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## AIRBORNE SULPHUR AND LAKE WATER ACIDIFICATION IN FINLAND

Kaarle Kenttämies

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During the last decades the atmospheric supply of sulphur has increased in Finland. The monitoring results of water authorities, however, have revealed no regional lake water acidification. Instead, the rising electrolytic conductivity of undisturbed lakes may be regarded as one of the first signs of growing atmospheric influence.

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Index words: Lake water, acidification, airborne sulphur, electrolytic conductivity.

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### 1. INTRODUCTION

The idea to discover relationships between airborne sulphur and the acidification of lakes and rivers is quite new in Finland and doubtless a reflection on respective Scandinavian research programmes. The research work on the effects of airborne pollutants in Finland is just beginning. The data from the Finnish water monitoring network has been used in this study to survey the general situation of water acidification.

### 2. ACID PRECIPITATION IN FINLAND

The national program for monitoring rain water quality started in 1971 (Haapala 1977). Earlier observations on the chemical composition of precipitations covered shorter periods and smaller

areas (e.g. Buch 1960).

Median values of some characteristics in precipitation from six years (Figs. 1 and 2) show a clear difference between the southern and northern parts of Finland (Järvinen 1978). pH-values are about one unit higher in Lapland than on the southwest coast. Sulphate precipitation is 3–6 times higher in southern Finland. Strong acids follow the same tendency though differences between observation stations are bigger.

Values for conductivity are higher in the south, too, but the local differences are smaller.

Comparing with sulphur precipitation in the 1950's (Viro 1953, Buch 1960) the doubling of the overall level seems to be a fact in southern Finland. In Lapland the increase is about 50 % (Haapala 1977).

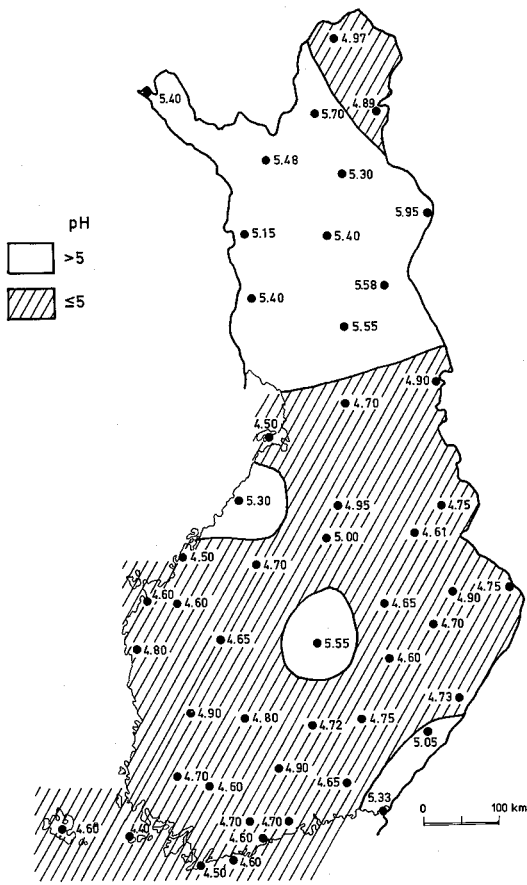


Fig. 1. Rain pH median values for the annual medians in the period of 1971 to 1976 (Järvinen 1978).

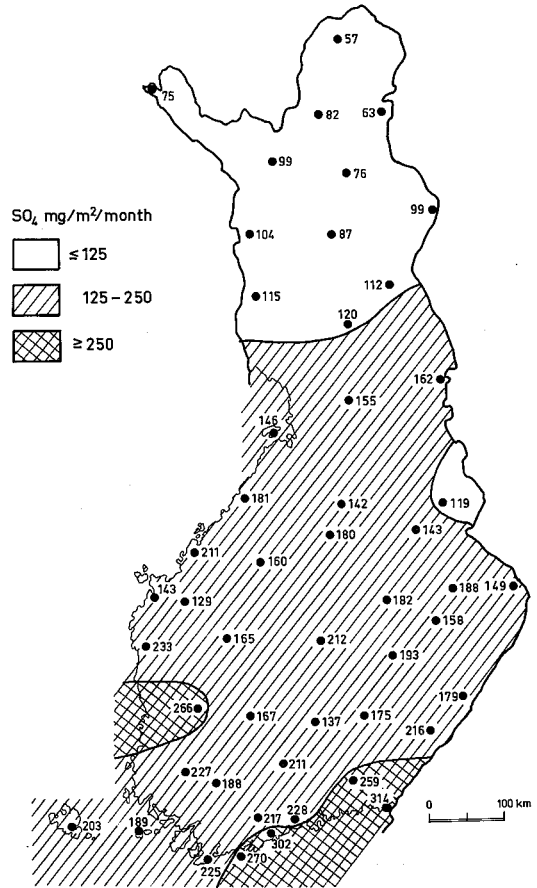


Fig. 2. Rain water sulphate means of annual median values in the period of 1971 to 1976 (Järvinen 1978).

### 3. pH, ALKALINITY AND ELECTROLYTIC CONDUCTIVITY CHANGES IN SURFACE WATERS

#### 3.1 Observations from the Finnish water monitoring networks

To find out the possible effects of growing acid precipitation, the trends of pH, alkalinity, conductivity and total sulphur in Finnish monitoring networks were examined. According to Laaksonen (1975) the growing trend of conductivity is very common. The sinking trend of alkalinity is observed only in some sampling stations of Kokemäenjoki and Oulujoki watercourses.

Statistically significant trends of pH-changes are very few. In river stations the observations

taken in May and October are perhaps the most indicative ones. The number of trends were as follows (Laaksonen 1975).

