

APPLICATION OF GEOPHYSICAL METHODS TO LOCALIZE FARMING POLLUTION

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ABSTRACT

In recent years large agricultural production complexes are being built in Czechoslovakia; due to insufficient geological survey, to the lack of technological discipline in operating productional and storage equipment, etc., harmful substances may sometimes leak into ground waters and consequently contaminate them. Therefore, considerable financial means are being devoted in Czechoslovakia to liquidate the consequences of contamination and to elaborate effective preventive measures. This paper contains a summary of some of the results of research and of verifying the methods, which would enable the extent of the pollution to be determined quickly and reliably without a substantial increase of expenses in building agricultural complexes.

INTRODUCTION

The sources of farming pollution may, in general, be divided into two basic types : extensive /regional/ and local.

As regards the e x t e n s i v e type, the pollution of sources of ground waters and of the geological medium is due to the incorrect selection of types and amounts of fertilizers and chemical substances, used to increase agricultural yield. The harmful substances then migrate into the ground waters via the vegetational and soil cover. Apart from the extensive area, usually a low concentration of harmful substances is characteristic for this type of pollution, the source of the pollution as well as its localization and its activity pattern being known. The liquidation of the source is based on terminating or changing the use of the contaminants involved.

As regards the l o c a l type, usually emergency leakages of waste products of agricultural production and of substances used in

agricultural production are involved. The source of the contamination is limited in area, but the places of leakage of contaminants frequently cannot be localized exactly; they are usually generated randomly. In comparison to the first /extensive/ type, the number of kinds of contaminants is usually considerable /fertilizers, manure, silage juices, oil products, plant protection chemicals, etc./. The quasi-point one-time concentration of contaminants is usually quite high.

In the years 1978-80, an original geophysical method for determining the extent and investigating the process of farming contamination of ground waters of the second /local/ type was developed and tested by GEOFYZIKA Brno, N.C., Prague subsidiary. The results of the geophysical measurements were compared with the results of hydrochemical investigations. The main reason for verifying the usability of the geophysical methods is their high degree of operativeness, relatively good reliability and, particularly, low costs.

In analysing a number of cases of emergencies not only in agricultural, but also in industrial installations, we came to the conclusion that it was necessary to make an estimate of the **d a n g e r z o n e** already during preparation of the project. This zone can be defined as the region of contamination of ground waters which occurs over a certain period after the emergency in the projected installation. Knowing this zone not only enables the locality for the installation to be selected reliably, but also enables an efficient signalling system to be designed, emergency plans to be drawn up, etc. In an ideal case, the time pattern of the contamination can already be estimated during project preparation, together with the effectiveness of sanative measures.

The research work concentrated on developing a complex of effective geophysical methods, because mere geological survey would increase the expence of building most agricultural installations. The methods were tested at the locality of Maletín under conditions which are typical of most of the Bohemian Massif with extensive occurrences of crystalline rocks. The pilot locality is characterized by shallow circulation of ground waters with a predominantly fracture-type permeability. The depth of the ground water level is about 1.0 - 1.5 m below the surface. Morphologically this territory is of intermediate vertical division /hills/. In the neighbourhood of this locality there is also a considerable number of farms specialized in animal production.

RESULTS OF RESEARCH AND TEST WORK

The Maletín Farm is situated on a morphological elevation at about 550 m above sea level. In building it, measures were taken /flumes, insulated holders, etc. were built/ to eliminate, or at least minimize the contamination of ground waters. Nevertheless, it was found that the potable water in the neighbourhood of the investigated locality had been contaminated. This called for the problem of the origin of the pollution, as well as of the protection of ground waters against pollution to be solved.

For this purpose a complex of surface geophysical methods, supplemented by laboratory measurements, was selected. The methods were concentrated on direct and indirect identification of the contaminant and on determining the extent of the pollution.

Direct detection

Direct detection requires the physical properties of the contaminated medium to differ from the physical properties of the same medium not affected by the contaminants. The possibility of detection will be the higher, the larger the difference in the physical properties of both media and the more accurately these properties can be determined geophysically. For direct detection we selected the fluid-resistivity method and geothermics. Whereas the former was successful, perturbing effects /viz. geological/ prevailed over the effect of increased thermal energy of the contaminant in the latter results.

