Contamination detection

Application of geophysical methods for environmental diagnostics on two contaminated test sites

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A consortium with three partners from different fields of environmental sciences (geophysics, hydrogeology, geotechnics) was formed for a three-year-long project to improve hydrogeophysical methods in order to detect and characterize special subsurface contaminants. Different contaminated sites were chosen in Hungary as study-areas to improve and calibrate special geophysical methods to provide remediation experts and hydrogeologists with necessary information for reliable transport modelling. A strong collaboration between the geophysicists and hydrogeologists evolved protocols and techniques to carry out successful site assessment and remediation schemes of contaminated lands.

This study presents the diagnostic works on two of these test sites: one with ionic and the other one with hydrocarbon contamination. At both sites high resolution geophysical methods were applied in order to give reliable information for site diagnostics and for further hydrogeological investigations. The results of the geophysical measurements were validated by geotechnical methods.

Keywords: resistivity, contamination, hydrogeology, transport modell, non-invasive methods, remediation

1. Introduction

Chlorinated organic compounds and hydrocarbons are among the most serious soil and groundwater contaminants because of their mobility and persistence in the subsurface, their widespread use, and their health effects. Developing and applying reliable and accurate geophysical methods and transport models is greatly needed to assess the risk posed by the plumes of these compounds to the subsurface.

The geophysical investigations had dual purposes: high resolution reconstruction of the underground structure and reliable detection and
characterisation of the contamination. There was a serious expectation from the applied method: they should give reliable and understandable information for hydrogeologists for further examinations and geotechnical experts for planning the remediation. To fulfil these expectations development of conventional measuring methods was necessary. This development concentrated on geoelectrical and IP methods and included improvement both in survey techniques and data processing.

As an advantage of the consortium’s structure the geophysicists got directly the expectations from the end users. The results were immediately applied in further examinations and tested by the environmental expert partners.

This study presents the application of 2-D and 3-D resistivity surveys and ground penetrating radar (GPR) profiling on the test sites.

2. Test Site 1

Site description

The test site is located in Northern Hungary at the bank of river Danube. The area is an abandoned aluminium works. The contamination is concentrated in the gravel aquifer of the ground water. The vertical distribution of the contamination is inhibited by thick clay layer at the depth of 5–6 m. The extreme high conductivity of the contamination refers to high chloride concentration of the ground water. Beside the salt content (mostly natrium, sulphate, chloride, phosphate, and ammonium ions) there is significant toxic metal content as well. The pH value of the ground water is also high: 8–10. The presence of the contamination causes strong increase of conductivity of the upper gravel layer so the application of resistivity measurements was obvious.

Reconstruction of geological structure

At the beginning a 250 m long, 2-D geoelectric profile with inverse Schlumberger array was measured in order to get familiar with the geologic structure. After the interpretation a 3-D resistivity survey was planned on the area. According to the interpretation results the contamination was accumulated in a buried old watercourse and it moves preferably along it (Fig. 1).
Fig. 1. 3-D Resistivity image on Test site 1. The shape of the buried river bed can be recognized (low resistive, light blue) where the conductive acidic contamination accumulates. The resistive uncontaminated gravel is marked with red, the intermediate resistive upper layers are yellow.

1. ábra. 3-D ellenállás kép az 1. tesztterületről. A betemetett folyómeder alakja felismerhető (kis ellenállás, világos kék szín) ahol a jólvezető savas szennyeződés felhalmozódott. A nagyellenállású szennyezetlen kavicsot piros színnel, a közepes ellenállású felső rétegeket sárgával jelöltük.
Fig. 2. Depth slices of a 3-D resistivity image on Test site 1.
The low resistive contamination appears at Depth Level 4. It reaches its maximal concentration at Depth Level 7. The aquifer is free from contamination from Depth Level 9 downwards.

Contamination delineation in 3-D

Consultations with geologists and analysing the geotechnical information of the area the theory of the buried watercourse filled with ionic contamination were proved. At the next phase detailed information was needed from the extension of the contaminated aquifer. From the dataset of combined interpretation of surface 3-D and borehole geoelectric surveys the delineation of the contamination was done in both horizontal and vertical directions. Creating depth slices from the 3-D resistivity images the vertical change of the contamination accumulation in the ground water can be defined: the contamination accumulates in the lower part of the aquifer (Fig. 2).

3. Test site 2

Site description

Test site 2 is located in a flatland in Southern Hungary. The geological structure of the contaminated zone does not show much diversity: sand layers with thin clay intercalations. A damaged pipeline crosses the area causing seriously chlorinated, organic and hydrocarbon contamination either in the subsurface formations or in the groundwater. After an unsuccessful remediation process the spread of the contamination and its compounds were defined from the data of observation wells in 2004. Then a new system of monitoring wells has been implemented in 2006. The monitoring data started flowing in the middle of 2007. Applying all these data a hydrogeological transport model was created to be used during the remediation process.

