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VEGETATION INJURY OCCURRING AFTER WINTER AT A FERTILIZER FACTORY

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Air pollution injury to vegetation often occurs at a fertilizer factory in central Sweden. The causing incidence often occurs in the winter and the symptoms appear when metabolism starts in the spring. Deciduous and coniferous trees and bushes were injured in the spring of 1979. Samples of pine needles were analysed for sulfur, total fluorine and nitrogen content, some of them for nitrate and ammonium. All the compounds show elevated levels, clearly connected with the degree of exposure of the sampling site. They are also higher in the spring than later, indicating involvement in metabolism or leaching. None is enough in excess, though, to clearly indicate the cause of injury. For technical reasons most probably the nitrogen compounds are involved. The problems encountered in tracing the causing pollutant, when injury appears long after the incident, might be easier solved with regularly used proper technical monitoring and bioindicator technique.

INTRODUCTION

Since 1962 the vegetation around a fertilizer factory in central Sweden has been checked regularly for air pollution injury. Severe symptoms often occured in the 1960:s, but from 1971 to 1978 no signs of acute injury were noted (KVIST 1976). The symptoms almost always appeared in the spring when metabolism starts after the low winter activity. This delayed effect of exposure to air pollution in similar climate has been observed also by others (HAVAS 1971). Mainly trees and bushes have been affected. Part of the explanation for this selectivity is that these species are not sheltered from air pollution by the snow, which covers the ground for several months, in the same way as vegetation closer to the ground.

The delayed discovery of injury often causes difficulty to trace the harming pollutant. For different reasons, climatic and technical, incidents with high concentrations of pollutants in the ambient air can occur without anyone noticing it. When vegetation injury has occurred it is important to decide the cause to be able to take precautions to prevent the incident from happening again. At a fertilizer factory the following toxic substances are most likely to appear: sulfur dioxide and related sulfur compounds, nitrogen oxides, ammonia, ammonium nitrate and fluoride compunds.

The following study deals with injury occuring in 1979 and shows the problems involved with the phenomenon discussed above. In April 1979 the needles of the coniferous trees turned red to a great extent in a wood of park character, south of the industry, Figure 1. Pines (*Pinus silvestris*) and junipers (*Juniperus communis*) were most severly injured, spruce (*Picea abies*) to lesser extent. In

