

SOME EFFECTS ON SWEDISH GROUNDWATERS FROM DIFFUSE POLLUTING SOURCES ILLUSTRATED
BY DATA FROM THE NATIONAL GROUNDWATER MONITORING PROGRAM

M. AASTRUP and G. PERSSON

Geological Survey of Sweden, Uppsala, Sweden

ABSTRACT

The paper presents the groundwater monitoring program executed by the Geological Survey of Sweden in cooperation with the Swedish Environmental Protection Board. One of the main aims of the program is to study the effects of diffuse pollution by precipitation and land use.

Using data from the monitoring program as a background, some pollution problems are discussed.

One of the most serious environmental problems in Sweden is the acidification of natural waters. The acidification has mainly struck surface waters, but effects on groundwater have been reported. The problems are expected to increase in the future.

The effects of the use of fertilizer in farming and forestry, as well as changes in groundwater quality due to clear-cutting of forests are also discussed briefly.

THE GROUNDWATER MONITORING PROGRAM OF SWEDEN

As a contribution to the IHD, the Geological Survey of Sweden (SGU) started to establish a national groundwater network in 1966 (ref. 1). Within this network variations in groundwater level, temperature and chemistry are recorded. In 1978 the Environmental Monitoring Program of Sweden (PMK) was established (ref. 2). This program includes monitoring of the atmospheric, terrestrial and aquatic environments. It is executed by the National Swedish Environmental Protection Board in cooperation with other national authorities. Within the aquatic program of the PMK, the monitoring of groundwater is executed by SGU as a part of the chemical program of the groundwater network.

The network for groundwater chemistry consists at present of 106 sampling stations all over the country (see Fig. 1). The stations represent different geological and climatological environments. Each station is sampled 2 - 6 times a year. The measurements include sodium, potassium, magnesium, calcium, aluminum, iron, manganese fluoride, chloride, nitrite, nitrate, ammonium, sulphate, pH, alkalinity, conduc-

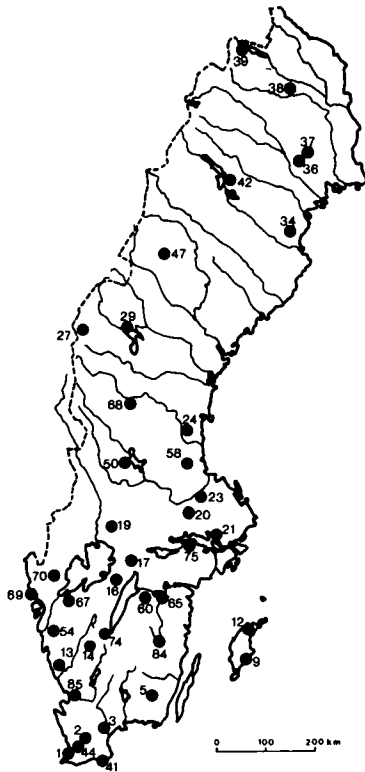


Fig. 1. Areas with stations for groundwater sampling in the groundwater network. Some dots represent more than one station.

tivity, redox potential, oxygen, tritium and temperature. At some stations more elements, e.g. certain metals, are included in the analysis program. All data are stored in a computerized data base system.

POLLUTION OF GROUNDWATER BY PRECIPITATION AND LAND USE

One of the main purposes of the groundwater monitoring program is to discover and study polluting effects, mainly of regional character, on groundwater. Such regional effect can be expected as a result of atmospheric transport of pollutants or extensive changes in land use.

Acidification of surface waters

One of the most serious environmental problems in Sweden in recent years is the acidification of natural waters. The waters of a great number of lakes in different parts of the country have become more and more acid. In some cases this has caused the extinction of fish in the lakes. The acidification of the lakes is most pronounced in areas with acid rocks and a thin layer or no layer at all of covering unconsolidated deposits. Such areas are however extensive in Sweden. It is assumed that the main reason for the acidification is the burning of fossil fuels, which has brought large quantities of sulphuric acid to the atmosphere.

To try to prevent further damages to the lakes, restrictions for the burning of fuels rich in sulphur have been made. However, measures only inside Sweden cannot solve the problem, as the amount of sulphuric acid received from abroad through the atmospheric circulation is larger than the amount released from the chimneys inside Sweden.

Acidification of groundwater

During the last five years the eyes of many Swedes have been focused on the problem of acidification of groundwater, and especially during the last year the

newspapers have had frequent reports on the subject. It often seems however, as though groundwaters that are acid for other natural reasons than acid precipitation are the sources of concern and excitement. The lack of data from the past might be a reason. Whenever somebody measures the pH of a groundwater and finds that it is on the acid side of the neutral point, he or she gets alarmed and blames it on the acidification process caused by the acid precipitation. A pH measurement made ten years ago, in the same groundwater body might have shown the same result.

