



## REAL-TIME PLUME DELINEATION USING LOW-LEVEL MIHPT (LL-MIHPT)



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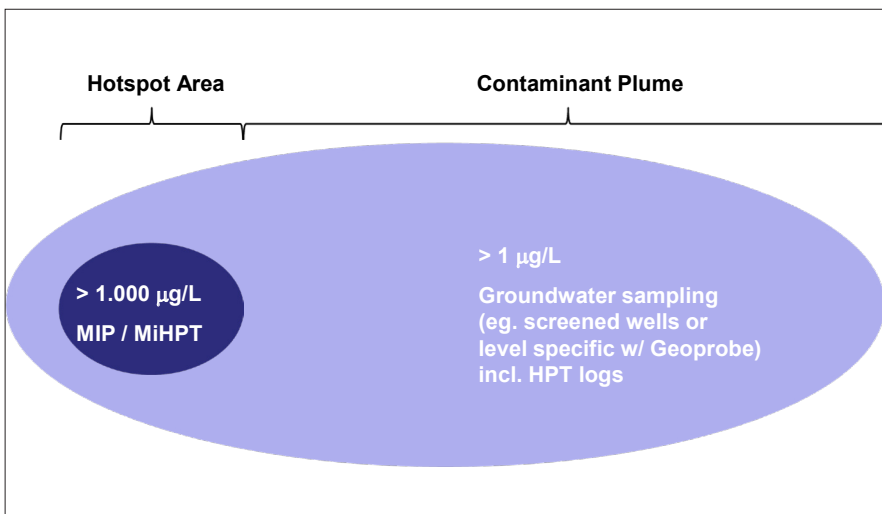
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## BACKGROUND

Plumes of dissolved contaminants may be widely distributed in the saturated zone, i.e. to great depths and over large areas. In addition, plume contaminant levels are generally much lower than source area concentrations. Characterization and delineation of contaminant plumes therefore typically require many investigation points at great depths. Often the delineation of a contaminant plume is conducted using traditional drilling techniques and installation of screened wells. However, this method is both time-consuming and resource-intensive and only a limited number of discrete depths can be screened in each well. Furthermore, screen depths are often chosen based on expected flow and contaminant distribution patterns in the saturated zone, rather than on detailed hydrogeological data and vertical contaminant distribution.



### TRADITIONAL INVESTIGATION METHODOLOGY

Conceptual model of a contaminant plume from a hotspot area.

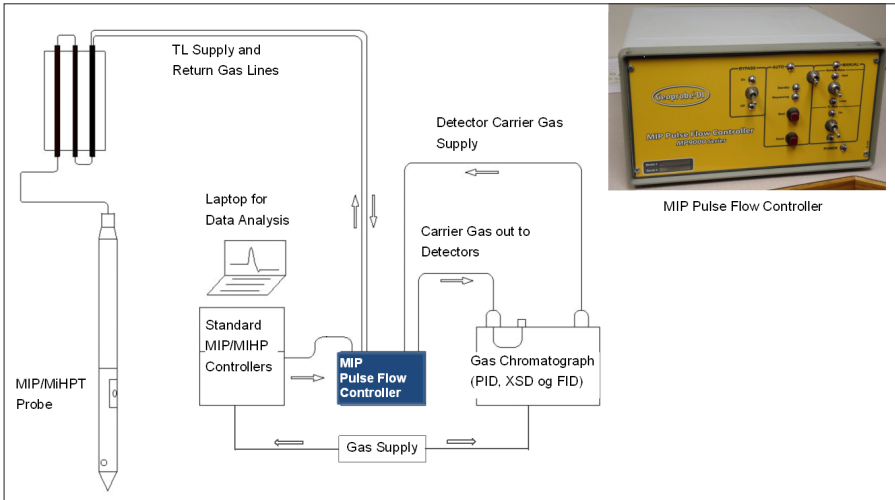
The range of investigation techniques available for delineation of contaminant plumes is limited and often the delineation of a plume is conducted taking out several groundwater samples.