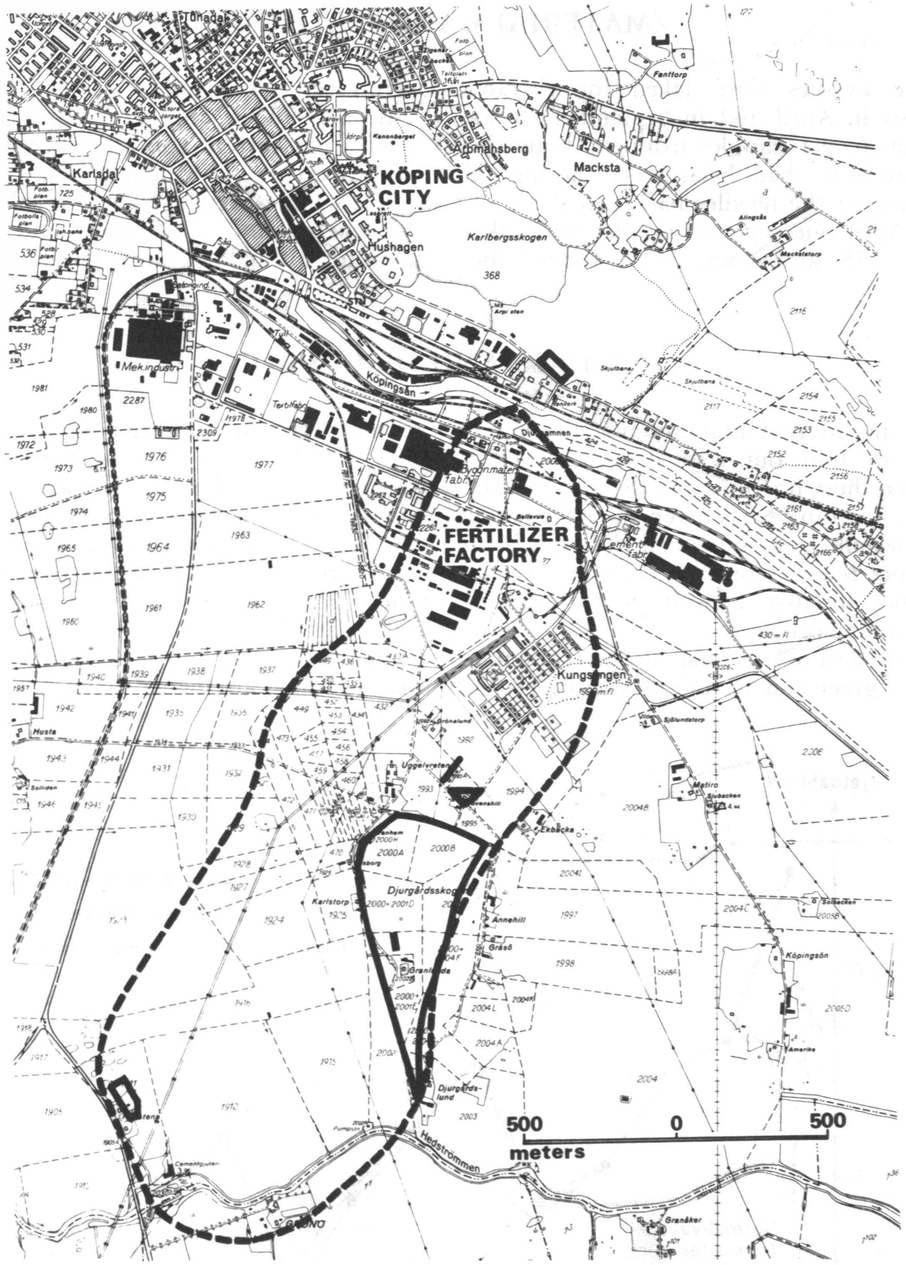

Figure 1. Area with vegetation injury.
—— indicates areas with injury on coniferous trees
– – – indicates areas with injury on deciduous trees

the most affected area, whole trees and bushes turned red-brown, and the new buds were killed on some trees. Deciduous trees had dead buds and twigs. This became even more evident at the time of normal bud-breaking. The affected area includes parks, private gardens and a horticultural enterprise. The deciduous trees grew new leaves on adventive shoots, replacing the dead leaf buds, later on in the season. The summer provided good growing conditions and many broadleaf trees recovered to a great extent.

MATERIALS AND METHODS

Pine needles were taken for chemical analysis in April and in September. It was difficult to get samples from the same sites because trees had been felled during the summer, or the needles had been shed.

In April one year old needles were taken (from 1978) and it was noted whether they were green or necrotic.

In September only green needles were taken from current year's (1979) shoots and from one year old shoots (1978).

The samples were analysed for sulfur, total fluorine and nitrogen content and some of them for nitrate and ammonium.

RESULTS AND DISCUSSION

The nitrate and ammonium analyses were made to find out if a connection exists between these fractions and the air pollution injury. Literature has given no information on how nitrogen sources of different kinds influence the two forms of nitrogen, nor has personal discussions with people working with similar projects.

Figure 2 shows the total nitrogen content in April of green and necrotic needles in relation to the degree of exposure of the sampling sites. No difference is found between green and necrotic needles, so the values from all samples are considered to be comparable. At the sites where injury was most severe, the levels are highest. At the less exposed sites, where green needles could be found, levels are relatively constant, but still elevated compared to the control. It should be noted that no values are higher than what has been

