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# Acid precipitation: A potential environmental problem at the UWM Field Station

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# ACID PRECIPITATION: A POTENTIAL ENVIRONMENTAL PROBLEM AT THE UWM FIELD STATION

## INTRODUCTION

Emissions into the atmosphere from man-related sources are changing precipitation quality and chemical climate over many parts of the United States, especially those areas downwind from highly urbanized and industrialized sections. Soils, vegetation and surface waters act as passive sinks for many elements found in the atmosphere (Oden, 1976). These elements are not fixed but are transferred from one component to the next at varying rates. High acidity in precipitation is a growing environmental problem (Oden, 1976, Cogbill, 1975b and USDI, 1973). Acids and other pollutants in the atmosphere which are washed out by rainfall can affect soil processes, plant growth, productivity and eventually species composition. The dynamic exchange of minerals between the biotic and abiotic components may be severely altered, thus reducing community stability.

Precipitation was monitored for acidity at the UWM Field Station as part of a study (Kobriger, 1975) to obtain data on mineral cycling and productivity of a maple-beech forest located on a ridge crest in the northwestern portion of the upland deciduous forest of the UWM Field Station. Precipitation samples were also collected on The University of Wisconsin–Milwaukee campus to examine comparable urban values.

## METHODS

The permanent rain gauge at The University of Wisconsin–Milwaukee Field Station provided the base record of precipitation quantity. Four rainfall collectors were designed to measure precipitation quality. Two of these rain

collectors were positioned under the forest canopy of the maple-beech forest (Figure 1) to collect throughfall, one was placed in a nearby open field (Figure 2) to collect direct rainfall, and one was placed at ground level near Lapham Hall on The University of Wisconsin–Milwaukee campus to examine urban rain. Each collector consisted of a plastic funnel 10.5 inches (26.3 cm) in diameter and a one gallon (3.8 liter) plastic bottle to hold the sample. The funnels were secured by means of a wire ring attached to three support stakes driven into the ground (Figures 1 and 2). The funnel stem was placed directly into the collection bottle and the bottle was seated on a solid base to provide additional stability. This arrangement of funnel, support ring and collection bottle with base, prevented the funnel from tilting during windy periods. Precipitation collection efficiency may decrease if the funnel is tilted. The rain collector used in this study is similar to the Hubbard Brook Bulk Rain Collector (Galloway and Likens, 1975).

Prior to each storm, the entire collection system (funnel and sample bottle) was acid-washed with 6N HCl and rinsed with distilled water until the flush water had the same pH as the distilled water used (usually five rinsings). The Wisconsin Department of Natural Resources Laboratory at Delafield, Wisconsin conducted the water quality analyses on the precipitation (rain and snow) samples.

Four snow samples, one from the UWM campus, one from the open field and two within the experimental plot in the maple-beech forest, were obtained on each of two dates, February 6, and March 12, 1975. Snow sample collectors consisted of plastic tubs which were 11 x 14 x 7 inches (28 x 36 x 18cm). The snow was allowed to melt at room temperature and poured into DNR plastic containers for analysis.

## RESULTS

The results of the pH analysis performed by the DNR on the precipitation (rain and snow) samples are shown in Tables 1 and 2. Because pH values can change with time, five rainfall samples were tested with a battery powered field pH meter immediately after a storm. One sample showed a difference between field tested pH and DNR reported values of 0.5 pH units (a pH of 6.4 vs. 5.9). The other four samples were within 0.1 to 0.2 pH units. Rain samples from the Milwaukee and Field Station collectors showed a pH range of 3.6 to 6.8 (Table 1), while snow samples showed a pH range of 4.5 to 6.7 (Table 2).