Within the groundwater network there are a number of stations, which are suited for showing effects of acidification. This means that the aquifer consists of coarse unconsolidated material, not covered by clay. The material originates from granitic or gneissic rocks, thus giving a low buffer capacity. The hydraulic conductivity is high and the residence time low.

Today there are time series of a little more than ten years from many stations. Not from one single station included in the chemical program of the groundwater network, there is a decreasing trend of the pH values.

In the southern part of Sweden there are however some stations with a more or less pronounced increasing trend of sulphate, probably caused by the acid precipitation. Where these sulphate trend occur, so far, we can find two patterns of evolution in time of the chemical constituents calcium, magnesium, alkalinity and pH in the groundwater, depending on whether the soil is rich in carbonate or not.

This is illustrated by data from two stations in southern Sweden. In fact these are the stations which most clearly show the effects of acidification. The bar graph diagrams in Fig. 2 show the trends of some parameters important to the interpretation of the acidification process. The data presented in Fig. 2 comes from a station situated 40 km inland from the west coast of Sweden (Djurarpsdalen station 1). The aquifer is a glaciofluvial sand, and the underlying bedrock consists of gneiss. The area is very poor in lime.

The sulphate content is increasing until 1976 when there is a depletion of the concentration. Calcium shows very much the same pattern, while the magnesium content increases throughout the period. The alkalinity is very steady. The pH values fluctuate a little, but no increasing or decreasing trend can be noticed.

In this case, where there is a catchment area poor in lime (calcium carbonate), there still is an ion exchange between hydrogen ions from the acid precipitation and magnesium and calcium, which are available in other forms than as carbonate. This ion exchange causes the stability of pH and alkalinity.

In case of an area rich in calcium carbonate, the acid precipitation percolating the soil and aerated zone, dissolves the carbonates giving an increasing alkalinity as well as increasing calcium and magnesium concentrations. This is shown in Fig. 3. The pH values are very steady (not shown in diagram). The station (Rövarekulan station 1) from which the data derive is situated in the sedimentary rock area in Scania, southernmost Sweden. The aquifer is an unconsolidated sand.

