GEOPHYSICAL SURVEY OF A MUNICIPAL WASTE LANDFILL USING ELECTRICAL RESISTIVITY AND INDUCED POLARIZATION METHODS (case history).

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SUMMARY

Abandoned gravel pits have been often used as landfill area for the municipal and industrial waste. From 1971 to 1990 the ancient gravel pit En Colliare (north of the city of Lausanne, western Switzerland) was filled with slags of incineration, garbage from car shredding and municipal waste. The base of the landfill is in its central part close to groundwater table and landfill leachate polluted groundwater and the near river Venoge. Objective of this survey was to test the applicability of the geophysical method at this particular landfill site. Electrical resistivity and induced polarization 2D tomographic survey has been carried out to add quantitative data about the landfill content and its volume. In addition to the photogrammetric data, these results have served for the remediation project of the landfill. Since 2005 a new project has been prepared. The preparatory works have started in November 2008. Induced polarization (IP) method seemed to be more effective than electrical resistivity method due to variable lithological conditions and heterogeneous landfill content. Nevertheless, the combination of both methods proved to be valuable for the assessment of the landfill dimensions.

INTRODUCTION

The first attempt to investigate municipal waste landfill in Switzerland by means of the geophysical methods (d.c. resistivity, induced polarization and magnetic methods) was made on landfill Illiswil (canton of Berne) and landfill Rafz (canton of Zürich) in 1978 (Holub, Scriba, 1979). At that time the purpose of these investigations was to assess what response the different geophysical methods may produce at known landfill sites. All three used methods proved that there was a great potential in such application. The use of induced polarization (IP) method has produced valuable results even in the geological context, where resistivity survey did not give the expected information (Rainone et al., 2003).

The municipal waste landfill En Colliare (canton of Vaud, Switzerland) originated from an ancient abandoned gravel pit (Dubath, 2010). During the period from 1971 to 1990 the ancient gravel pit was filled with slag, car shredding scrap, residua from bio-stabilizer and municipal waste. The contaminant's content in the waste is high (especially for heavy metals) and part of the waste is still in process of degradation. Thus, the gas emanation with a significant methane content is still observed on the surface. Fortunately, only one part of pollutants is mobile and affects the environment. Polluted groundwater from the landfill reaches the near river Venoge. Because of surface-water and groundwater pollution issues the landfill was closed in 1990. According to the Swiss federal law for the environmental protection the landfill site has to be remediated.

The landfill is divided in three areas (Fig. 1): The Butte, an artificial hill with a global volume of 650'000 m^3, the Fosse (volume 28'500 m^3) and the Morlataire (volume 41'500 m^3). In 2006 geophysical investigations were carried out on five profiles located over the three landfill areas. During the excavation works in 2009 the results of geophysical investigations could be verified.

SITE CONTEXT

The local geology consists of the molasse basement (marls and sandstones), overlayed by basal moraine, glacio-lacustrine deposits and glacio-fluvial sediments dominated by coarse-grained gravels and sands. The molasse basement lies underneath 400 m a.s.l. and was not concerned by geophysical investigations. The surface of the landfill has very pronounced topographic relief with altitudes between 430 m and 460 m a.s.l. The groundwater table within the landfill area lies between 415 m and 430 m. Because of a shallow groundwater table below the landfill and the lack of impermeable barrier at its bottom, surface- and groundwater was polluted in the near environment.

During the nineties, observation boreholes and trenches were carried out at the landfill site. The hydrogeological study has shown that the landfill bottom under the Fosse area was in direct contact with groundwater during the periods of high groundwater table. Since 1991, electrical conductivity of the surface water (river Venoge) and the groundwater were continuously measured in observation boreholes. The landfill leachate westwards from the Butte increased the groundwater conductivity slowly but regularly, the latter reached about 7'000 µS/cm in the year 2002. The increase of the groundwater conductivity downstream from the Fosse area was only from 700 µS/cm to 1'300 µS/cm due to dilution through more significant groundwater flow under this area.

