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GROUND WATER POLLUTION BY ARSENIC

A-C. ANDERSSON and C. GEDDA
the KM GROUP, Kjessler & Mannerstråle AB, Gothenburg, Sweden.

ABSTRACT

An acid-arsenic sludge mixed with lime have been deposited in a landfill. To check the ground water quality shallow pipes were used for sampling. When an increased arsenic content was indicated by this sampling, boreholes were drilled which allowed sampling of soil and water at every meter throughout the 15 meter thick layer of sand. The arsenic content of the ground water was a maximum of 2890 mg As/l and the lowest pH was 1.2. The polluted water moves along the bottom of the aquifer. To reduce the polluted area ground water is pumped up for further treatment. For future checks on ground water multi-level monitoring pipes have been installed.

INTRODUCTION

An industrial waste which mainly consists of an acid-arsenic sludge mixed with lime has been deposited in a landfill situated in Sweden. The ground water quality has been checked since 1974 by samples from check pipes. These are 3 m long 2 inch pipes which penetrate only the upper part of the aquifer, Fig.2. In the beginning of 1979 the concentration of arsenic suddenly increased in the check pipe no I about 250 meters from the landfill. An hydrogeological investigation of the area around the landfill was started in May 1979, to explain the increased arsenic content.

HYDROGEOLOGICAL INVESTIGATION

To determine the geological structure and the status of the ground water a total of 19 boreholes were drilled around the landfill Fig. 1. Two-inch perforated pipes were driven through the entire aquifer of the quaternary deposit. Soil and water samples were taken at every meter. The soil samples were sieved and examined visually. Water samples were analyzed for pH, As and Cl. A typical result is shown in Fig. 4.

GEOLOGY AND HYDROGEOLOGY

The ground consists mainly of a 10-17 m thick layer of fine sand. Underneath the sand is a thin layer, mostly less than 1 m, of boulder clay overlying the sedimentary rock of stratified siltstone and claystone. The geology of the area is shown in Fig.2.

The geological formations constitute two different aquifers. The sand layer forms an upper unconfined aquifer and the sedimentary rock forms a confined aquifer. They are separated from each other by the lowpermeable layer of boulder clay.

The water table is about 2 meters below ground surface. The main ground water flow is to the sea, Fig. 1. One of the boreholes allows monitoring of the piezometric pressure of the confined aquifer. The pressure at this point is about 0.4 m higher than the water table at the same place.

The sand, which is very homogeneous, has a hydraulic conductivity of about $2 \cdot 10^{-4}$ m/s and a transmissivity $T \approx 3 \cdot 10^{-3} m^2/s$. The boulder clay has a very low hydraulic conductivity.

POLLUTION

The first sign of contamination of the ground water was that the arsenic content of the water in one check point increased from 0.6 to 88 mg As/l within 4 months, Fig. 3. Our investigation with sampling at several levels gave a more detailed picture of the polluted area.

The highest arsenic concentration was 2890 mg As/l and the lowest pH was as low as 1.2. High As-concentration were usually coupled with a low pH. The highest As-concentration was observed in the lower part of the unconfined aquifer and the polluted water seemed to move along the bottom of the aquifer like a dense mass. At one point the As-concentration could, at different levels, range between the detection limit, 0.01 mg As/l, and more than 2000 mg As/l.

The size of the polluted area is about 500 x 500 meters and the total mass of As in the unconfined aquifer has been estimated at about 80 tons.

The results of the investigations are presented in the vertical sections in Figs. 5 and 6. These sections show the values of the As- and Cl-content and the pH. The location of the sections can be seen from Fig. 1. From the sections it can be observed that the area is probably polluted from two different sources. One is the landfill. The other is situated somewhere between boreholes 3 and 12, and was found to originate from an accidental discharge during the winter of 1978/79. It was probably this pollution which caused the increased As-concentration in one of the old check pipes in the beginning of 1979.

