Monitoring Study on Acid Rain in Kanagawa Prefecture, Central Japan

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Introduction

Acid deposition has a long historical background. In the 17th century, scientists noted the adverse effects that industry and acidic pollution had on vegetation and people. However, the term acid rain was not coined until two centuries later when British scientist Robert Angus Smith published ‘Air and Rain: The Beginning of a Chemical Climatology’ in 1872. Acid deposition is defined as the atmospheric acids deposited on the earth as wet deposition (snow, rain, fog, mist, etc.) and dry deposition (gas and dry particles). However, this paper deals exclusively with what is commonly called “acid rain”. Acid rain forms in the air, and is caused by burning fossil fuels to produce electricity and run automobiles. The burning of these fuels results in emissions of sulfur dioxide and nitrous oxide into the air. In the 1960s, the problems associated with acid rain became an international concern when fishermen noticed declines in both fish numbers and diversity in many lakes throughout North America and Europe. Indeed, acid rain has become one of the most serious worldwide environmental problems to date.

The Environment Agency, Government of Japan—renamed the Ministry of the Environment, Government of Japan in 2001—has been performing surveys of acid rain since 1983. In recent years, acid rain in Japan has been observed at roughly the same levels as those in Europe and North America (Ministry of the Environment, Government of Japan, 2004). In addition, starting in 1984, a more detailed investigation of acid rain began in Yokohama City—located in Central Japan—by the Yokohama Environmental Science Research Institute. They have been collecting and analyzing rainfall and their initial 1 mm rainfalls, which were then used for determining the differences within one-time collected rainfall. However, sampling sites for acid rain monitoring by federal and local governments are limited, and it is necessary to accumulate more data in local areas in Japan.

The following study monitored acid rain at two sites in Kanagawa Prefecture where acid rain previously had not been monitored. This study analyzed rainfall in 1 mm increments, in order to (1) estimate the effect of acid rain on ecosystems and (2) explain the relationship between one-time collected rainfall and the initial 1 mm rainfall.

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Materials and Methods

The rainfall was collected at a residential area in Kagawa, Chigasaki City, Kanagawa Prefecture (E139°24′, N35°19′) in May-December 2000 and in Eda-cho, Aoba area, Yokohama City, Kanagawa Prefecture (N35°33′, E139°33′) in January-December 2002 (Figure 1). The rainfall collector (Horiba, AR-8II) was set-up using one automatic open rain sensor cap and 8 cups used for collecting the initial rainfall in 1 mm increments (Figure 2). Amounts over 8 mm of rainfall were collected by one drainage cup up to 30 mm. After collection, the rainfall pH and electrical conductivity (EC) of each cup were measured using a pH meter (Horiba, Twin pH B-212) and a EC meter (Horiba, TwinCond B-173). Statistical analyses were conducted using XLSTAT software (1995-2004 Addinsoft, XLSTAT 7.1); as described in the text, significant differences among the rainfall data were analyzed by Student’s t test for paired samples (α<0.01) and Pearson’s correlation coefficient test (α<0.01).

Results

Acid rain below pH 5.6 was observed in 83% of 103 rainfall samples collected in Chigasaki City (2000) and Yokohama City (2002) (Figure 3). In the detailed result of the collected rainfall sample, the volume-weighted mean pH (VWMpH) of rainfall showed an average pH of 4.7 in Chigasaki City in 2000 (range from pH 3.6 to 7.7), and VWMpH of rainfall in Yokohama City was estimated at an average pH of 5.3 in 2002 (range from 3.9 to 7.5).

Furthermore, it has been concluded that rainfall below pH 4.0 can damage certain varieties of plants (Evans et al. 1980; Jacobson 1980). In our study, readings at or below pH 4.0 were observed 6 times in Chigasaki City and once in Yokohama City during the study periods of 2000 and 2002. Umeda and Katou (2002) reported that the rainfall pH in Yokohama City decreased as a
result of volcanic gases emitted during the eruption of Mt. Oyama (elevation: 813 m, location: N 34°04' 43", E 139°31' 46") in Miyakejima Island, which is located 160 km south of Chigasaki City, during September 2000-August 2001. Also, particularly strong acid rain was detected in Chigasaki City from August to December 2000. This may be a result of differences in the intensity of volcanic gases over time. As above-mentioned, it can be concluded that during the study periods most of the rainfall pHs were observed in the 4.0 - 5.6 range.

Of particular note, acid rain below pH 5.6 was observed in 56% of 103 initial 1 mm rainfall samples in Chigasaki City (2000) and Yokohama City (2002) (Figure 4). Contrasting with the result of Umeda and Katou (1998 and 2002), our data indicated a higher level of pH (less acidic) for the initial 1 mm rainfall. Even though the reason for this result is not clearly understood, it is interesting to note that initial first 1 mm rainfall pHs were significantly different from one-time collected rainfall pHs in our study (Figure 5).

Umeda and Katou (1998) reported that the concentrations of each measured ion in initial first 1 mm rainfall were higher compared with its one-time collected rainfall. This result may reflect that rainfall pH is dependent on the processes of proton (H+) formation and consumption of limited materials (e.g.: H₂SO₄, NH₃, etc.) in the air. Consequently, there is a possibility that the chemical property of the initial first 1 mm rainfall measurements was different from their rainfall measurements. In our study, there was a significant difference between the initial first 1 mm rainfall electrical conductivity (EC) – which estimates the amount of total dissolved salts (TDS) or the total amount of dissolved ions in the water – and the rainfall EC (Figure 5). In addition, as acid rain pH decreased downward to pH 3.6 there was a corresponding increase in the acid rain EC, with a significant correlation coefficient between pH and EC in each of the initial 1 mm acid rain measurements and corresponding one-time full rainfall measurements below pH 5.6 (Figure 6).
Figure 4. The initial first 1 mm rainfall pHs in Chigasaki City (2000) and Yokohama City (2002) (Dashed line: acid rain at pH 5.6; Solid line: acid rain at pH 4.0, crop-damageable level. 2001: no data)

Figure 5. Means of: (1) Initial 1 mm rainfall pHs and (2) one-time collected rainfall pHs; (3) Initial 1 mm rainfall ECs and (4) one-time collected rainfall ECs. Vertical bars indicate maximum and minimum values (n=103). Symbol of *** shows a significant difference (Student’s t test for paired samples, $\alpha = 0.001$)

Figure 6. Relationships between initial 1 mm rainfall pH and EC (n=58, upper), and one-time collected rainfall pH and EC (n=85, bottom). Symbol of *** shows significant correlation coefficients (Pearson’s correlation coefficient test, $\alpha = 0.001$)
Conclusion

This study showed acid rain in Kanagawa Prefecture was still observed with a high frequency of 83% in 103 rainfall samples in Chigasaki City (2000) and Yokohama City (2002). Also, there was a significant difference between the initial 1 mm rainfall pH and the one-time collected rainfall pH in Kanagawa Prefecture through the study periods of 2000 and 2002. Significantly, acid rain was more acidified with increasing acid rain EC in this study. Furthermore, the initial first 1 mm rainfall ECs were higher compared with their one-time collected rainfall ECs. This result suggests that a high concentration of dissolved ions was absorbed by the initial first 1 mm rainfall. Consequently, this study suggests that further study on effect of the frequency of rainfall on an ecosystem is required to illuminate the complex ecological effects of acid rain. Especially in unique conditions such as active volcanoes, acid rain can be further acidified within a regional wide area in Japan. Consequently, a successive monitoring study of acid rain in Japan is needed to explain acid rain and elucidate possible countermeasures.

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References


