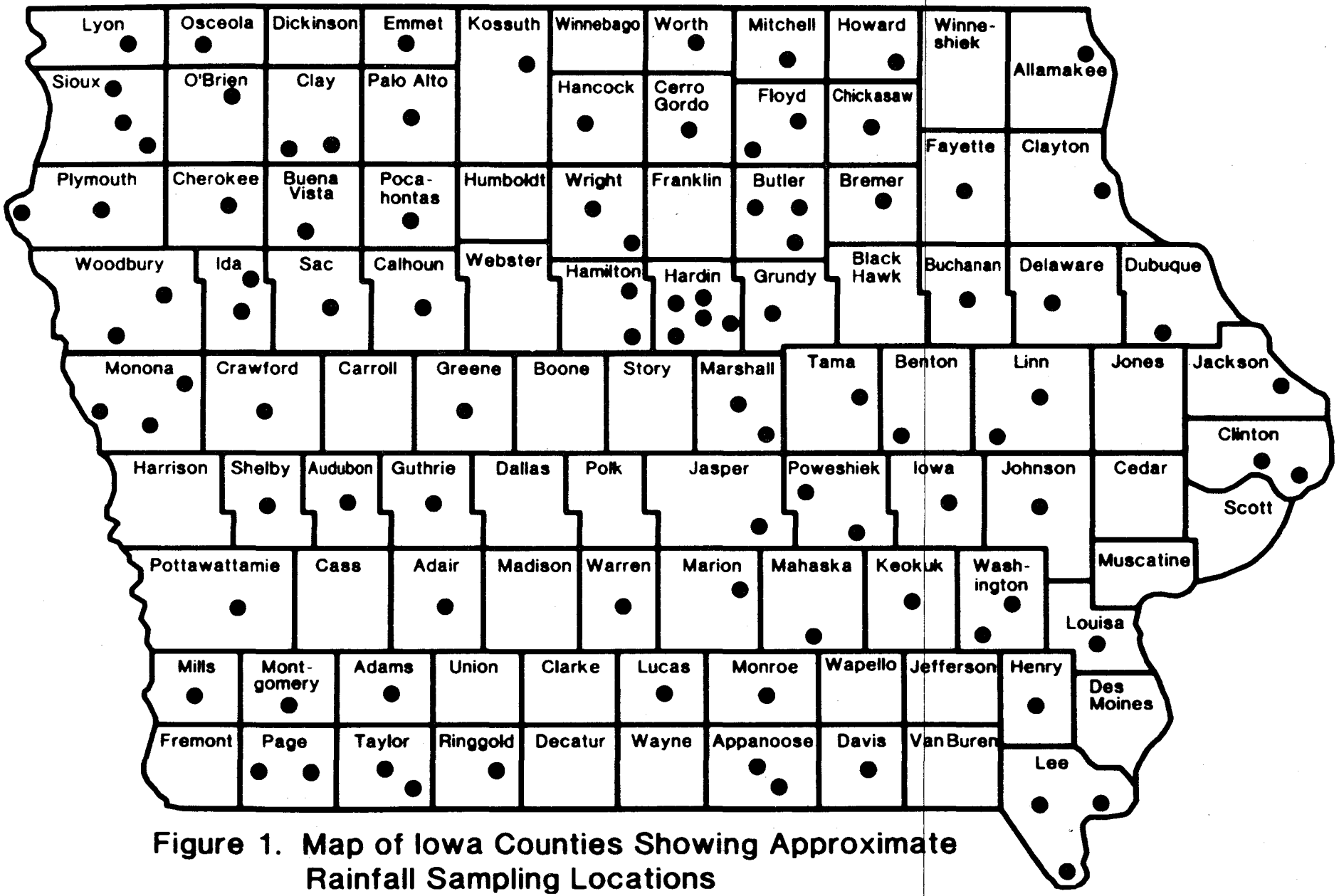


Figure 1. Map of Iowa Counties Showing Approximate Rainfall Sampling Locations

RESULTS AND DISCUSSION

Data return frequency was somewhat lower than anticipated with data sheets being received from 101 out of 120 stations (84%). Four of the 101 were unusable (no name, forgot to do tests, etc.) leaving 97 locations that were used in developing data for this report. The 97 locations (Figure 1) represent most areas of the state and 69 of Iowa's 99 counties. Statewide pH values ranged from a low of 4.0 to a high of 7.0. Figure 2 is a bar graph representing the number of occurrences of each pH value between 4.0 and 7.0. The pH values 5.7 and 5.9 were observed most often (39% and 28% of the time, respectively) and represented 66% of the 4,197 values measured. Approximately 79% of the values observed were in the range from 5.7 to 7.0. Of the 21% occurring in the acid rainfall range (below 5.7), slightly over 1% (43) were below pH 5.0. In assessing these data, it was noted there were several values reported for which there was no color code. Upon review, it was determined that over 95% of the values were based on the color chart provided, whereas approximately 4.7% were best estimates between two given values. In addition, the mean pH value (computed by averaging concentrations and converting to pH) for all pH values was 5.62, which compares favorably to the value of 5.65 for rainfall in equilibrium with carbon dioxide.

Because of the difficulties inherent in the calculation of mean pH values, median[2] values were used in this report. Median values were calculated for each of the 97 locations and ranged from 5.1 to 6.2 (Figure 3). Eighty-two (84%) of the median values were pH 5.7 or 5.9, while 11 (11%) were less than 5.7 and 4 (4%) were greater than 5.9. Of the eleven locations with medians less

[2] *The median of a ranked set of values is the value below and above which there is an equal number of values.*