The fluid-resistivity method, i.e. the direct measurements of the resistivity /or conductivity/ of ground or surface water, was applied everywhere in the farm area and its neighbourhood where it was possible. The resistivity of the contaminated water /20 - 40 ohm.m/ was at least 1.5 to 2 times less than that of the uncontaminated water /about 60 ohm.m/. The fluid-resistivity isolines clearly indicate the direction of propagation of the contamination.

Indirect detection

The indirect detection was founded on the assumption that the pollution substances would mostly move in a medium characterized by minimal hydraulic resistance. Therefore, the geophysical survey concentrated on investigating increased thicknesses of the overburden, weathered zones, tectonically disturbed rocks, zones with increased occurrence of fractures or porosity, the direction of flow of ground

waters, etc., i.e. on the localization of such places and zones in which an increased accumulation and migration of ground water and/or of contaminants can be anticipated. Only surface geoelectrical methods were selected for indirect detection, because the presence of the contaminant in the rock medium, as well as the increased accumulation of ground waters /contaminated and uncontaminated/ is reflected in anomalously decreased resistivities /both real and apparent/ of the medium. Of the geoelectrical methods, resistivity methods were applied successfully, in particular vertical electrical sounding and symmetric resistivity profiling, as well as the "mise-a-la-masse" method /ref.1,2/. The results of the other geoelectrical methods, viz. spontaneous polarization and the "very-low-frequency" method, although their application was theoretically justified, were irreproducible at the investigated locality due to insuppressable perturbing effects.

The r e s i s t i v i t y methods were used to differentiate metamorphites, forming the fundamental geological formation of the locality, according to their resistivities down to depths of about 50 - - 100 m. Undisturbed metamorphites display resistivities of the order of thousands ohm.m. In weathered, water-bearing or tectonically or otherwise disturbed regions the resistivity may decrease even below 500 ohm.m in direct dependence on the degree of disturbance and on the resistivity of ground water. The resistivity of a rock will decrease below 200 ohm.m only if the fractures or pores are more or less saturated by the contaminant or by its solution in ground water. The mathematical model of resistivity sections /ref.3/ was obtained from the results of vertical resistivity sounding with the aid of programmable computers /see profile G in Fig.1 - the existence of the water-bearing and possibly contaminated zone can be detected between the points -15 to 45/. The results of the resistivity methods conform to the results of the fluid-resistivity measurements first mentioned. The mise-a-la masse method in its hydrogeological variant was applied for the purpose of determining the direction of ground water flow. The results of this method are compatible with the results of the two methods mentioned above.

The interpretation of all these geophysical methods was supplemented by l a b o r a t o r y measurements of samples, the dependence between resistivity and porosity being investigated in particular. A statistically significant indirect dependence with a correlation coefficient $r = -0.84$ was proved. This proved that the working hy-

potheses, on which the interpretation of the geoelectrical methods mentioned above was based, were correct.

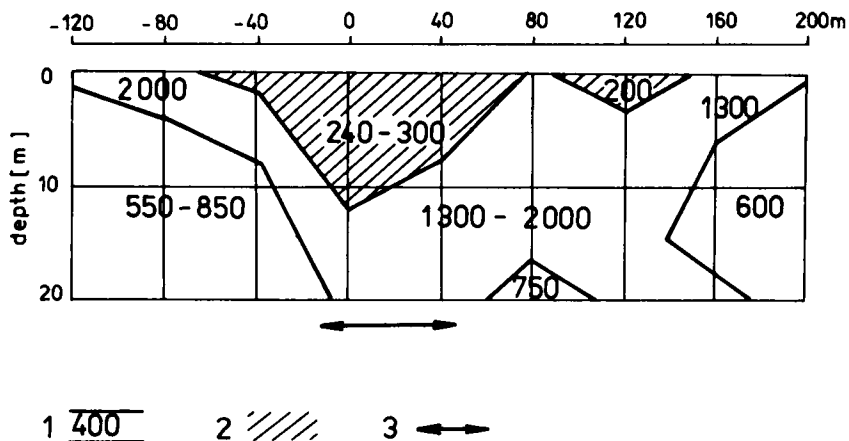


Fig.1. Vertical geoelectrical section after vertical electrical soundings. 1 - geoelectrical layer and its resistivity in ohm.m, 2 - water and/or pollution bearing aquifer, 3 - water and/or pollution bearing zone.