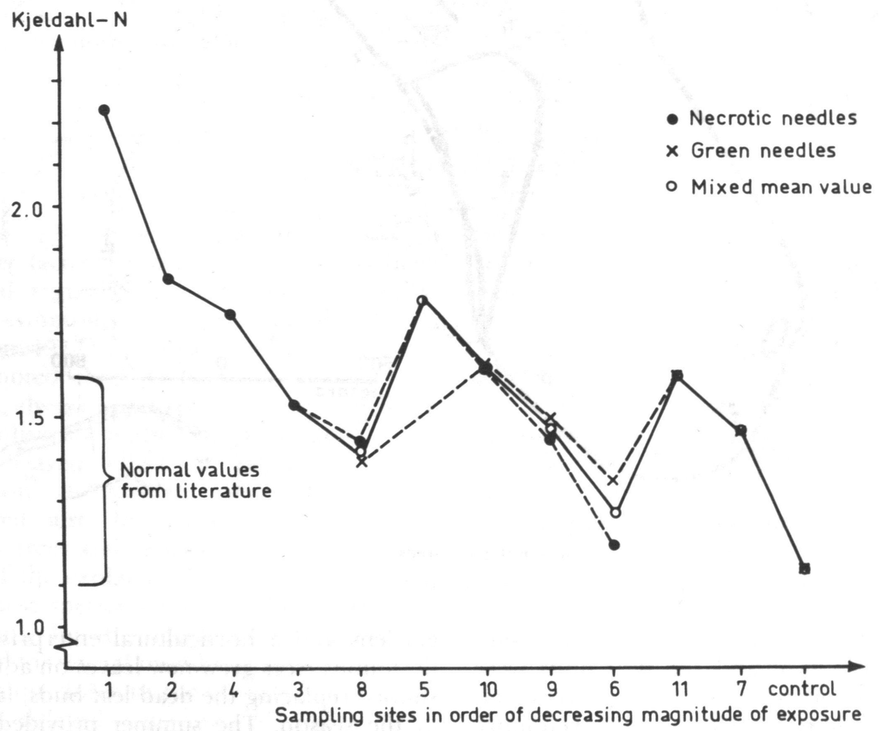

Figure 2. Content of total nitrogen in one year old pine needles (1978) in correlation to the degree of exposure of the sampling site. The samples were taken in April 1979.

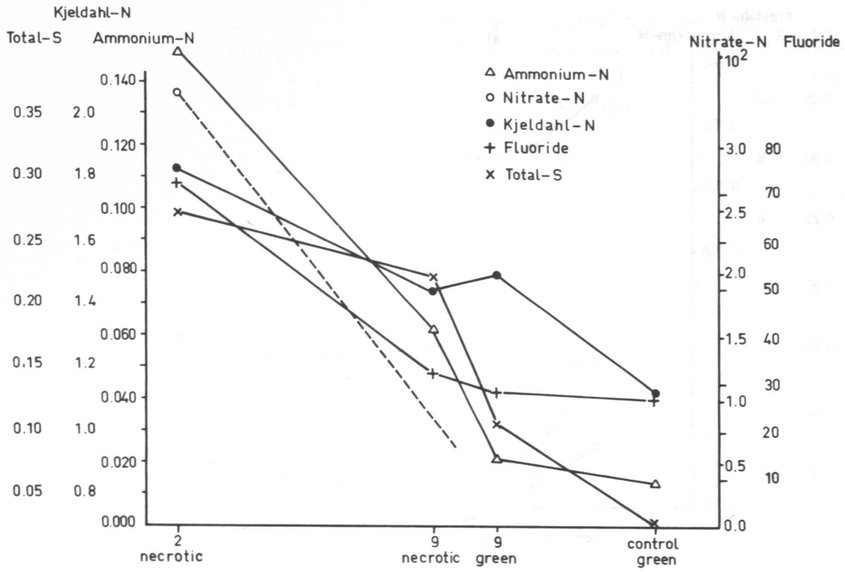

Figure 3. Content of sulfur, fluoride, total nitrogen, nitrate and ammonium of one year old pine needles (1978). The samples were taken in April 1979.

found in fertilized pine stands, 1,4–2,9 % (HATTEMER et al 1977, TAMM et al 1974). Unfertilized pines had 1,1–1,6 % nitrogen.

Figure 3 indicates a difference in levels of sulfur and ammonium nitrogen between green and necrotic needles from April. Fluoride levels are equal for both kinds. They are lower than the limit value, 50–60 ppm, at which injury has appeared on pines at other places in Sweden, where fluoride has been considered to be the main cause of injury (KVIST 1975). The nitrate content is too low to be measured with the used technique (PAUL & CARLSON 1968). For the September samples another method was used (BAKER & SMITH 1969).

Figures 4a and 4b show the results from the September samples from sites comparable to the April samples. The total nitrogen content is higher in the exposed sites than in the control. The level is also higher in current year's needles than in older needles, which is a normal condition (ARONSSON et al 1977). The levels of sulfur, fluoride, ammonium and nitrate are at all sites on a level comparable to the control. Neither can any difference be seen between needles of different ages for any of these substances.

The April samples had higher levels than the September samples at the exposed sites of all the substances, sulfur, fluorine, total nitrogen, nitrate and ammonium. The largest difference is noted in the nitrate values, which are about ten times larger at the most exposed site, than at the other sites.

All the three elements, sulfur, fluorine and nitrogen occur in the factory's emissions. The levels of all of them are enhanced, clearly connected with the degree of exposure of the sampling site. They were also higher in the spring, closer in time to the cause of the injury than later in the growing season, which indicates an involvement in metabolism or leaching.