MOVEMENT OF THE POLLUTED WATER

Due to the high content of dissolved solids the density of the pulluted water is greater than that of natural ground water and therefore it moves vertically in the aquifer as well as horizontally with the ground water flow. The velocity of the polluted water is difficult to calculate from available information because the starting point of the leachate is not known. From regular observations it is evident that the pollution (As) moves noticeably Figs. 3 and 7.

In Fig. 5 the contaminate can be observed reaching the sea. An upward flow due to different densities seems to force the pollution towards the water table before the outflow to the sea. The salt water edge acts as a barrier and prevents the main part of the polluted water from reaching the sea. Instead it moves along the coast.

POLLUTION MONITORING SYSTEM

To check the movement of the polluted water in the future, water samples can be taken from the 19 exploration pipes. These pipes are only perforated half a meter in the bottom and therefore cannot allow sampling from several different levels. To allow this type of sampling multi-level monitoring wells were installed. They consist of 2-inch fully screened plastic-pipes Fig.7. Water sampling is performed by a submersible pump (Ø 30 mm) equipped with inflatable packers above and below the intake.

MEASURES TO REDUCE POLLUTION

It is of great importance to stop the movement of polluted ground water along the coast. Multi-level sampling showed that the concentration of arsenic increased rather quickly at the boundary of the polluted area.

To reduce this unwanted flow of polluted water it was decided to pump up contaminated ground water for further treatment. Four 2-inch wells with a 2-meter screen at the bottom of the unconfined aquifer were installed and have been pumping since July 1980. The discharge rate is about 6-10 m^3/h. The concentration of As in the discharged water has decreased from 800 mg As/l to 400 mg As/l during four months. During this time about 9 tons of arsenic have been removed from the aquifer. The result of this measure is shown in Fig. 7. The As-concentration has decreased from about 1000 mg As/l to 1 mg As/l in four months in a monitoring well just beside the pump gallery.