Figure 2.
Number of Rainfall Samples for each pH Value

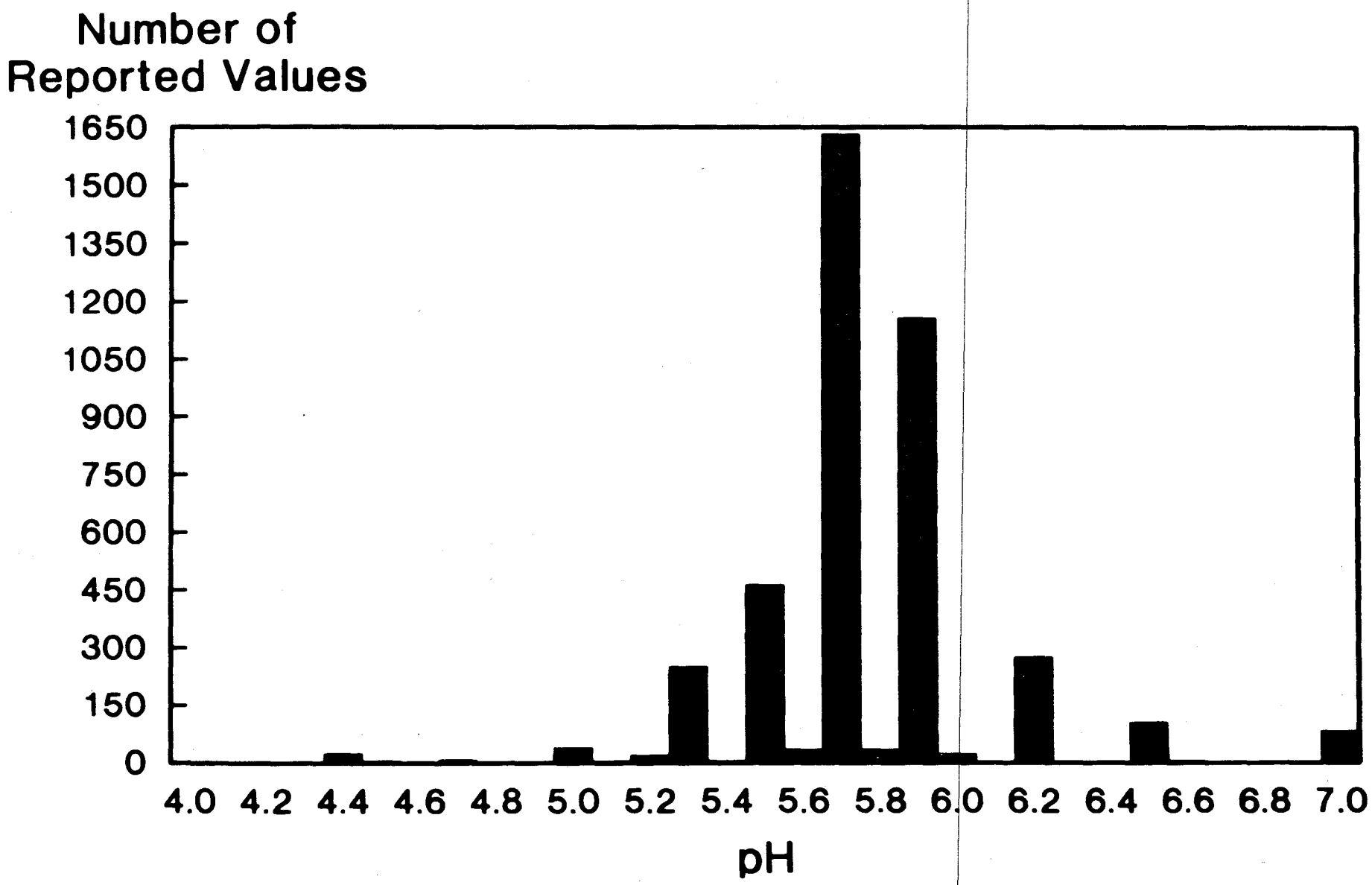
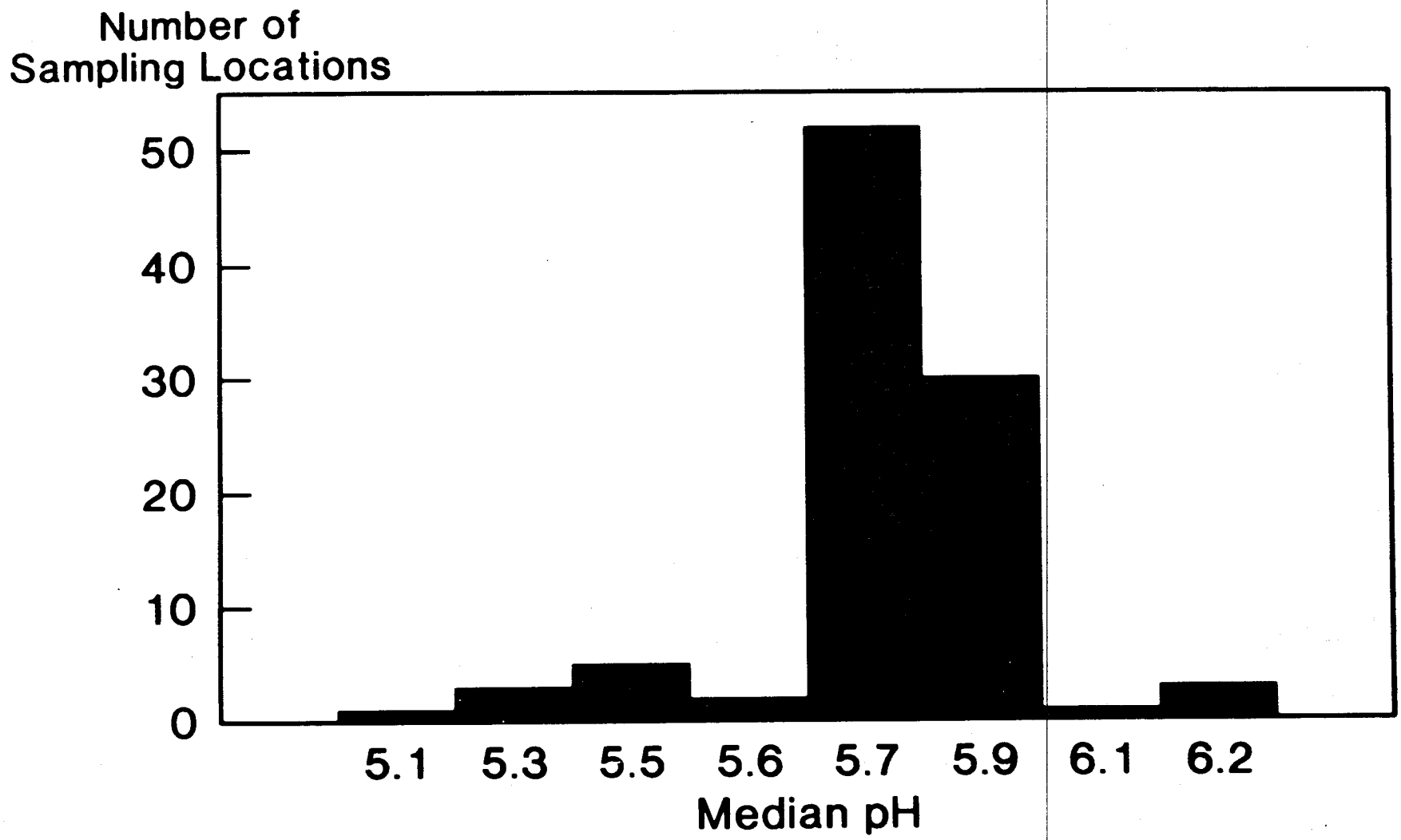