Though all the investigated substances show elevated levels, none of them is enough in excess to clearly indicate the cause of injury. We found it impossible from the result of the chemical analysis to trace the main causal agent. For which pollutant is the possibility greatest to get an accidental emission, which in connection with unfavourable weather conditions can reach phytotoxic levels? There are small possibilities to get high irregular emissions of sulfur or fluoride compounds at this factory with its technical equipment and the raw materials that are in use. The cause is probably to seek among the

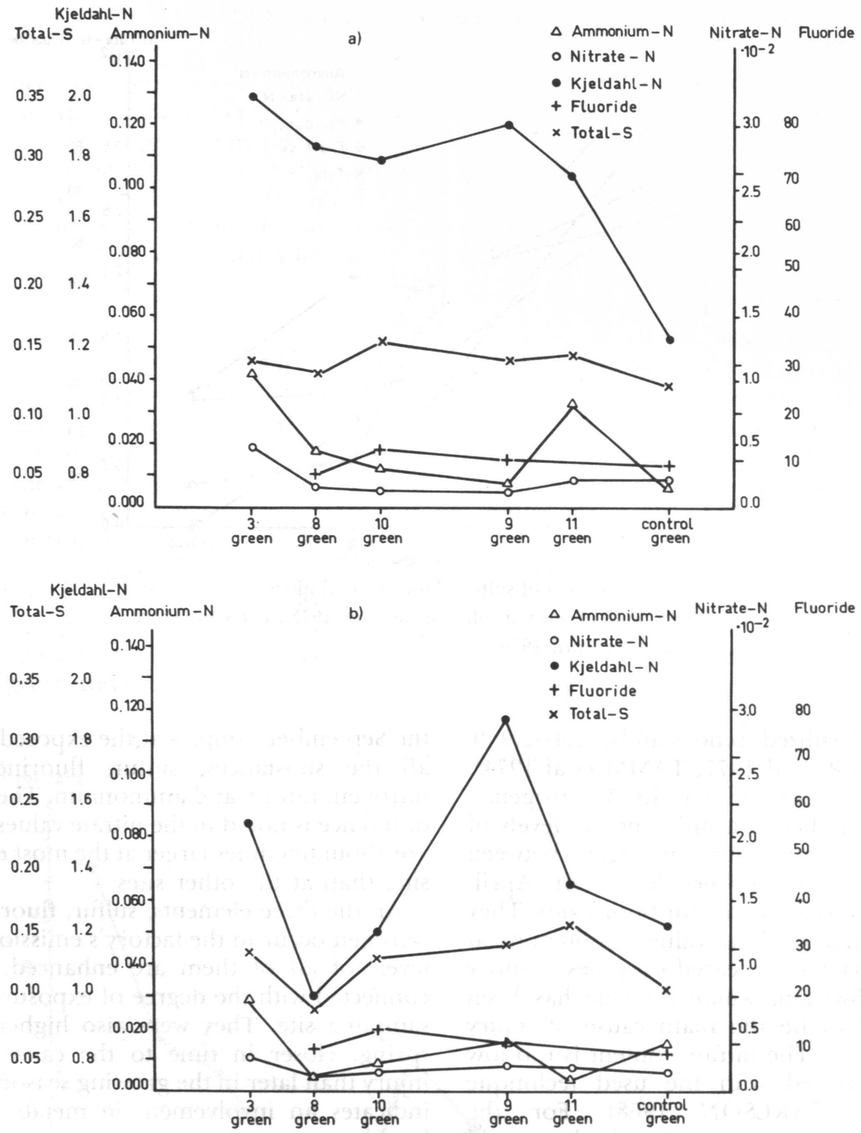

Figure 4. Content of sulfur, fluoride, total nitrogen, nitrate and ammonium of a) current year's pine needles (1979), b) one year old pine needles (1978. The samples were taken in September 1979.

nitrogen compounds, such as nitrogen oxides, ammonia or ammonium nitrate. These can be released in large amounts at start-up procedures or disturbances in the operation of the factory. As a possible agent has also been mentioned ammonium sulfate aerosol, as a product of chemical reaction in the air, when plumes of ammonia and sulfur dioxide meet.

To decide the cause of injury can be difficult when the visible symptoms appear only a long time after the actual incident occurred. The problems encountered are most pronounced when the cause is to be sought among substances, that take part in the metabolism or that are easily leached out. That includes many of the more commonly appearing pollutants. In this particular case nitrogen and sulfur take part in the normal metabolism. Fluorine has been considered to be rather stable in the plants once it is accumulated, but recent reports indicate that it is removed from the plant to a great extent when exposure ceases (NISANCIOGLU & DAVISON 1980). Continuous monitoring could diminish the problem as well as regular use of some bioindicator technique. Techniques useful for this purpose could be chemical analysis of pine needles, of transplanted lichens or transplanted Vaccinium shrubs. Samples should be collected at regular time intervals. These methods would reveal the incidence at an earlier stage than the natural vegetation does when metabolism is low during the winter.

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