Hydrogeological investigations

As a first step, a hydrodynamic model was created to describe the main hydrogeological properties of the investigated site. Then, a transport model was elaborated in order to characterize the time movement and the behaviour of the contamination plume. It was revealed that mainly BTEX compounds (Benzene, Toluene, Ethylbenzene and Xylene) were found in the TPH (Total Petroleum Hydrocarbons) contamination. The Processing Modflow Pro program package was used for our simulation activity. The MOCD and RT3-D modules were applied for transport modelling. The initial contamination concentrations in the model were based on the site
assessment results from 2004. The measured concentrations from 2006 and the monitoring data of 2007 were involved to calibrate accurately the transport model. The results of the geophysical interpretations were also utilized to refine the flow as well as the transport model. The derived transport model is able to predict accurately the movement of the investigated contamination plume in space and time for different scenarios. Based on the transport model simulation, Fig. 3 describes the BTEX concentrations at the investigated site in 2008.

Reconstruction of geological structure

Among the non-invasive geophysical methods GPR profiling and 3-D resistivity imaging were applied on the area during the summer of 2006. Eleven parallel GPR profiles were measured in order to reconstruct the underground geological structure. The shielded 250 MHz antennas provided detailed geological information. The structure of the lower regions was mapped after 3-D geoelectrical images.

Contamination detection

The detection of contaminated zones had to be divided into two phases. In phase one the contaminated earth was investigated above the water table. Then in phase two the delineation of the contaminated groundwater was done. The CH contamination caused low resistive anomaly either above or below the water table. In both cases the geophysical results were compared with the data of ground sampling and groundwater analysis (Fig. 4 a, b).

4. Conclusions

Investigations on two test sites proved that applying non invasive geophysical methods the reconstruction of the near surface geological structure and 3-D delineation of contaminated zones can be reliably executed.

The obtained pieces of information provided by the geophysical methods were included into the transport models to predict the behaviour and future movement of the investigated plumes. The advantages and applicability of this new approach are well illustrated by means of theoretical investigations and geophysical and hydrogeological case studies.
Fig. 3. The expected distribution of BTEX by the end of 2008 based on hydrogeological modelling

3. ábra. A BTEX becsült eloszlásképe 2008. végén a hidrológiai modellezés alapján
Fig. 4. Resistivity depth slices above (A) and below (B) the water table. In both cases the contamination accumulation causes low resistive (blue) anomalies. In the case of A geophysical results are compared with chemical analysis of ground samples. At B the isoclines indicate the BTEX distribution based on the data of monitoring wells.

4. ábra. Ellenállás mélységszeletek a talajvízszint felett (A) és alatt (B). Mindkét esetben a szennyeződés felhalmozódás kisellenállású anomáliákat okoz. A esetben a geofizikai eredményeket összehasonlítottuk a talajmintavétel vegyi elemzésének eredményeivel. B esetben az izovonalak a BTEX eloszlását mutatják a monitoring kutak adatai alapján
Acknowledgement

The authors gratefully acknowledge the Bolyai János Research Scholarship program of the Hungarian Academy of Sciences, the Hungarian Research Fund (OTKA T 048329) and the GVOP (GVOP-3.1.1.-2004-05-0187/3.0) for support of this work.

Geofizikai módszerek alkalmazása két szennyezett terület környezeti diagnosztikájához

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A környezettudományok három szakterületét (geofizika, hidrogeológia, geotechnika) képviselő tagokból álló konzorcium jött létre abból a célból, hogy végrehajtson egy három éves projektet, melynek célja a hidrogeofizikai módszerfejlesztés volt bizonyos felszín alatti szennyezódések kimutatására és jellemzésére. Különböző magyarországi teszt területeken zajlott a speciális geofizikai módszerek fejlesztése és kalibrálása abból a célból, hogy a hidrogeológusok és kármentesítési szakemberek megbízható folyadéktranszport modelljeikhez szükséges adatokat kapjanak. A geofizikusok és hidrogeológusok közti erős együttműködés eredményeként eljárások és technológiák kerültek kidolgozásra, melyek sikerre alkalmazhatók a terepi felmérésekben és a kármentesítésben.

A tanulmány ismertet két tesz területen folyó diagnosztikai munkát: az egyik ionos anyaggal, az egyik pedig szénhidrogénnel szennyezett terület. Mindkét helyszínen nagyfelbontású geofizikai méréseket végeztünk annak érdekében, hogy megfelelően megbízható adatokat tudjunk nyújtani a későbbi kármentesítéshez és hidrogeológiai modellezéshez. A geofizikai mérések eredményeit geotechnikai módszerekkel hitelesítettük.