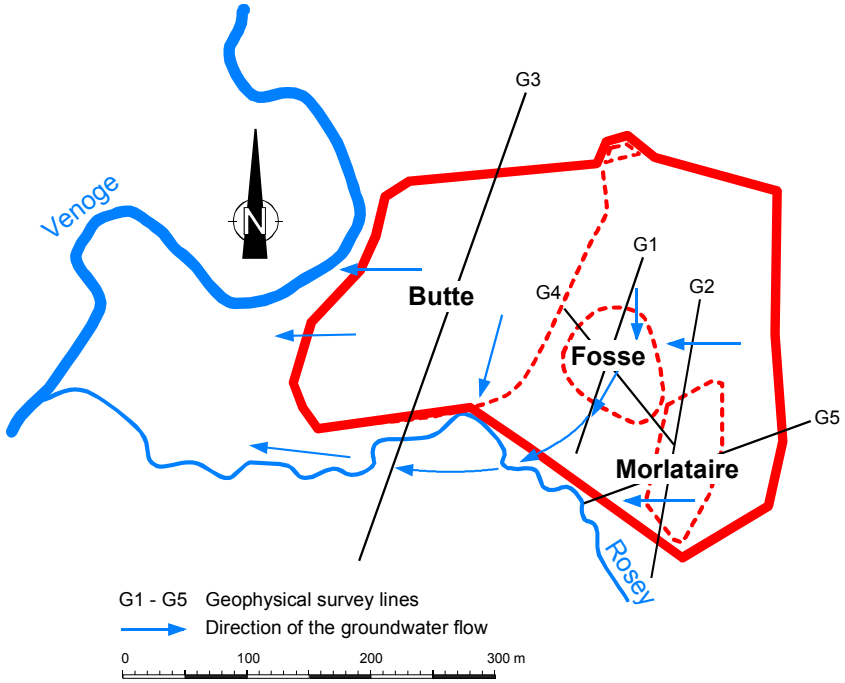

Figure 1: Situation of the landfill with geoelectrical profiles and main groundwater flow paths (after Dubath, 2010)

The whole landfill area covers a surface of about 6 ha. The landfill has a total volume of 720'000 m^3. The Butte alone has a volume of 650'000 m^3 and maximum waste thickness between 20 m and 30 m. The base of three landfill areas was not correctly tightened to avoid possible groundwater contamination. Under the waste, locally sandy or even gravel materials remained in place and the waste was partly in direct contact with ground water. Since the beginning of monitoring of the ground- and surface water no significant contamination by heavy metals (Zn, Pb, Cu, Cr) could be evidenced. This is explained by their low mobility. By contrast the near river Venoge and the groundwater have been polluted by high content of ammonia and organic carbon.
The natural setting of the whole area has hardly been affected by the landfill. But the natural milieu is very sensitive and has to be preserved during the breeding period of the European Bee-eater (May – mid-August). The excavation works on the site have been interrupted during this period in 2009.

Before beginning the decontamination project, accurate boundary and volume of all three landfill areas had to be estimated. During 2006, all available photogrammetric data were analyzed and the execution of geophysical investigations was approved. The combination of electrical resistivity and induced polarization 2D tomography was carried out.
The decontamination project of the landfill started in 2008. The waste in the areas Fosse and Morlataire was excavated and put on the slope of the Butte after installation of the new sealing barrier to prevent percolations of polluted water into the groundwater.

DATA ACQUISITION AND RESULTS

The electrical survey was carried out using Syscal R1 Plus equipment with 72 electrodes. The electrode spacing was 2 m, 2.5 m and 3 m at the Fosse and Morlataire areas and 5 m on the Butte. The electrode spacing was chosen in function of the investigation depth and supposed landfill borders. Five profiles with a total length of 1030 m were carried out in 3 working days. For the induced polarization (IP) method, current injection with an impulse length of 1'000 ms and alternating polarity was utilized. The measured data were processed with RES2DINV software, (version 5.0).
The resistivity 2D tomography sections did not always show clear images of the landfill geometry. Unlike, the induced polarization (IP) method provided very valuable results. Main disadvantage of the combination resistivity and IP methods is a much longer data acquisition time in the field. But the combination of both methods helps to better understand the nature of materials put in the landfill and give more reliable results about the geometry of the landfill.

According to results from the boreholes, the following resistivities could be attributed to the different lithological formations:

sandy gravel (glacio-fluvial)	150-600 Ωm
sandy alluvions, more or less silty	80-150 Ωm
clayey silt and silty sand (glacio-lacustrine)	30-60 Ωm

Most boreholes within the landfill area did not reach the molasse basement.
The waste has resistivities from about 5 Ωm to 80 Ωm, in some places even more if intercalated with sandy layers. The chargeability of the waste varies from about 10 to 50 mV/V.
The waste volume was calculated with help of photogrammetric data and geophysical results. During the excavation works in 2009 it became obvious that the calculated volume slightly exceeded the real one, especially at the Morlataire area.

EXEMPLES OF RESULTS (Fosse area)

The profile G4 (together with profile G1) helped to estimate thickness and composition at the Fosse landfill area. The low resistivity anomaly under the waste (Fig. 2) marks a possible preferential flow path of the contaminant leaving the waste downwards to the groundwater. During the excavation works the occurrence of silty sand without waste could be proved in the south-east part of profile G4 (Fig. 3, 96-114 m, no IP anomaly). Waste was found beyond the known limit of the old gravel pit in the north-western part, at the left end of the profile (Fig. 3, IP anomaly). This IP anomaly was verified during the excavation works in 2009. The IP anomaly located at the point 128 m belongs to the Morlataire landfill. The IP results of the profile G4 provided a good estimate of the waste's thickness. In other areas (Morlataire and Butte) with a higher chargeability values (up to more than 40 mV/V) the IP imaging produced greater apparent waste thickness, which could be due to a higher metal content and to very heterogeneous structure of the landfill.