## OBJECTIVES

On behalf of The Capital Region of Denmark and in cooperation with Geoprobe Systems (US), NIRAS (DK) has tested a novel tool, Low-Level MIHPT (LL-MIHPT), for delineation and characterization of contaminant plumes in groundwater. The purpose of the project was to test the LL-MIHPT technique for delineation of contaminant plumes at two sites with different geological formations; sandy and clayey, respectively. The objectives have thus been to determine at which concentration level the LL-MIHPT system could detect the site specific contaminants and to investigate the correlation between observed LL-MIHPT responses and results from analysed water and soil core samples from targeted depths.

## CONCEPTS OF THE LL-MIP/MIHPT SYSTEM

The LL-MIHPT system is based on the existing high resolution direct push investigation tools MIP and HPT developed by Geoprobe Systems and it is developed with the objective to detect contamination at low concentrations.



### LL-MIHPT SYSTEM

Concepts of LL-MIP/MIHPT. The LL-MIP/MIHPT system is based on the existing MIP/MIHPT system. Only an additional control unit, MIP Pulse Flow Controller (incl. software), is required. The carrier gas stream is pulsed, which allows a build-up of contaminant mass before it is led to the detectors. This provides a greater signal at the detectors and thereby results in a lower detection limit.

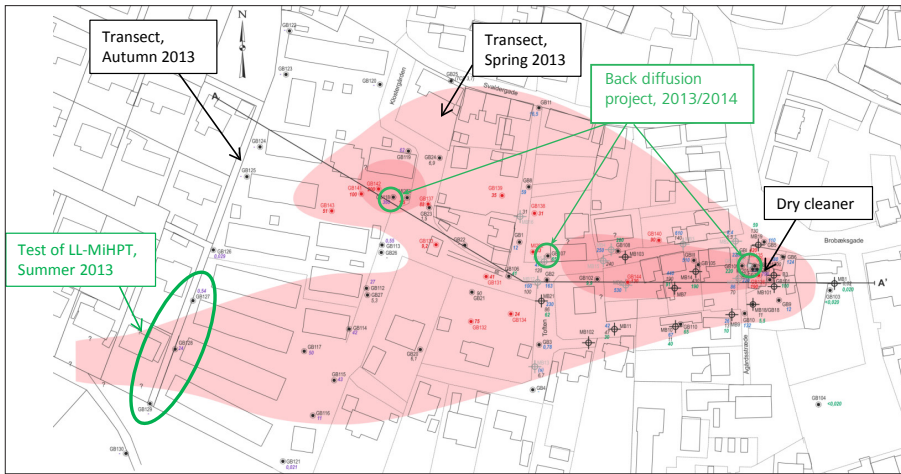
## FIELD ACTIVITIES

The LL-MIHPT system has been tested at two sites in Denmark as part of ongoing field investigations. 9 LL-MIHPT logs to 20-25 meters below surface have been carried out. At each log location, water samples were collected at specific depths for verification of the observed responses from the LL-MIHPT and for correlation of contamination levels. For further correlation of the LL-MIHPT data, core samples were collected at three locations.

The field tests were conducted and evaluated in 2013-2014. Since then, NIRAS has used the LL-MIHPT system in field investigations at several other sites (including investigations of contaminant back diffusion from low permeable layers).

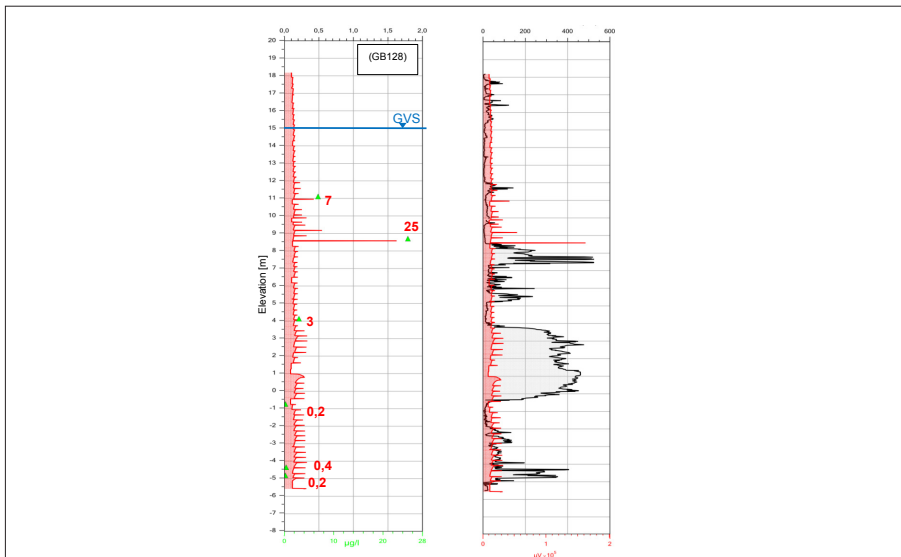
Representative results are presented below.