	May		October	
	+	-	+	-
pH	73	0	93	0
alkalinity	3	15	17	6
pH	4	13	3	13
tot.S	36	1	35	2

Compared with the number of observation stations (179), the growing trend of conductivity is striking. Significant trends both in alkalinity and pH are few. The trends of total sulphur are mostly concentrated in polluted waters and may not indicate atmospheric load.

In lake deep stations, the sinking trends of pH are very few, too (Laaksonen 1975).

### 3.2 Lake water acidification studies

The general monitoring programme are not necessarily the best possible to reveal the atmospheric pollutants. In 1972 a study dealing only with unpolluted lakes was made by the water authorities (Kenttämies 1973). According to the study the pH-values of surface water in winter had decreased about 0.1 pH units from 1962–1964 to 1970–1972.

In 1977 another study on lake water acidification was made by Water Research Institute. The purpose was to compare the pH (and  $[H^+]$ ), alkalinity and conductivity levels in 1975–1977 to those in 1970–1972 and in 1962–1965. The study was restricted to surface water (1 m) of lakes in unpolluted, "natural" state. The lack of long sampling series from that kind of lakes made it impossible to use other than Student's t-statistic in comparing observations. The statistical significance of changes in particular lakes remain thus unsolved.

Most lakes are situated in the southern and central parts of Finland.

The differences in pH and alkalinity means in

three observation periods were small (Table 1) and not statistically significant. In fact a slight increase in pH-means and decrease in alkalinity could be noticed. The separate treatment of summer (5.–9. months) and winter (10.–4. months) data did not change the overall direction.

However, using a variation of t-statistic, it was tested whether the mean of differences in observation pairs (periods) differ from null (Mäkinen 1974). Some statistically significant differences were gained in this way (Table 2). Alkalinity was lower and conductivity higher in 1975–1977 than in 1962–1964. In pH (and  $[H^+]$ ) values no significant changes were observed.

Table 2. Student's t- statistic of the means of differences between periods 1962–1964 and 1975–1977.

	I	II	III
Alkalinity	-3.312**	-0.939	-3.236**
pH	0.407	0.672	0.694
$[H^+]$	0.873	0.404	0.834
$\chi^2_{25}$	6.637***	2.442	6.115***

I all samples, n = 37

II summer (5.–9. months) samples, n = 6

III winter (10.–4. months) samples, n = 28

\*\*\* confidence level 99.9 %

\*\* confidence level 99 %

Table 1. The arithmetic means and standard deviations of some surface water parameters in research lakes in periods 1962–1965, 1970–1972 and 1975–1977.

	1962–1965			1970–1972			1975–1977		
	I	II	III	I	II	III	I	II	III
Alkalinity mekv/l									
Mean	0.187	0.186	0.187	0.158	0.164	0.154	0.170	0.164	0.174
Std.dev.	0.104	0.165	0.94	0.108	0.111	0.107	0.113	0.112	0.115
pH									
Mean	6.63	6.88	6.59	6.75	6.91	6.65	6.77	7.03	6.61
Std.dev.	0.35	0.22	0.35	0.39	0.40	0.35	0.49	0.50	0.42
$\chi^2_{25}$ mS/m									
Mean	4.75	5.94	4.55	5.10	5.07	5.13	5.52	5.37	5.62
Std.dev.	3.11	5.92	2.49	2.62	2.98	2.42	3.05	3.15	3.02

I all samples

II summer (5.–9. months) samples

III winter (10.–4. months) samples

## 4. DISCUSSION

The effects of airborne sulphur on lakes in Finland are not very strong compared for example with those in Norway (Braekke 1975). However, changes in alkalinity and conductivity in lakes of natural state may be an alarm of troubles in future. As an area of Archaean rocks, mostly acidic by nature, the buffering capacity of Finnish soils is not very high. Besides, the acidifying exchange reactions of sulphur in turf and podsol soils, both very common in Finland, must be kept in mind.

The origin of sulphur in precipitation is under discussion in Finland. The general marine effect, long range transport of anthropogenic sulphur and native emission of sulphur are not easily separable from one another. Long range transport is a fact but its quantification is still under work. The native emission of sulphur into atmosphere is roughly 250 000 t/a S. Theoretically, distributed evenly over the land area of Finland, this gives the monthly value of  $185 \text{ mg/m}^2 \text{ SO}_4$  that well agrees with the measured level of sulphur precipitation in southern Finland (Fig. 2). In fact, the atmospheric sulphur load is bigger than that given by rain water monitoring stations, because the stations represent weakly the urban and industrial short range emissions.

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## LOPPUTIIVISTELMÄ

Sadeveden mukana tuleva rikkilaskeuma on 3–6 kertaa suurempi Etelä-Suomessa kuin Lapissa. Sadeveden pH on taas Lapissa n. 1 yksikön korkeampi kuin Etelä-Suomessa. Rikkilaskeuma on kaksinkertaistunut 1950-luvun alusta. Vesistöjen happamuus ei valtakunnallisten seurantatulosten mukaan ole kuitenkaan merkittävästi muuttunut. Yleisellä sähkönjohtavuuden kasvulla saattaa kuitenkin olla yhteyksiä sadeveden laatumuutoksiin.

Likaantumattomien järvien pintavedestä tehdyn erityistutkimuksen mukaan ei yleistä pH-laskua voida havaita. Sen sijaan alkaliniteetti on pienentynyt ja sähkönjohtavuus kasvanut vuosijaksolta 1962–1964 jaksolle 1975–1977 tultaessa, mikä saattaa osoittaa happamien rikkipitoisten sadevesien kasvavaa vaikutusta.

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