Figure 3

Number of Rainfall Sampling Locations of Each Median pH Value



than 5.7, two locations had median values of 5.6, five had 5.5, three had 5.3 and one had 5.1. The medians were recorded geographically (Figures 4 and 5) for trend analysis. Figure 4 identifies locations having median pH values of 5.7 or greater. Eighty-six locations appear in Figure 4 and geographically cover the entire state. The eleven sampling locations with median values below 5.7 are shown in Figure 5. With the exception of the three-county area in southeast Iowa, locations with median values below 5.7 are widely separated and scattered throughout the state.

In evaluating for trends, another type of analysis applied to these data was frequency of occurrence of acid rainfall. For each station the number of pH values 5.6 or less was tabulated and divided by the total number of values reported for that station. The resulting ratio from the 97 sampling stations are expressed as percentages in the following table:

Frequency of Acid Rainfall (Percentage of values 5.6 or less)	Number of Sampling Locations Having Stated Percentage
0 to 10%	43
11 to 20%	19
21 to 30%	14
31 to 40%	6
41 to 50%	5
51 to 60%	3
61 to 70%	1
71 to 80%	0
81 to 90%	1
91 to 100%	5

From these data it is apparent that sampling locations with frequencies higher than 80% are significantly different from the other locations. Moreover, locations with frequencies of 80% or higher represent areas where acid rainfall was