# RESULTS



TEST SITE

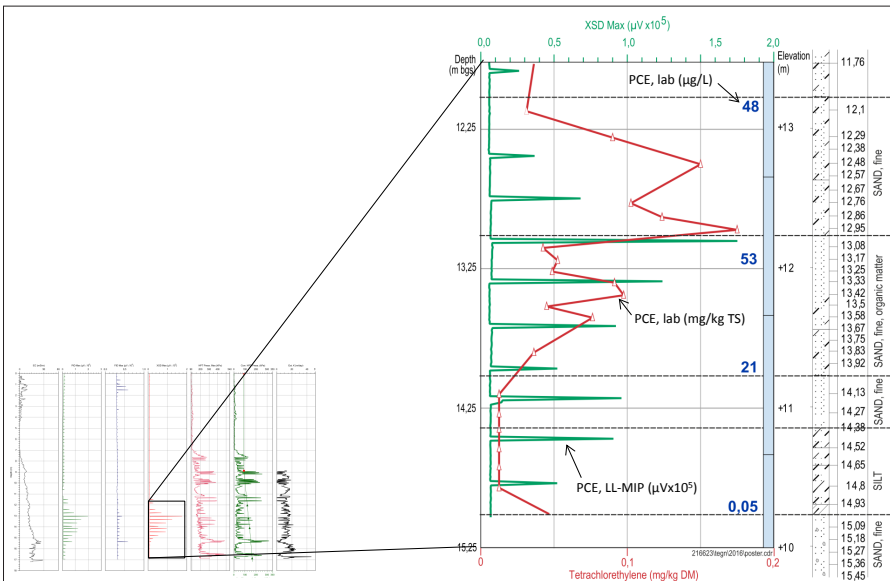
Activities at a former dry cleaning facility have caused pollution of soil and groundwater with chlorinated solvents (primarily PCE). Former investigations show that a plume of dissolved PCE has spread more than 200 meters from the hotspot area and in depths of 4-17 m bgs. In order to further delineate the plume, three LL-MIHPT logs were performed in 2013. Additionally three LL-MIHPT logs were performed as part of a project describing back diffusion from low permeable layers in the plume.



LL-MIHPT-LOG VS WATER SAMPLES

Example of LL-MIHPT log (GB128) with results from corresponding depth specific water samples. **Red line:** LL-XSD log. **Black line:** HPT log. **Blue line:** Groundwater level. Depth specific water sampling have been carried out within intervals of only 10 cm.

The results from GB128 show good correlation between LL-XSD responses and measured concentrations of chlorinated solvents. However, a concentration of for instance 3 microgram/L did not give rise to significant LL-XSD responses. At the bottom of the LL-XSD log there seems to be false positive responses. This should always be verified by analyses of water samples. The log GB128 also shows that the contaminant mass is associated with layers of lower permeability (higher HPT pressure).