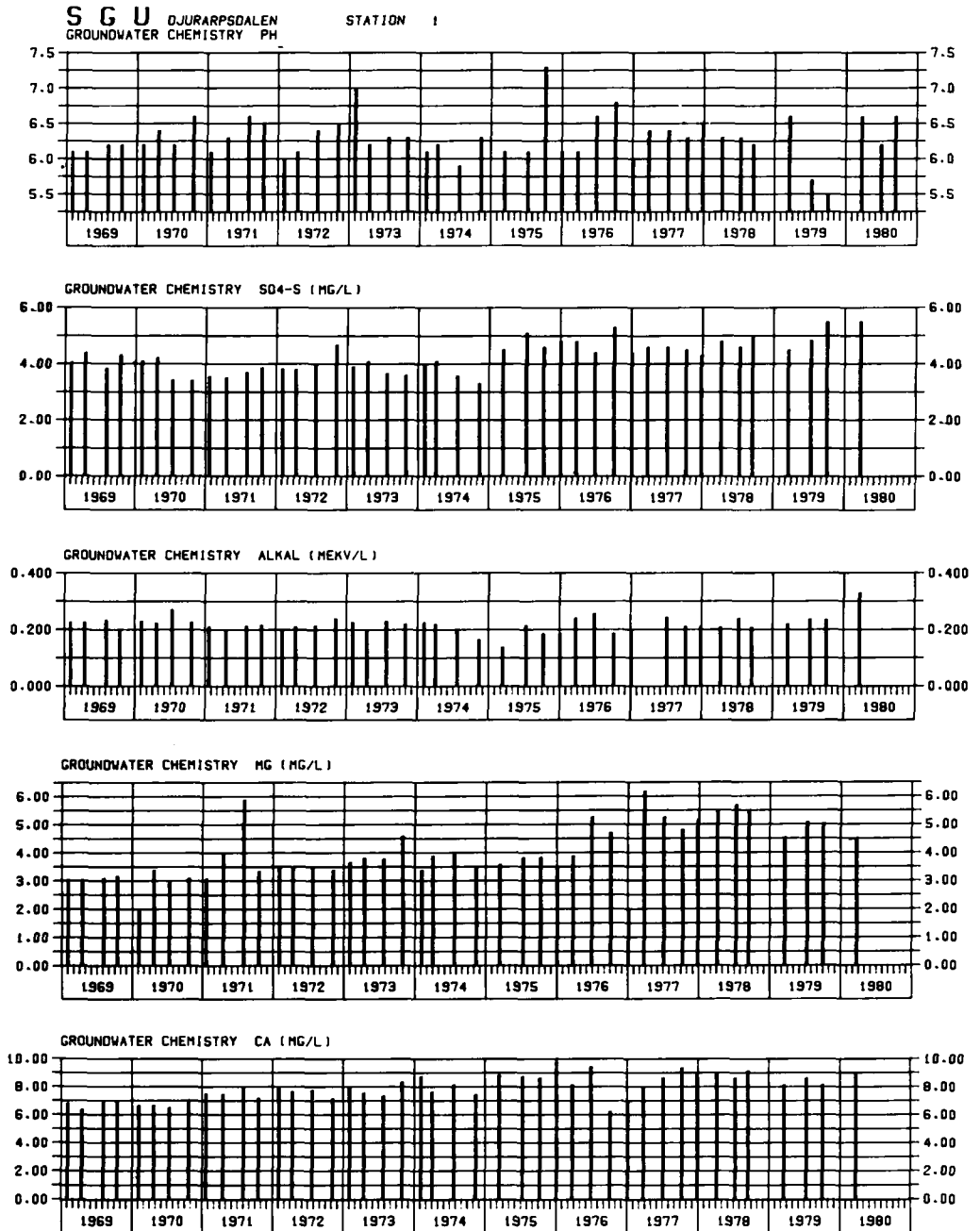


Fig. 2. Diagrams showing time series of pH, sulphate, alkalinity, magnesium and calcium from a groundwater station in an area poor in carbonates.

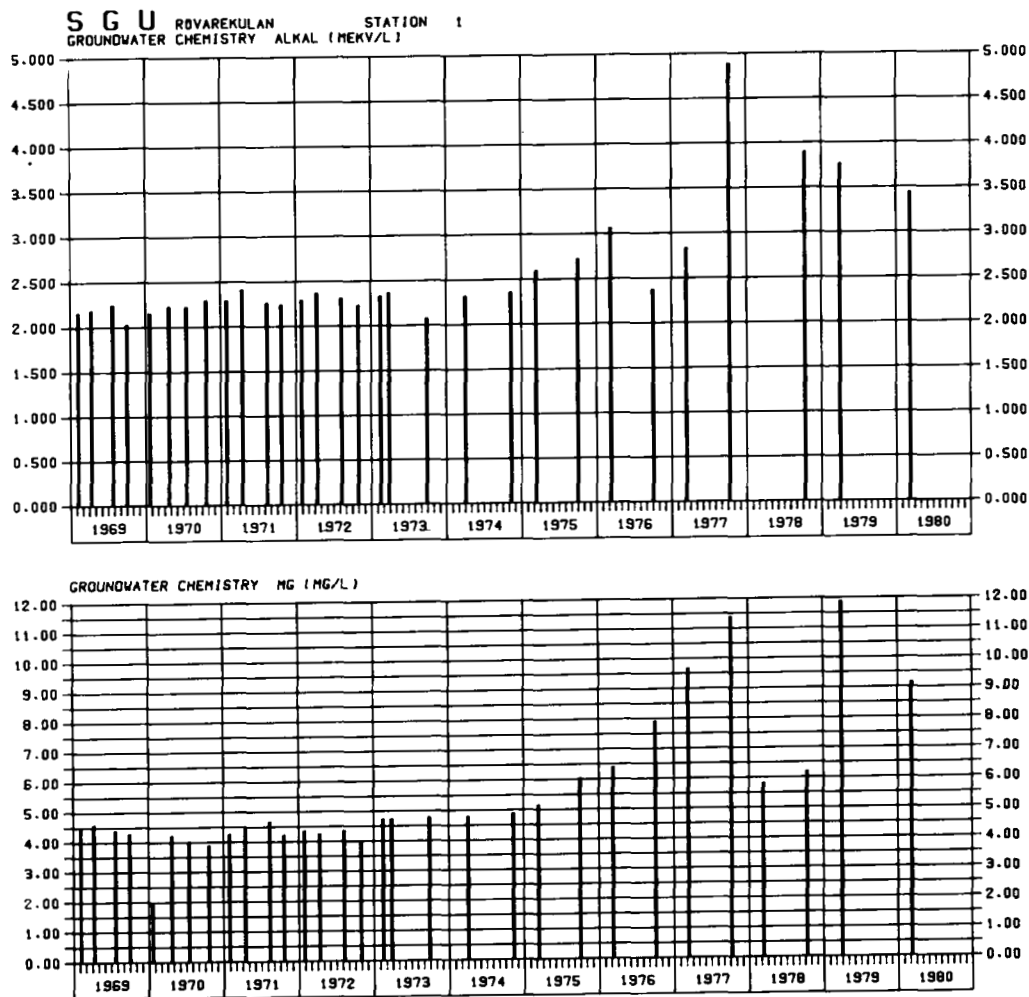


Fig. 3. Diagrams showing time series of alkalinity and magnesium from a groundwater station in a carbonate rich area.