Fig. 1
Plan

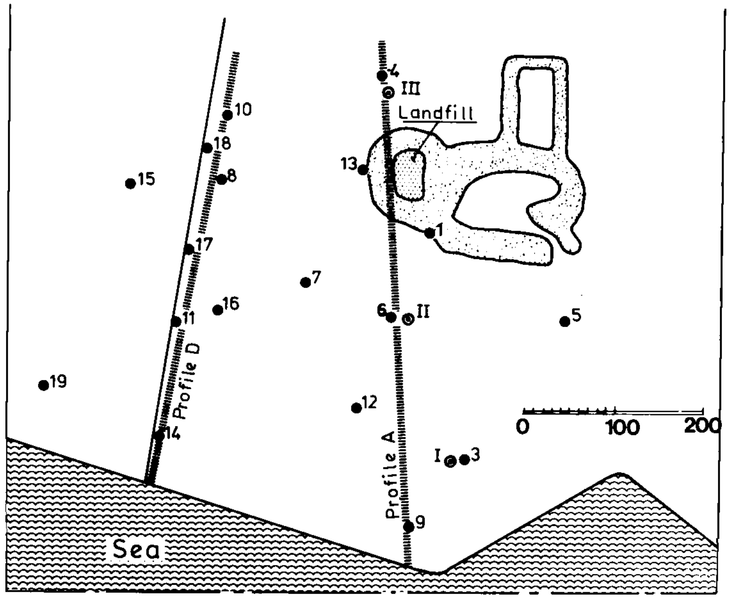


Fig. 2
Profile A

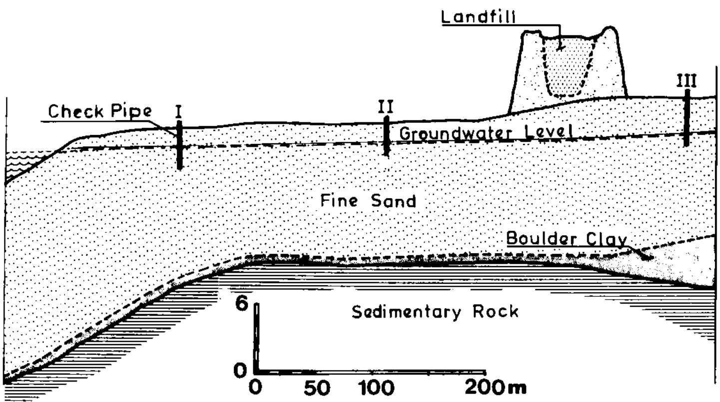
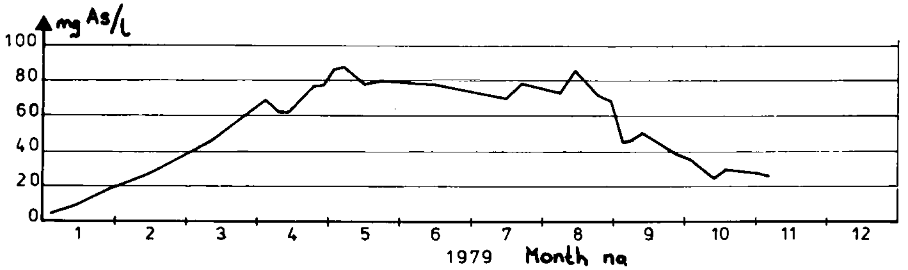


Fig. 3
Check Pipe I



depth, meter below ground	pH	As (tot) mg/l	As (dis) mg/l	Cl^- mg/l	k 10^{-4} m/s
2.2-2.7	5.4	35	8.5	67	3.0
3.2-3.7	6.6	4.6	0.7	99	2.3
4.2-4.7	5.9	11	0.7	265	2.6
5.2-5.7	5.9	11	0.6	316	2.0
6.2-6.7	5.8	85	15	379	2.0
7.2-7.7	4.3	800	720	435	2.0
8.2-8.7	4.1	1020	940	407	2.0
9.2-9.7	3.8	950	930	468	2.3
10.2-10.7	4.0	2060	1850	634	2.3
11.2-11.7	5.5	2310	2020	951	2.3
12.2-12.7	5.6	1380	1030	1045	-

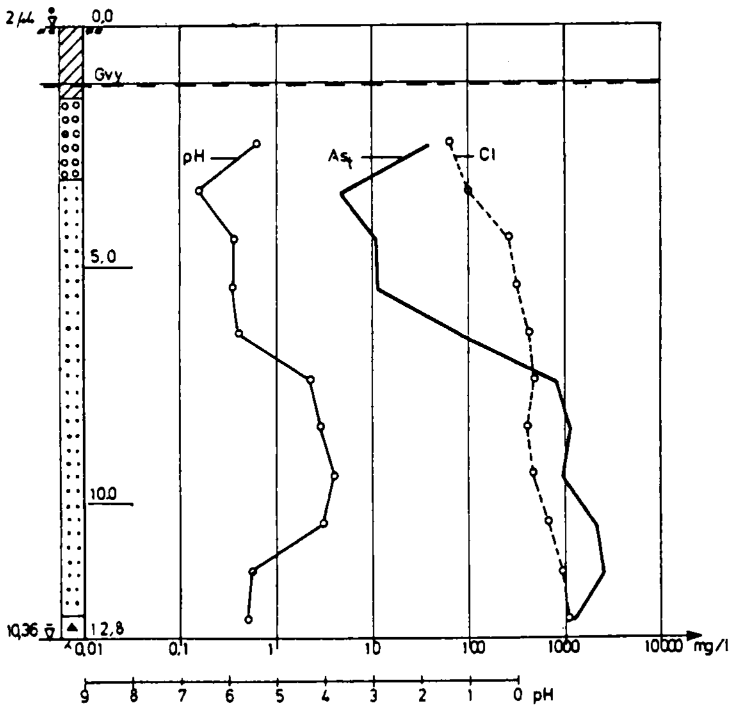


FIG 4. A typical result from the investigation.Borehole no 7.

