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IN-SITU INVESTIGATION OF CONTAMINATED SOIL AND GROUNDWATER WITH MIP- AND ROST™-CPT

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INTRODUCTION

Risk assessments and remedial desk studies require detailed knowledge of the subsurface structure as well as the contaminant geometry and spread in both source and plume areas. In-situ investigation techniques are therefore substantial for the vertical and horizontal delineation and characterization of contaminated sites.

Cone Penetrometer Testing (CPT) is a world wide known geotechnical investigation method to determine soil and groundwater characteristics in situ. Fugro has developed a variety of penetrometers, probes and samplers which are hydraulically pushed into the subsurface soil to obtain physical and chemical data. Lightweight detachable CPT units are offered for difficult access sites as well as large trucks and all-terrain vehicles with weights in the range 15 to 30 tonnes to provide penetration reaction.

For the purpose of environmental data collection the CPT cone (see Figure 1) is basically used as an adapter to the screening sensors. It provides subsurface stratigraphy through tip resistance and sleeve friction logs. By interpreting tip resistance and friction ratio, CPT data give detailed lithological information of the subsurface soil.

For the direct measurement of organic compounds MIP and ROST™ sensors are available. These probes are able to detect the vast majority of organic contaminants which are present in the environment.

THE MIP-CPT PROBE

Technical description

The MIP (Membrane Interface Probe) is used for in-situ screening of CHC (Chlorinated Hydrocarbons) and other VOC (Volatile Organic Compounds) in both the saturated and vadose zone. The MIP cone detects VOC like PCE (tetrachloroethene), TCE (trichloroethene) and their biodegradation daughter products via a heated membrane on the cone's sleeve (see Figure 2). When heated, these compounds are being thermodesorbed and diffuse across the membrane. They are then transported by a carrier gas stream through capillaries in the MIP cable up to the truck where they are detected with a gas chromatograph equipped with a PID (Photo Ionisation Detector), FID (Flame Ionisation Detector) and a DELCD (Dry Electrolytic Conductivity Detector). This detector combination allows for selective specification of the contaminant type (see Table 1). Equipped with a 10.6 eV UV lamp, the PID responds on unsaturated chemical compounds like chloroethenes or monoaromatic hydrocarbons with a lower ionisation potential compared to the excitation energy. The FID detects organic carbon, while the DELCD is able to detect organic bonded chlorine. In total the following data can be acquired in one push: Cone resistance, sleeve friction, friction ratio, electrical conductivity, dynamic porewater pressure, DELCD-, PID- and FID-logs.

NAPL detection

Fugro's MIP units are equipped with a unique heated cable to increase sensitivity and reduce detector tailing effects caused by VOC condensation or retardation in the capillaries (memory effect). These so called memory effects make it difficult to exactly determine the thickness of a highly contaminated layer, especially when the probe is exposed to NAPL. Several approaches have been tested to determine NAPL thicknesses. One method which had been performed in Vicenza Italy during a NAPL investigation project for ECOAPPRAISAL TAUW for the first time is to determine the lower NAPL edge by additional MIP measurement during casing retraction. This approach did allow for NAPL thickness estimation, which had later been proven by liner coring. But still narrow NAPL layers in the cm-range, which are observed most often especially in case of CHC DNAPL, cannot be resolved. Another method is to compare CPT and conductivity data. In many MIP applications (e.g. Geoprobe or other percussion techniques) the electrical conductivity serves as an indicator for lithological interpretation, which leads to false results in many cases. The reason is that on contaminated sites either groundwater itself shows a high electrical conductivity, which is falsely interpreted as fine grained soil (silt, clay), or strongly reduced conductivity is observed due to NAPL presence, which is then falsely interpreted as coarse sand or gravel. The latter can nevertheless be used as an indicator for NAPL presence and thickness, when comparing MIP, conductivity and CPT data. As CPT can provide the most accurate geological information in a 2 cm resolution unaffected from contamination or groundwater salinity, layers with a sharp decline of conductivity together with high MIP detector response can provide evidence of NAPL.

Detection limits and false positives

MIP sensitivity to different compounds strongly depends on the detector/membrane conditions, the length of the cable and the membrane temperature, but also on the vapour pressure and other physical/chemical properties of the relevant compound. Average detection limits can be given for PCE (300 ppb), TCE (200 ppb), DCE (400 ppb), VC (500 ppb), Benzene (400 ppb), Toluene (300 ppb) and Xylenes (200 ppb) in groundwater. It has to be noted that these are orders of magnitude which can vary site specific.

False positives (dupes) were found to be caused by hydrogen sulfide (DELCD/PID response), carbon disulfide (PID) and ammonia (PID).

It is strongly recommended to prove MIP detector response by sampling and lab testing at selected locations (e.g. BAT, Direct Push).

