The LINKIP project – geophysical investigation to characterise the subsurface for groundwater management and protection purposes

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2019

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Access to clean drinking water is a necessary requirement for life. With increasing difficulty in securing safe drinking water from surface waters, it is anticipated that the use of groundwater will increase. There are, however, several threats to the quality of this groundwater, such as the migration of pesticides and nitrates from agricultural applications into the water, waste leachates, and industrial contaminants (chemical industry, gasworks, impregnation plants, dry cleaning, etc.). In order to plan for protection, mapping of both groundwater resources and potential contaminant sources is necessary.

In the Link Induced Polarisation project (LINKIP) we focus on improving groundwater mapping using the geophysical induced polarisation (IP) method to characterise the underground and provide better three-dimensional (3D) models of the subsurface, both of which are connected to groundwater properties.

Different soil or rock material can be described by their resistivity, which quantifies how strongly a material is resistant to electric current, and by the chargeability, which determines the capacitive properties of the material. By measuring both quantities, it is possible to get information about the underground material and status.

The geophysical electrical resistivity tomography (ERT) method is already an established technique for engineering and environmental applications and is used to create two-dimensional (2D) sections of the subsurface (a photo of a measurement is shown in Figure 2). Subsequently 3D resistivity models can be made by combining several 2D ERT measurements. In addition to resistivity measurement with ERT, the IP method also provides information about the chargeability of the underground and can be measured either in the time-domain (TD) or in the frequency-domain (FD).

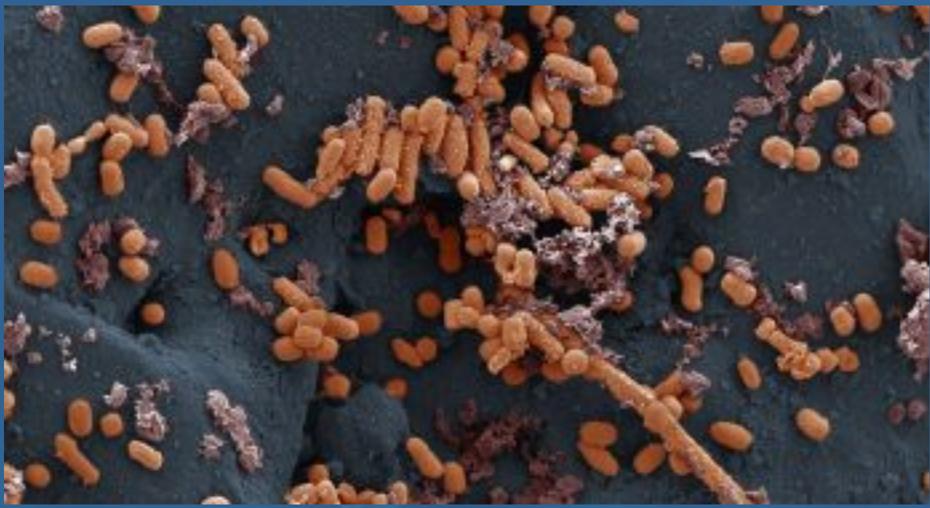

Figure 1. E. coli bacteria (orange) attached to a grain of sand (grey). The magnification is 1: 4 300

In theory, time-domain data can be converted to the frequency range and vice versa. Practically, it is much more complicated due to instrumental limitations and noise from various sources such as railroads, underground infrastructure and cables.

The measurement of the chargeability is often carried out in-time domain (TDIP) due to the easy and fast use of this method. On the other hand, measurements in the frequency-domain (FDIP) – also called, spectral induced polarisation (SIP) method — give more detailed (spectral) information, even though it might be harder and more time-consuming. However, this SIP method is starting to be developed into a quantitative exploration tool, particularly for groundwater and environmental investigations (Kemna et al, 2012; Revil et al., 2012). With this method, a relationship between the SIP parameters and groundwater properties (also called hydraulic properties) can be shown (Börner et al., 1996; Binley et al., 2005; Slater 2007; Hördt et al. 2009).

Furthermore, due to significant improvements in instrumental and computational developments as well as an increased understanding of polarisation processes within the underground material, the IP method has improved significantly in past years (Fiandaca et al., 2016; Günther et al., 2016). This provides an opening for 3D mapping of groundwater properties via SIP, as well as detection of certain pollutants (Johansson et al., 2015) and can be a valuable tool for mapping the groundwater. This is needed for improving management and protection for use by future generations.

The objective of the LINKIP project is now to assess how the spectral resolution can also be used in time-domain to better characterise the subsurface. The aim is to evaluate the extent to which the spectral content in TDIP data can be enhanced using the newest optimised data acquisition hardware, in combination with the latest developments in data processing algorithms (Olsson et al., 2016). This will enable the possibility to link information related to groundwater and pollution status properties to such geoelectrical 3D models of the subsurface more practically. The link between time-domain IP and frequency-domain IP will be studied to examine to what extent these two domains can be made equivalent in practical application (regarding handling and time consumption). This would open the possibility for practical application of the IP technique, which could be beneficial for not only assessing groundwater vulnerability through mapping, but also contamination detection and monitoring, reuse of mineral materials (landfill mining) and other engineering applications.