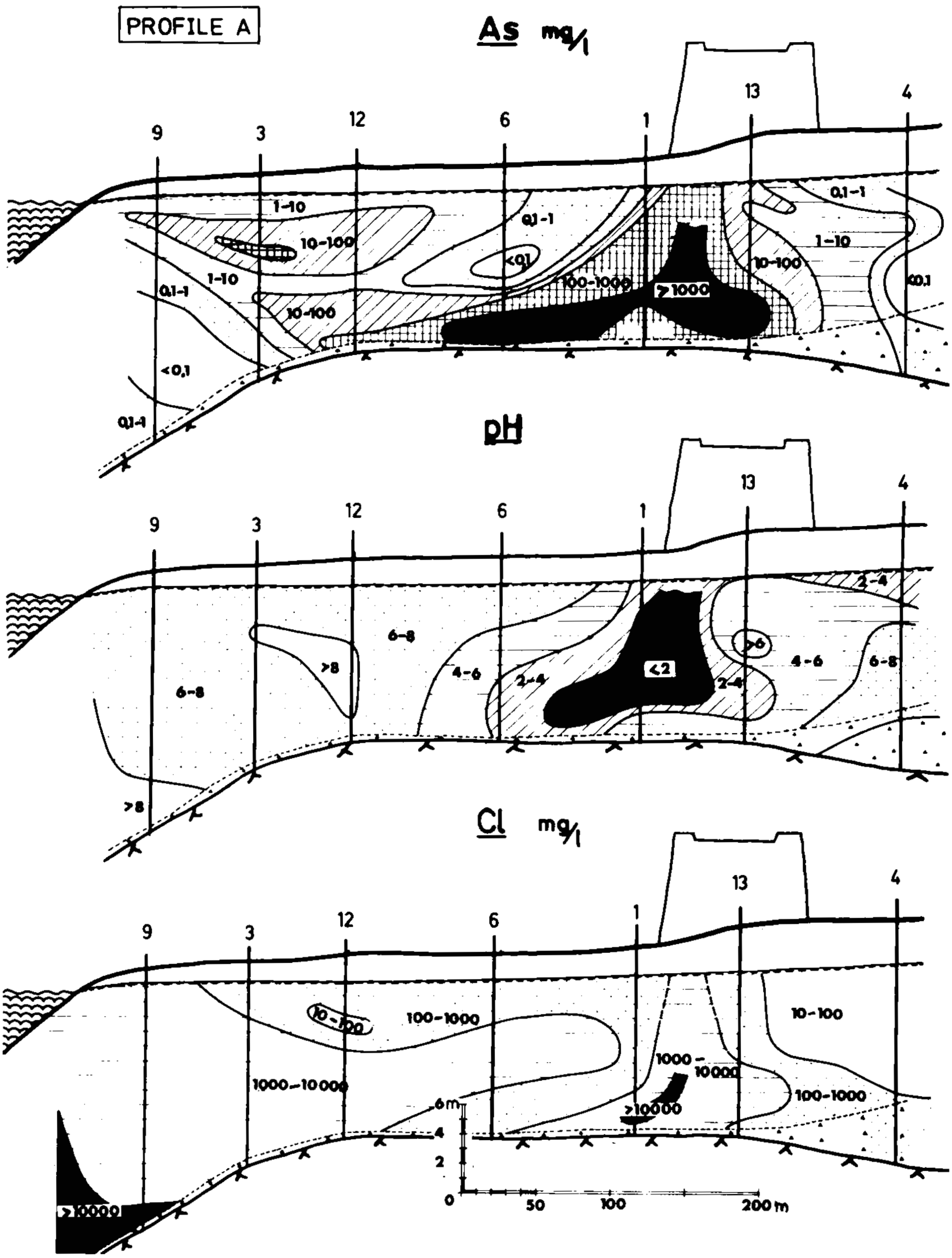


FIG 5. Profile A.