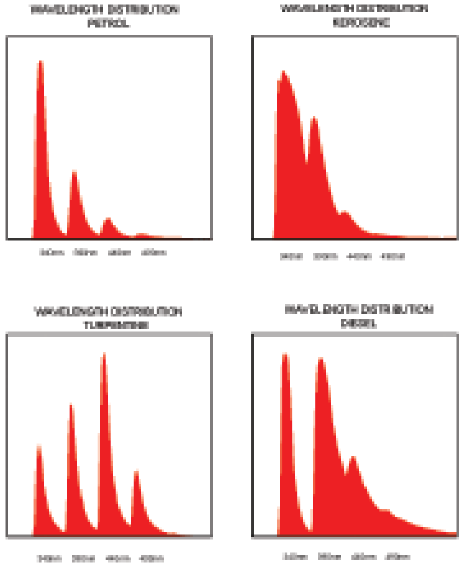

Fig. 1 - Layout of the MIP-CPT probe

THE ROST™-CPT PROBE

The ROST™ (Rapid Optical Screening Tool) is used as an in situ tool for screening of hydrocarbon derived contamination in soil and groundwater.

PAH (Polycyclic Aromatic Hydrocarbons) fluoresce if they are excited by light of a specific wavelength. This excitation leads to light emission in a certain wavelength range which is called Fluorescence. ROST™ is based on LIF (Laser Induced Fluorescence) which means excitation with monochromatic laser light (ROST™ uses 290 nm at 50 Hz). As PAH occur in all types of oil (sometimes in very small amounts) ROST™ is able to detect every contamination caused by oil derived hydrocarbons, i.e. jet fuel, diesel, petrol, mineral oil, tar, creosote etc.

COMPOUND	PID	FID	DELCD
PCE	++	+	+++
TCE	+++	+	+++
cDCE	++	+	++
tDCE	++	+	++
VC	+	+	+
TCA/TCM	-	+	+++
Benzene	++	++	-
Toluene	+++	+++	-
Xylenes	+++	+++	-

Tab. 1 - Detector sensitivities to CHC and BTEX (PCE: Tetrachloroethene, TCE: Trichloroethene, cDCE: cis-1,2-Dichloroethene, tDCE: trans-1,2-Dichloroethene, VC: Vinylchloride, TCA: Trichloroethane, TCM: Trichloromethane)

Every shot of the laser causes light emission in a certain wavelength range. The total ROST™ fluorescence intensity is the sum of four specific emission wavelengths: 340 nm, 390 nm, 440 nm and 490 nm. This means every wavelength "window" or "channel" has a certain fluorescence intensity depending on what type of oil component is excited. In other words each fluorescence signal contains a spectrum of four wavelengths.

Now every oil type has its own characteristic wavelength pattern or "waveform", as shown in Figures 2 and 3.

The difference between lighter hydrocarbon mixtures like petrol, kerosene or diesel, where the lower wavelengths predominate, and the heavier hydrocarbons e.g. tar or creosote, where the higher wavelengths predominate, can be clearly seen.

This so called wavelength shift can be also shown in a profile related to the total fluorescence at a given test location (see ROST™ profile in Figure 4). Shift to higher wavelengths is marked red, shift to lower wavelengths is shown blue. This allows an interpretation of whether there are different contaminant types or the contamination is rather homogeneous. Even low concentrations or compounds with reduced fluorescence properties which cause signals in the lower detection range can thus be clearly identified.

ROST™-CPT can provide a maximum of information in one push if needed: tip resistance, sleeve friction, friction ratio, electric conductivity, porewater pressure and fluorescence profile incl. wavelength shift. Waveforms can be printed out in the field to identify oil or fuel types.

ROST™ is ideal for NAPL detection and identification, moreover ROST™ fluorescence response can be even calibrated against TPH. No memory effects are involved due to the optical sensor, and NAPL thicknesses can be measured accurately.

ROST™ response is nevertheless restricted to oil derived hydrocarbons, e.g. CHC, PCB, BTEX and other monoaromatic compounds cannot be detected, unless they occur in a hydrocarbon matrix.

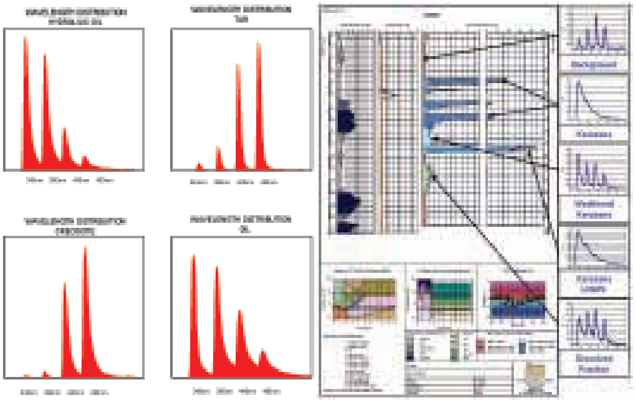

Fig. 2 - a) ROST™ waveforms petrol, kerosene, turpentine, diesel
- b) ROST™ waveforms hydraulic oil, tar, creosote, crude oil