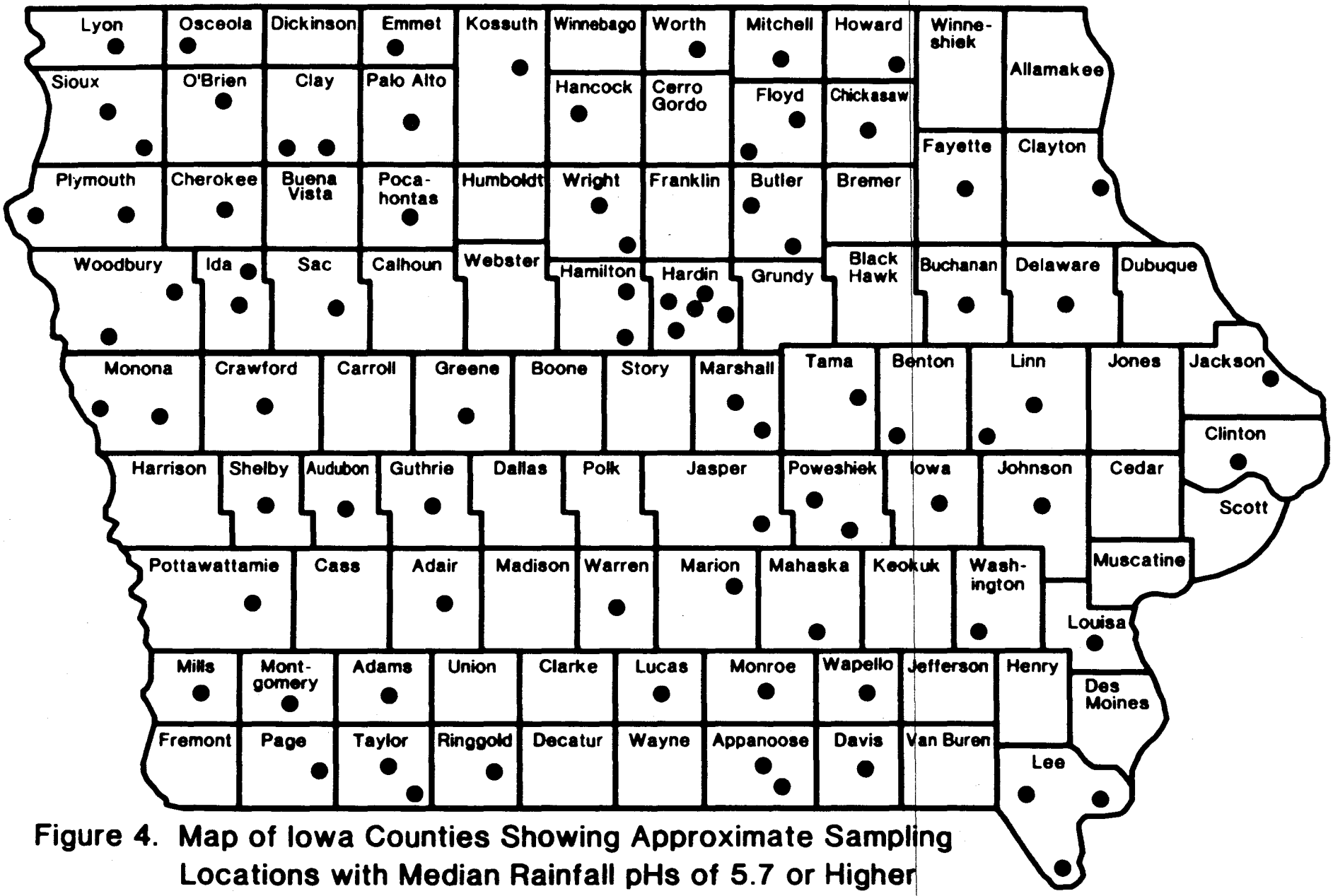


Figure 4. Map of Iowa Counties Showing Approximate Sampling Locations with Median Rainfall pHs of 5.7 or Higher