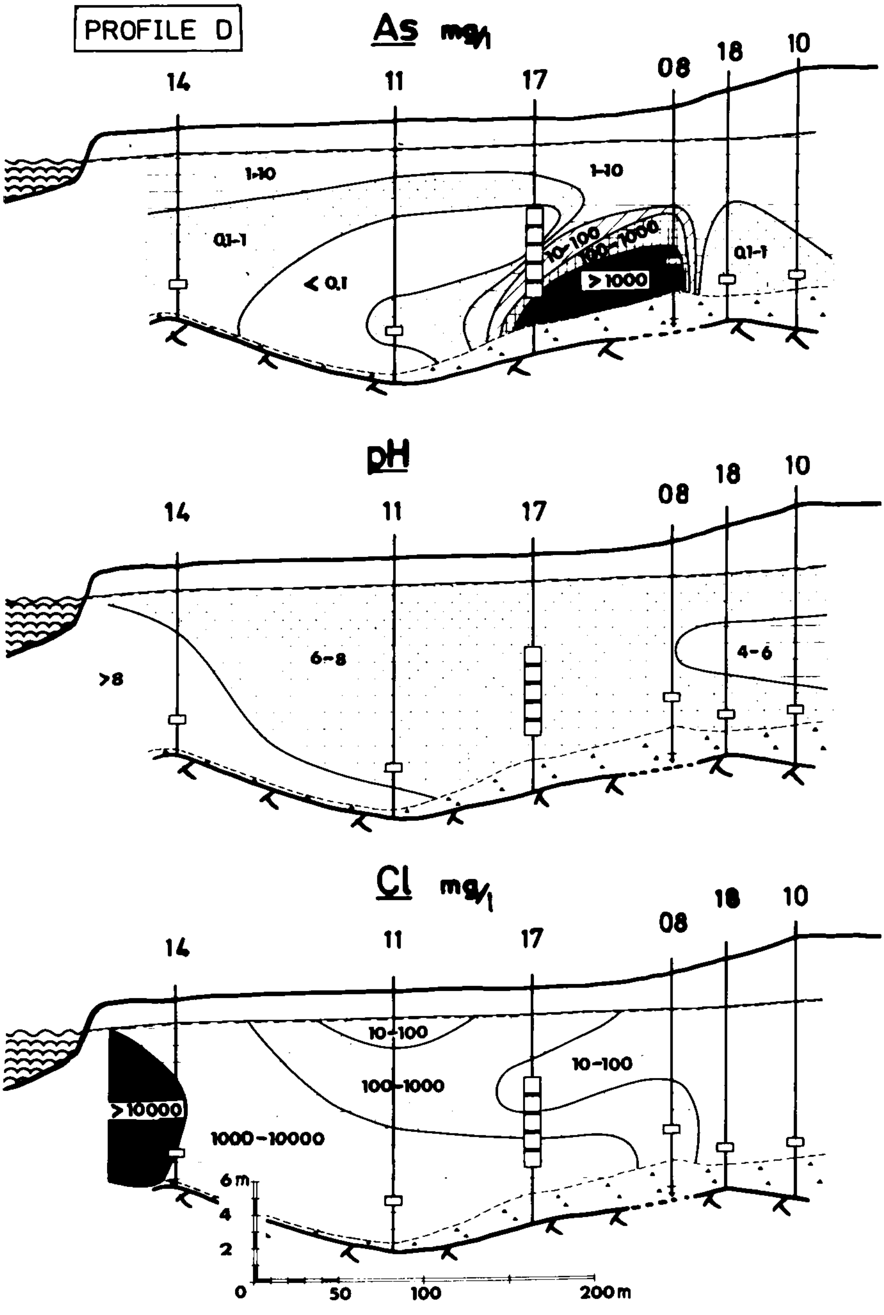


FIG 6. Profile D.