CASE STUDIES

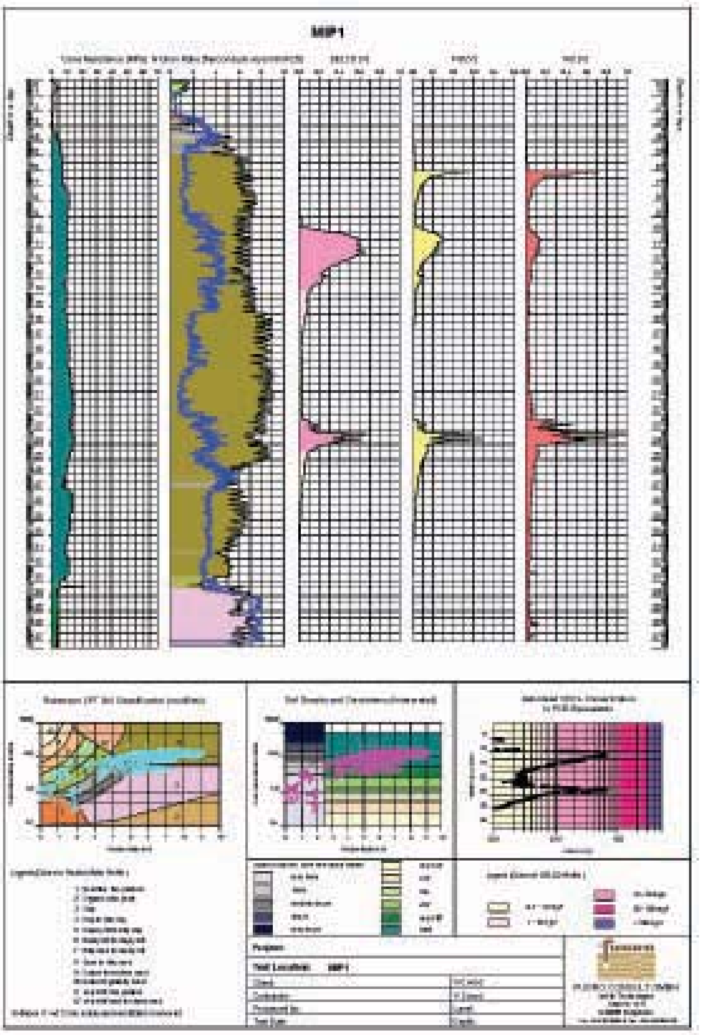

Fig. 3 - Fugro's MIP-CPT-Layout incl. Robertson soil classification, soil density and consistency and estimated VOCl groundwater concentration

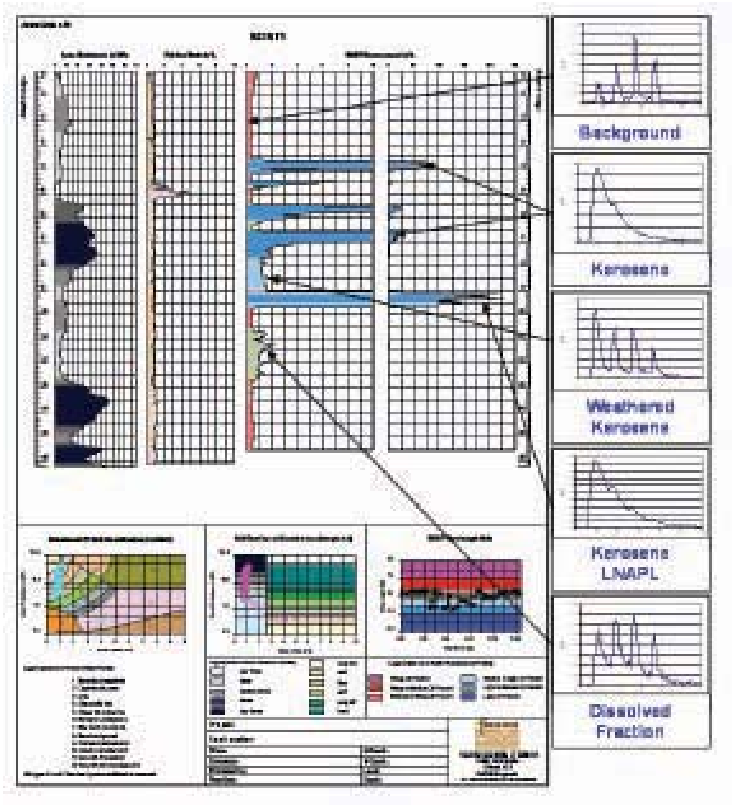

Fig. 4 - Fugro's ROST™-CPT layout incl. Robertson soil classification, soil density and consistency and ROST™ waveform interpretation

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