CONCLUSION

Drawing on the complex evaluation of field and laboratory measurements it was possible to determine the extent of the pollution and direction of its propagation. The number of pollution indications was determined by the results of four above mentioned methods. The statistically defined criteria for possible existence of contaminants are : apparent resistivity in symmetrical profiling with current electrodes spacing up to 20 m should be less than 200 ohm.m and with spacing 40 m less than 500 ohm.m, actual resistivity in the results of vertical electrical soundings less than 300 ohm.m, fluid-resistivity less than 20 ohm.m. The higher the number of indications /maximum number is four/ the higher probability of the existence of the contaminants in the geological medium /Fig.2/. The extent of the pollution, determined in this manner, was also proved by independent bacteriological and chemical analyses of ground and surface waters /ref.4/

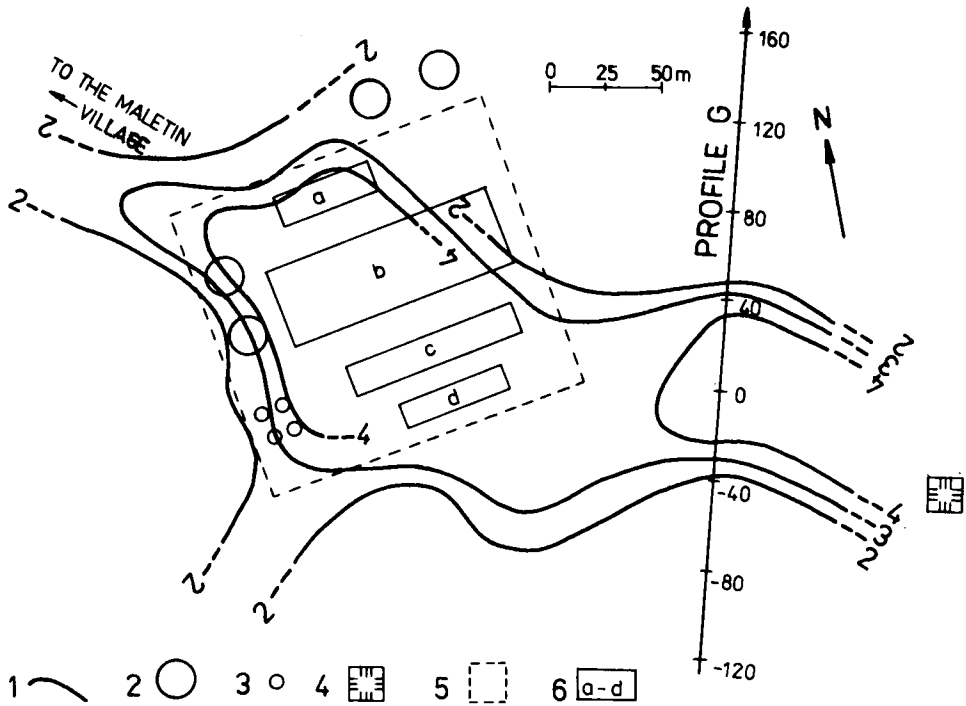


Fig.2. Map of extent and propagation of farming pollution. 1 - isolines of the number of pollution indications, 2 and 3 - liquid manure containers, 4 - river spring, 5 - farm boundary, a to d - farming installations.

A check of the farm installations proved that the cause of the leakage of harmful substances from the farm was the lack of technological discipline. The extent of the pollution and, particularly, its direction of propagation indicated not only danger for water way flowing from the spring east of the farm, but also for the ground waters in the adjacent village of Maletín located west of the farm. As a result of these findings effective sanative measures were recommended.

In general it may be said that the existence of farming pollution /particularly of the local type/ may affect the geoelectrical properties of the rock medium in the neighbourhood of the pollution source. This enables geoelectrical methods to be used successfully, in particular the resistivity methods in modification of vertical electric sounding and/or profiling and fluid-resistivity measurements.

From the list of recommended methods one cannot exclude the other methods either /e.g., the very-low-frequency method, spontaneous polarization and geothermics/, which did not prove successful in the actual medium of the farm investigated, but which may theoretically prove to be successful on other localities.

The reliability of the geophysical interpretation depends on whether data, e.g., on geoelectrical and temperature conditions and fields, which existed in the given area before the farm was established, are available. If these conditions were known, it would be possible to detect the pollution much more accurately than when geophysical methods are applied only after the emergency has occurred.

We recommend, therefore, that a limited volume of geophysical measurements /in a stabilized network of points/, supplemented by the necessary laboratory measurements, be made as part of the project design.

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