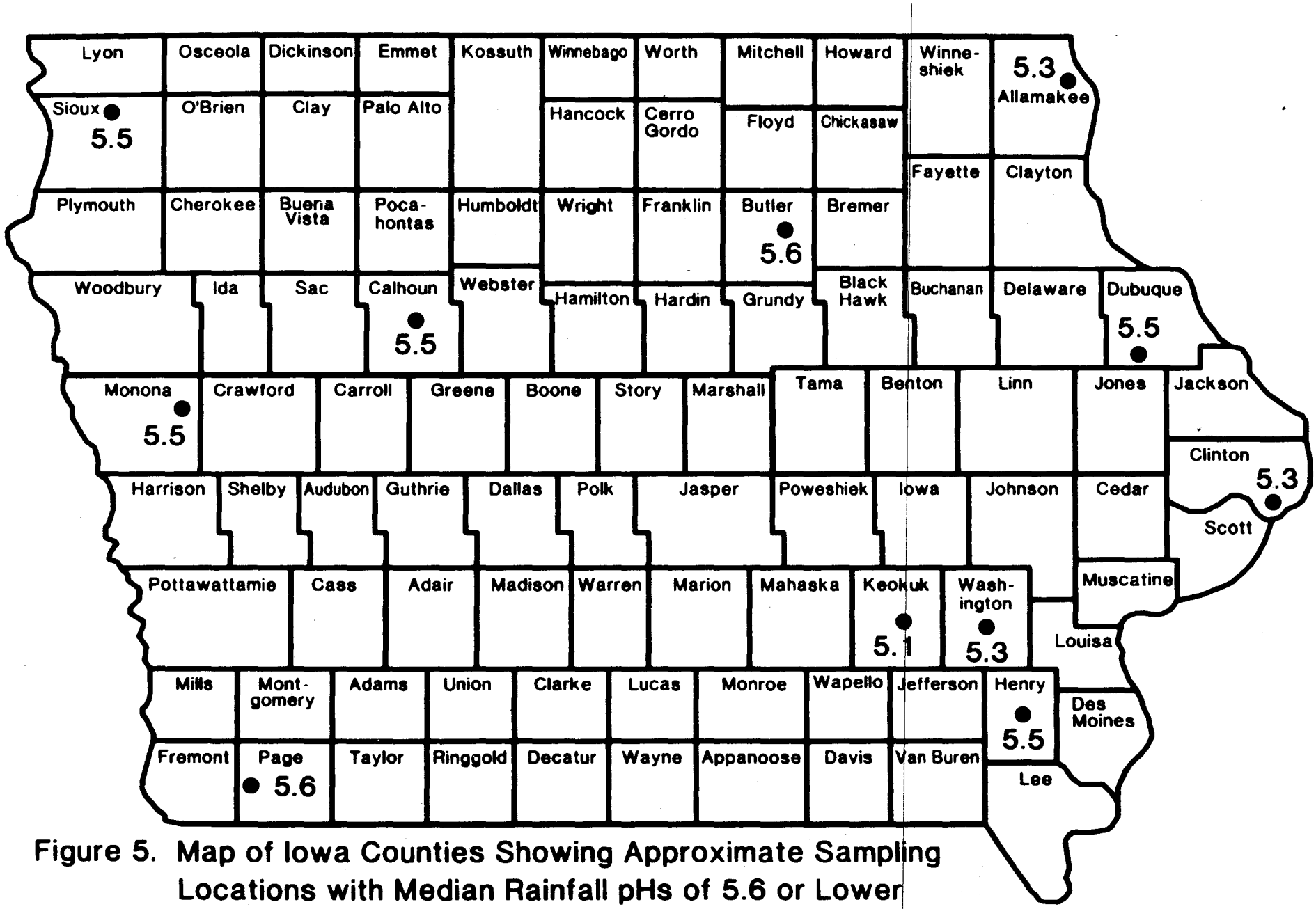


Figure 5. Map of Iowa Counties Showing Approximate Sampling Locations with Median Rainfall pHs of 5.6 or Lower

clearly occurring the majority of the time during the sampling period. The following table lists the eleven sampling locations with median values of 5.6 or less and their corresponding frequencies of acid rainfall.

SAMPLING LOCATIONS	MEDIAN pH	FREQUENCY OF ACID RAINFALL (%)
Page	5.6	69
Butler	5.6	50
Sioux	5.5	100
Henry	5.5	98
Calhoun	5.5	56
Monona	5.5	54
Dubuque	5.5	53
Clinton	5.3	92
Washington	5.3	91
Allamakee	5.3	85
Keokuk	5.1	100

This method of analysis better defines the problem areas. In the preliminary evaluation the seven median values of 5.5 and 5.6 were considered borderline for acid rainfall. From this analysis, Sioux and Henry County locations show a much higher frequency of acid rainfall than the other 5.5 and 5.6 locations and should be grouped with the lower median pH locations (Clinton, Washington, Allamakee and Keokuk) for evaluation. The data suggest that if acid rainfall is exerting a significant effect in Iowa, it would be at these six locations. Three of these locations (Sioux, Clinton and Allamakee) are geographically isolated from one another, indicating that the source of the low values are

probably independent of each other. In addition, there are several other sampling locations near those counties with higher (less acidic) median values, and this also indicates a localized problem. One may speculate that the low value seen in Clinton County may be a result of the highly industralized area located along that reach of the Mississippi River. The three other sampling locations with low median values and high frequencies of acid rainfall are in close geographical proximity, occurring in three adjacent counties (Henry, Washington and Keokuk).

The Keokuk County location had the lowest median value statewide with 26 of its 56 values less than pH 5.0 and the highest frequency of acid rainfall (100%). It is in the area defined by these three counties that Iowa's most significant acid rainfall effect may be occurring and this area should be considered for future study.

SUMMARY AND CONCLUSIONS

A statewide screening for acid rainfall was conducted from April through October 1980. Results of the survey show that 79% of the rainfall pH values fell in the range of 5.7 to 7.0, and only 21% in the acid rainfall range (5.6 or less). Median values calculated for the 97 sampling locations ranged from 5.1 to 6.2, with 5.7 and 5.9 medians occurring most frequently. Most of the locations with low median values (5.6 and below) were widely separated and probably represent local problems. Three adjacent counties located in southeast Iowa had low median pH values and this area is recommended for further study.

AUTHOR'S NOTE

As a result of the inconsistency found among the various references examined in the preparation of this report, we feel it necessary to comment on the calculation of average pH values. In calculating the mean of a set of pH values, it is not correct to simply sum the pH values and divide by the number of values. This method of calculating a mean is correct only for a set of real numbers and a pH value is not a real number. A pH value is the negative logarithm of the concentration (in moles per liter) of hydrogen ions in a solution. To correctly calculate the mean of a set of pH values, each pH value in the set has to be first converted to its concentration; the mean concentration can be calculated and then converted back to a pH value. The following example will help illustrate how an erroneous average pH value can occur. Consider the following set of pH values: 3.0, 5.0, and 7.0. The arithmetic mean obtained without converting to concentrations is 5.0. Converting to concentrations and then calculating the average gives a mean pH of 3.47. When a mean pH is calculated without converting to the concentration, the resulting pH is always higher (more basic) than the true value. This error can be especially misleading when one is more concerned with acid values. It is recommended that if the phrase "average pH" is used in a report, the method of calculating that average is detailed so that one may be assured as to the validity of the data.

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