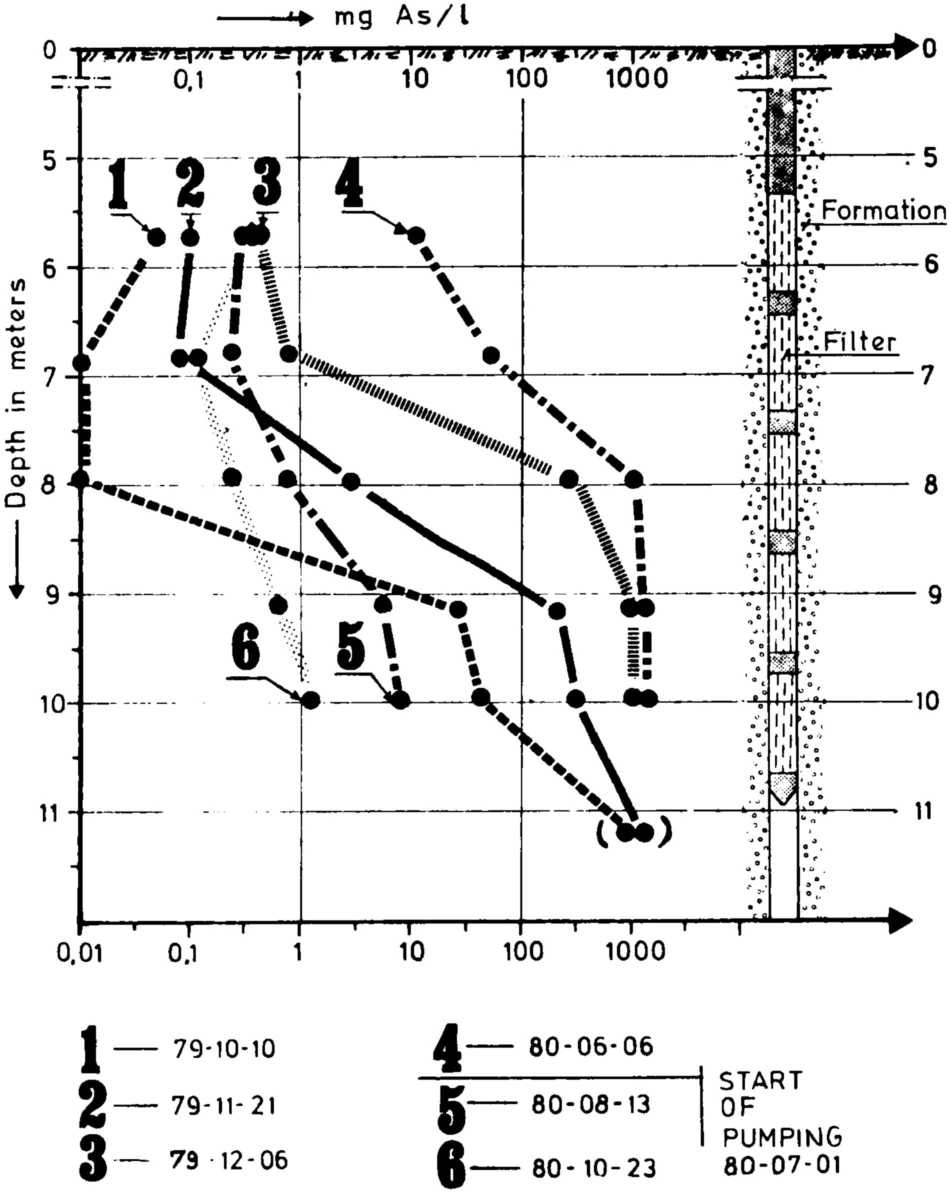


FIG 7. Results from the multi-level device no 17.