Except for the first two sampling events, the pH for the rain samples in Milwaukee did not generally differ significantly from the open field rain samples from the UWM Field Station (Table 1). However, the Field Station is not remote enough to be free from the effects of urbanization and industrialization. Pollutants from large emission sources may cause significant air concentrations 500 to 1000 miles away, causing acid precipitation remote from the source (Nordo, 1975). Industrial sources of air pollutants, such as paper mills in the Fox River Valley and the Wisconsin Electric Power Company in Port Washington, may also have an effect on the acidity of rainfall at the Field Station. Acids commonly found in low pH rainfall are $H_2SO_4$, $HNO_3$, HCl and organic acids. In northeastern United States (Cogbill and Likens, 1974), the components of acidity were 62 percent $H_2SO_4$, 32 percent $HNO_3$ and 6 percent HCl. $SO_2$

Figure 1. Rainfall collector located within experimental plot of maple-beech forest.

Figure 2. Rainfall collector located in open field.

Table 1. Rainfall pH for selected 1975 samples

Storm Dates

| Location | 5/30 | 6/11 | 6/16 | 7/11 | 7/19 | 7/23 | 8/2 | 8/25 | 9/30 | 11/3 | 11/9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Milwaukee | 4.6 | 6.4 | 5.9 | 6.6 | 6.6 | na | na | na | 4.2 | 6.0 | na |
| Open Field | 3.6 | 3.9 | 5.7 | na | 6.8 | 4.3 | 4.5 | 4.2 | 5.9 | 6.2 | 5.0 |
| Woods West | 4.1 | 4.9 | 5.9 | na | na | na | na | na | 7.1 | na | 5.9 |
| Woods East | 4.6 | 4.6 | 5.9 | na | na | 5.3 | 5.7 | 5.8 | 6.0 | 6.4 | 6.0 |

*Note: na is the abbreviation for no analysis performed*

Table 2. Snowfall pH for selected 1975 samples

Storm Dates

| Location | 2/6 | 3/12 |
|---|---|---|
| Milwaukee | 4.8 | 4.5 |
| Open Field | 4.9 | 5.2 |
| Woods South | 5.4 | 5.3 |
| Woods North | 6.7 | 5.8 |

oxidation to sulphuric acid accounts for much of the acidity in rainfall. Wisconsin industry emits 1951 metric tons of $SO_2$ per day (EPA, 1974). Many rainfall samples at both the Field Station and Milwaukee appear abnormally acid since pure water in equilibrium with atmospheric concentrations of $CO_2$ should have a pH not less than 5.6 (Barrett and Brodin, 1955).

An average pH of 6.2, with a range of 5.8 to 6.5, was reported for six Iowa monitoring sites over four years (1971-1973) (Tabatabai and Laflen, 1975). In Michigan, rural samples gave pH values in the ranges of 5.27 to 5.35, while an urban-industrial area at Saginaw Bay had an average pH of 4.90 (Richardson, 1975). A study in New York during 1970-71 found an average pH of 3.98 at Ithaca, 3.91 at Aurora and 4.02 at Geneva (Likens, 1972). In the fall of 1978, two rain samples collected near the Menomonee Industrial Valley in Milwaukee, Wisconsin, both showed pH values of 3.8 (Unpublished Data). At Hubbard Brook, the average annual weighted pH for the period 1964-1974 ranged between 4.03 and 4.21; the lowest value recorded for a storm at Hubbard Brook was pH 3.0 and the highest was 5.95 (Likens, *et al.,* 1977). For a single storm at the Field Station, the lowest pH was 3.6 and the highest was 6.8. Like many of the areas mentioned above which have highly polluted atmospheres, the Field Station receives a significant amount of acid precipitation.

Rainfall passing through the canopy (throughfall) in all cases showed a slightly higher pH than directfall (open field) (Table 1). These findings are in accord with those by Hornbeck, *et al.* (1975). As rain descends through the canopy, hydrogen ions may exchange with other cations. This can cause accelerated leaching of cations from the canopy. In dense deciduous forests an average raindrop washes over three tiers of foliage before reaching the forest floor (Tamm and Cowling, 1975).