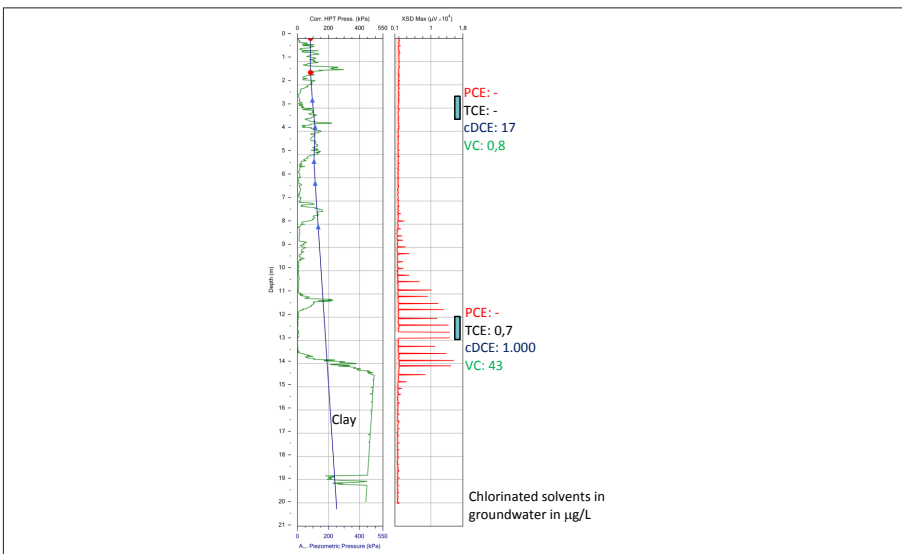


**LL-MIHPT-LOG VS. SOIL CORES**

Example of LL-XSD log (MI202) with results from corresponding soil core samples and depth specific water samples. The Mi202 log was carried out as part of a back diffusion project.

The results from the Mi202 log show good correlation between LL-XSD responses and measured concentrations of PCE in soil core samples and pore water.

**Degradation products**



**LL-MIHPT RESPONSE TO DEGRADATION PRODUCTS**

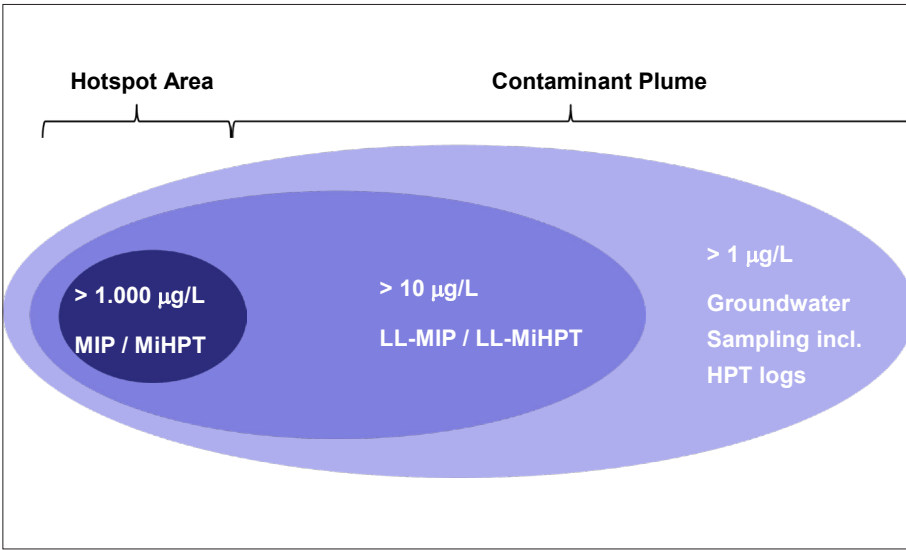
Example of LL-MIHPT log with results from corresponding depth specific water samples from a site with groundwater contamination constituting primarily of degradation products of chlorinated solvents.

**Red line:** LL-XSD log    **Green line:** HPT log

The figure shows that the most significant LL-XSD responses are observed just above a low permeable layer (clay). LL-XSD responses at the top of the low permeable layer indicate a potential of back diffusion of chlorinated solvents. The results also show good correlation between observed LL-XSD responses and measured concentrations of degradation products of chlorinated solvents in water samples.

## CONCLUSION AND PERSPECTIVES

The results from the field tests show that it is possible with the LL-MIHPT to track relatively low concentrations of chlorinated solvents and BTEX's in the saturated zone. Hence, for chlorinated solvents a detection limit in the order of 10 microgram/L has been achieved with an optimized detector system. For comparison the detection limit for chlorinated solvents with the standard MIP system is in the order of 500 microgram/L.



NOVEL INVESTIGATION METHODOLOGY

Based on the results obtained from the field tests the LL-MIHPT system has proven valuable for real-time delineation of contaminant plumes in the saturated zone with simultaneous retrieval of hydrostratigraphic data. Thus, LL-MIHPT logs followed by depth specific groundwater sampling is considered to be an optimal combination of tools for delineation and characterization of contaminant plumes in saturated zones in unconsolidated geological formations. The combined output data can be used directly for mass flux estimates.

Furthermore the LL-MIHPT system may be a good tool for investigations of back diffusion in unconsolidated permeable geological settings.