Figure 2. Geophysical SIP field measurement along a profile at a test site in Germany

The LINKIP project cooperates with the Swedish MIRACHL project (http://mirachl.com). This project focuses on the development of methods and methodology for monitoring of in situ remediation of (chlorinated hydrocarbon) contaminants by using a range of techniques, of which IP is one. Here, bacteria are used to degradate the contaminants. Due to the similar focus on contaminated ground, joint laboratory measurements are performed.

The first laboratory experiments are designed to study the influence of bacteria on the IP signal in general to check which signals can be expected from the field measurements. To design the simplest system, we started by inoculating a single strain of E. coli bacteria in sand and measuring how the data collected changed with the growth of the bacteria. In Figure 1 the E. coli bacteria (orange) growing as a biofilm (pink-grey) attached to a sand grain (grey) can be seen. After some time, the bacteria form biofilm (network of bacteria cells), which also affects the IP signal. This slimy biofilm can often be found in pipes and tanks with regular water content/flow. After more basic bacteria experiments, the next planned step would be the investigation of natural field samples with a mixture of different bacteria.

Geophysical field investigations are also needed to compare the IP method in both time-domain and frequency-domain. Test sites in Germany and Sweden have been chosen with different underground rock structures and targets, e.g. one site with black shale and one with dolerite, to evaluate the field data acquisition methods. A well known hydrogeological test site is also investigated to correlate the IP results with important groundwater parameters, e.g. groundwater flow. We have used different instruments (Figure 2) to inject current into the ground and measure the voltage difference between various electrode combinations arranged in profiles along the surface. As measurements are collected, we receive information about the resistivity and the chargeability (in TD) and, respectively, phase shift effects (in FD) of the underground. By developing a model based on the measurement data, we get information about the structure of the underground. Figure 3 displays both parameters (resistivity – top, chargeability - bottom), showing some basic structures, such as a top layer in the first 2.5 m depth with higher resistivities and lower chargeability, but also some different structures (below 3 m depth). Using both measurement quantities allows us to make a better interpretation.

For the remainder of the project, which finishes on 1 July 2020, the focus will be the detailed processing and interpretation of the measured field data and the correlation to the groundwater properties together with supporting laboratory experiments.

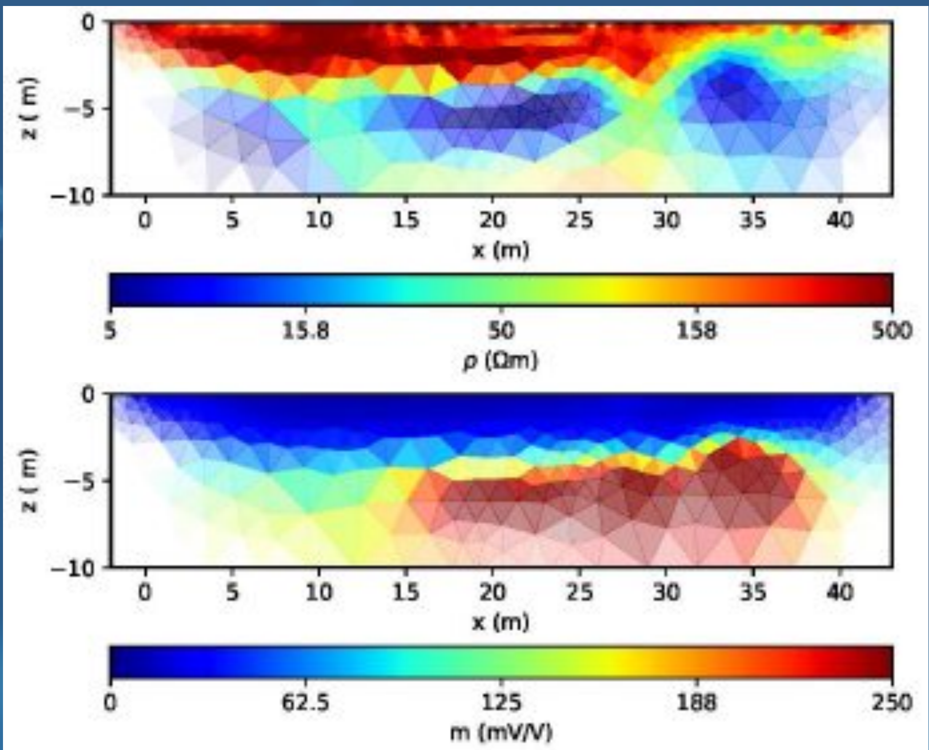

Figure 3. Geophysical inversion results showing the resistivity ρ (top) and chargeability m (bottom) distribution of the subsurface in several meters depth along a measurement profile. Different colour zones can be seen, which can be interpreted as specific underground structure.

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SUMMARY

LINKIP assesses how enhanced spectral resolution in geophysical IP data characterise the subsurface, for groundwater management and protection purposes, by linking IP data to groundwater properties. This can be also used for further applications, e.g. contaminations, landfill, mineral exploration.

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PROJECT LEAD

Dr Tina Martin studied geophysics at Free University Berlin and is a Marie Sklodowska Curie fellow at Lund University, Division of Engineering Geology. Her research interests are the geophysical induced polarisation method and its use in different field applications such as geological (rocks), biological (wood, trees, bacteria) and anthropogenic investigations (waste/mining dumps).

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FUNDING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement no. 752671.