Hornbeck, *et al* (1975) observed seasonal patterns in precipitation acidity. Precipitation was most acid during the growing season (May-September) and least acid in winter (December-February). Data for the open field did not show a strong seasonal pattern although the lowest pH values for the Field Station did occur in May and June (Table 1). Highly acid rainfall during the early part of the growing season could have serious effects on canopy development, ground flora and species that develop reproductive structures during this time. Unlike the seasonal pattern observed by Hornbeck, *et al.*(1975) snow samples (Table 2) had low pH values. However, acidity declines in snow stored in the snowpack, lessening its impact on the ecosystem (Hornbeck, *et al.,* 1975). Seasonal patterns in precipitation at Hubbard Brook were highly correlated to patterns of sulphur deposition from the atmosphere. Presumably, the well defined atmospheric sulphur pattern at Hubbard Brook does not exist at the Field Station.

## DISCUSSION

Potential effects of acidic precipitation on vegetation include (Tamm and Cowlings, 1975):

A. Direct effects
   1. Damage to protective surface structures such as cuticle.
   2. Interference with normal functioning of guard cells.

3. Poisoning of plant cells after diffusion of acidic substances through stomata or cuticle.
4. Disturbance of normal metabolism or growth processes without necrosis of plant cells.
5. Alteration of leaf- and root- exudation processes.
6. Interference with reproductive processes.
7. Synergistic interaction with other environmental stress factors.

B. Indirect effects
1. Accelerated leaching of substances from foliar organs.
2. Increased susceptibility to drought and other environmental stress factors.
3. Alteration of symbiotic associations.
4. Alteration of host-parasite interactions.

In an attempt to determine the effect of acid precipitation on tree growth, Cogbill (1975a) compared tree growth patterns in New Hampshire to that in Tennessee. The New Hampshire site lies near the center of the acid precipitation in the northeast while the Tennessee site (Smoky Mountains) is on the periphery of the acid rainfall pattern. At the New Hampshire site the average pH of precipitation is 4.1. The acidity at the Tennessee site has changed from pH of 5.2 in 1955 to 4.4 in 1974 (Cogbill and Likens, 1974). However, they found no correlation between acid precipitation and a decrease in the growth rate of mature trees. None the less, this remains a matter of long term conern, because if the buffering capacity of a forest soil is lost, production could be severely hampered.

Data collected at the Field Station show that as the acid water from directfall, throughfall and stemflow percolates downward through the soil, the pH of the groundwater becomes neutral to slightly basic (Kobriger, 1978). The buffering effect of the soil with depth was considerable as monitored by the zero tension lysimeters installed within the experimental plot of the maple-beech forest (Kobriger, 1978). The storm of June 16, 1975 (Table 1) is a good example. The range of pH for directfall, throughfall and stemflow was 4.6 to 5.9 while the water flowing through the litter was 6.8 and the pH range of the other soil horizons was 7.3 to 7.8. The buffering by soil minerals and organic matter minimizes changes in soil pH when acids are added. This prevents possible damage to soil microorganisms and vegetation. For the humid temperate zone, Frink and Voight (1975) concluded that if acidity in precipitation should increase substantially or if the buffering capacity of the soil ecosystem is seriously reduced, they would expect detrimental changes in soil productivity.

## CONCLUSION

The data suggest that the UWM Field Station does receive a significant amount of acid precipitation. The most acid precipitation occurs during the early part of the growing season which may have serious effects on developing foliar organs. The groundwater lysimeter data show that the soil of the maple-beech forest at the UWM Field Station still has a large buffering capacity which protects soil microorganisms and vegetation from possible damage. However, with the recent change to fossil fuels which contain a higher sulphur content

(natural gas to coal), acid precipitation in the area could increase to the point where soil buffering processes would no longer be effective. Increased acidity in precipitation could also damage vegetative structures and could possibly reduce plant growth, productivity and community stability.

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