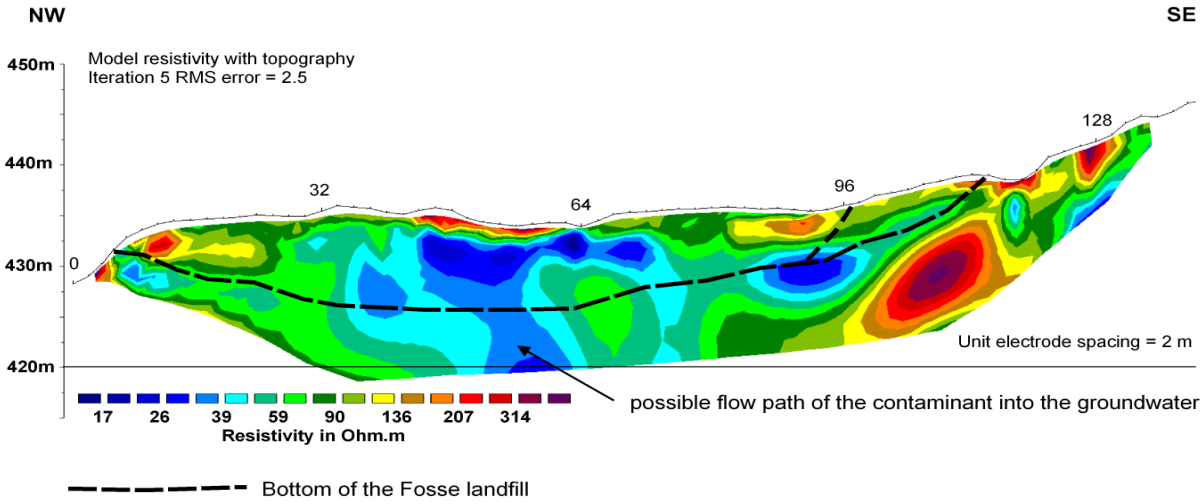

Figure 2: Profile G4 with resistivity tomography

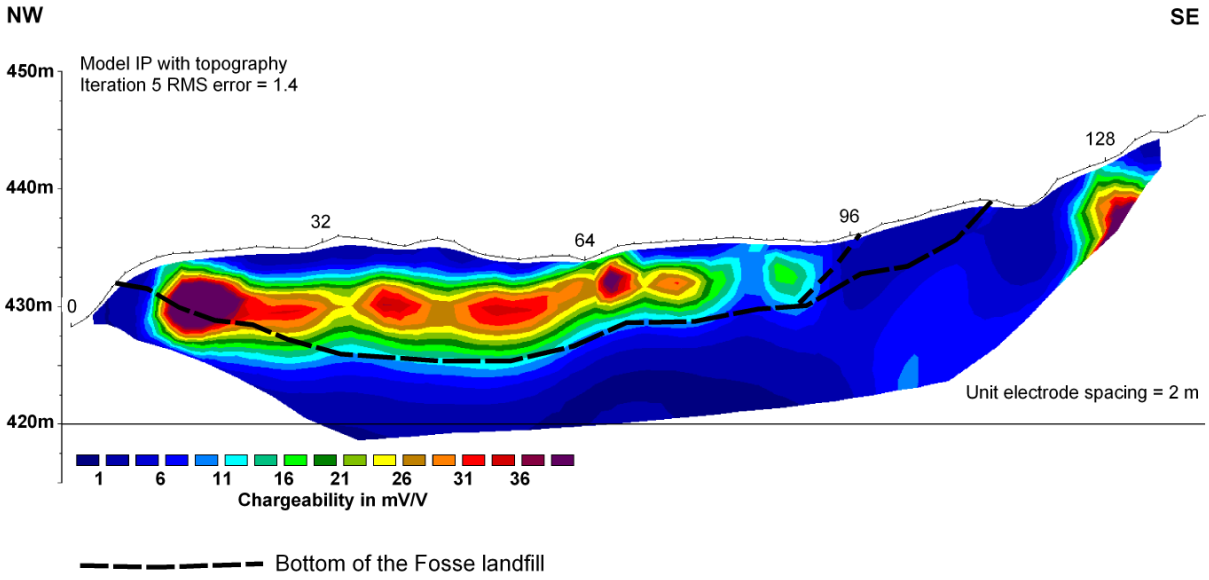

Figure 3: Profile G4 with induced polarization tomography

CONCLUSION

The waste landfill En Colliare, north of Lausanne, is now in the process of remediation since 2008. Before starting the remediation project, the accurate volume indications were necessary for the planning of different phases of oncoming works. Two-dimensional electrical resistivity and induced polarization (IP) tomography have been used to better constraint the dimensions of a complex waste landfill.

The results of the combined electrical resistivity and induced polarization methods helped to estimate the lateral dimension and volume of all three landfill areas. The results of geophysical investigation (executed in 2006) could be verified in two investigated areas during the excavation works started in 2009. The real situation was quite similar to the predictions from the geophysical survey. In particular, the induced polarization method was very useful at this complex waste landfill site.

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