Even if there are until now evidence only of effects of the acid precipitation on the groundwater, such as shown above, and no real acidification in the sense of decreasing pH at the stations of the groundwater network, the "problem" cannot be neglected.

It has been shown by other workers that in areas with very low buffer capacities on the westcoast there are very acid groundwaters with high concentrations of heavy metals. This is in fact the part of Sweden with the heaviest subsidence of acid matter and precipitation.

Generally it seems however that at present the buffer capacities of the soils

are sufficient to keep the pH level steady.

Farming and forestry

Farming and forestry influence extensive areas in Sweden. The changes in methods and development of new techniques, thus may effect e.g. the groundwater condition over large areas.

The increasing use of fertilizers in farming during the last decades has led to some changes in water quality. Most of the cultivated soils in Sweden consist of clay, which as a rule gives good protection to the aquifers beneath. However, in minor areas with sandy soils the groundwaters have been influenced to a certain degree. Generally the nitrate content has increased, but as a rule not to a degree rendering the groundwater unsuitable for consumption. Rising trends are however known and in some areas concentrations of nitrate above 50 mg/l are recorded. The example given in Fig. 4 is from a station in the groundwater network situated within an area in southwestern Sweden, where problems with high and rising nitrate content in the groundwater are rather common.

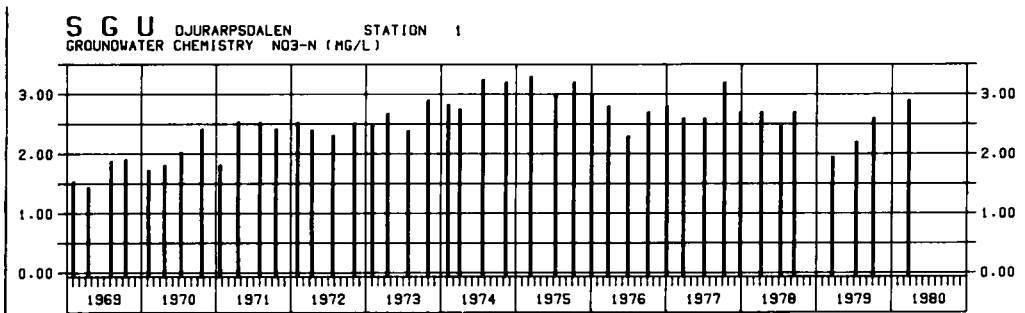


Fig. 4. Changes in nitrate (NO₃-N) content in groundwater of a partly cultivated sand and gravel deposit in south-western Sweden.

Also in forestry the use of fertilizers has increased. Effects on groundwater have been reported, although the recorded increases in nitrate concentrations are relatively small. Clear-cutting of large forested areas also cause a small rise in the nitrat content of the groundwater, due to decay of organic material, and lack of plants consuming the released nitrate. An example of this is shown in Fig. 5.

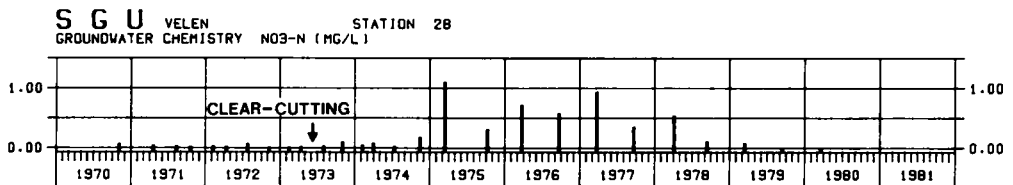


Fig. 5. Changes in nitrate (NO₃-N) content in groundwater due to clear-cutting of the forest around the sampling station.

REFERENCES

- 1 L. Nordberg (Ed), The National Groundwater Observation Networks of the Nordic Countries, Nordic IHP Report No 3, Oslo, 1980, p.23.
- 2 C. Bernes (Ed), The Environmental Monitoring Programme in Sweden, National Swedish Environment Protection Board, Bulletin 1327, Solna, 1980, p.48.