

# Application of the membrane interphase probe (MIP): an evaluation

Jan Bronders · Ilse Van Keer · Kaatje Touchant ·  
Guido Vanermen · Daniel Wilczek

Received: 17 April 2008 / Accepted: 25 November 2008 / Published online: 16 December 2008  
© Springer-Verlag 2008

## Abstract

**Background, aim, and scope** The membrane interphase probe (MIP™) from Geoprobe Systems® has frequently been applied in different countries for the characterization of soil contaminated with volatile organic carbons (VOCs). Experience shows that misinterpretation of the collected data is common. This is mainly due to the lack of understanding and knowledge related to the detectors used, their detection limits, and the sensitivity of the MIP system. It has been noticed that the sensitivity of the system given by the producer and by different users are rather optimistic, e.g., the values given are lower (= better) than those actually experienced in the field. A need for a better understanding of the MIP system sensitivity, combined with a more scientifically based interpretation of the collected data, exists.

**Materials and method** Both laboratory tests (using solutions) as well as field measurements were carried out using different detector configurations to allow a better interpretation of the detector signals/system sensitivity and to collect qualitative information. These configurations were: (1) detectors stand alone; (2) the use of a 2-ml sample loop, and (3) a purge and trap system. The configurations (2) and (3) are used in combination with a capillary column to carry out on-site qualitative and semiquantitative analyses.

**Results and discussion** With respect to the configuration of “detectors stand alone,” detection limits for toluene (in aqueous solutions) range between 4 ppm (flame ionization detector—FID) and 10 ppm [photo ionization detector (PID)]. For chlorinated aliphatic hydrocarbons (CAHs),

observed limits are 10 ppm (FID), 4–50 ppm (PID), and 3–10 ppm [dry electrolytic conductivity detector (DELCD)]. When using the 2-ml sample loop, relatively high concentrations have to be initially present in the soil. Observed detection limits for mono-aromatic hydrocarbons are 5–100 ppm; for CAHs, 1–50 ppm; for alkanes, 250–400 ppm; and for MTBE, 25 ppm. The application of purge and trap results in a better resolution and the detection of lower concentrations. Consequently, a better identification of the pollution with depth is possible. In this case, the detection limits are a function of the concentrations and the flushing time. In relation to the qualitative analyses, it was found that the configuration of the MIP-system with the built-in capillary column and the 2-ml sample loop or the purge and trap preconcentrator, respectively, are useful to carry out on-site analyses, thus allowing a better identification of the pollution in a vertical profile.

**Conclusions** The measurements carried out using the MIP with detectors stand-alone or in combination with a loop or trap, or connected to a column, confirm that analysis is indeed very useful to characterize VOC source zones when knowing and understanding its performance. This relates mainly to the detection limits of the MIP system. For a selection of parameters, such limits have been obtained. These values seem to be more realistic than those found in the few references where numbers are given. For the qualitative measurements, it can be concluded that a better resolution is obtained, and pollutants present in lower concentrations will be detected when using the purge and trap. It is advised to determine the optimal flushing time and the detection limit of the expected pollutants in advance.

**Recommendations and perspectives** This study indicates that there is still a need for further measurements and discussion between users. Finally, additional data should result in a better interpretation of the collected field data.

---

J. Bronders (✉) · I. Van Keer · K. Touchant ·  
G. Vanermen · D. Wilczek  
Flemish Institute for Technological Research (VITO),  
Boeretang 200,  
B-2400 Mol, Belgium  
e-mail: jan.bronders@vito.be

**Keywords** Alternative soil investigation techniques · Detection limits · Characterization of soil contamination · Membrane interphase probe (MIP) · Volatile organic carbons

## 1 Background, aim, and scope

In soil investigations, there has been a growing interest in the application of so-called alternative soil investigation techniques. If properly applied, methods different from the classic sampling methods (e.g., drilling and the installment of observation wells), such as geophysical methods, direct-push systems, soil gas sampling, and field analytical techniques, supply additional and very useful information (Griffin and Watson 2002; Van Keer et al. 2008). Therefore, the use of these methods has been encouraged both by consultants and public authorities.

For the characterization of contaminations of volatile organic carbons (VOCs), the membrane interphase probe (MIP™) from Geoprobe Systems® (Christy 1996; Christy and Gillespie 1996; Rogge et al. 2001) has frequently been applied in different countries (Lookman and Rogge 2000; Griffin and Watson 2002; McAndrews et al. 2003). The system has been on the market for more than 10 years now. Although the use of the MIP can be very useful, experience has indicated that the application of the method and the interpretation of the received data are not straightforward. Results are often misinterpreted with respect to the presence and the concentrations of soil and groundwater pollution. This is mainly due to the lack of understanding and knowledge related to the detectors used and their detection limits. As a consequence, these misinterpretations may lead to incorrect risk assessment and finally to non-efficient remedial actions.

In the literature, detection and system limits have not been discussed. Reports and papers referring to the use of the MIP system are mainly part of a project and are therefore only supporting discussions or conclusions. Even specific technical documents, e.g., ASTM (2007), do not discuss or identify the sensitivity of the detectors nor the system itself.

With respect to soil investigations, the MIP system has been applied at several sites in Flanders (Belgium; e.g., Van Keer et al. 2003a, b; Touchant et al. 2004). Unfortunately, the results of the MIP profiling could not always be explained straightforwardly. Sometimes high MIP detector signals were observed, but when samples were analyzed, no significant pollution was observed. In other cases, pollution was present (observed and analyzed), but no signals were observed when using the MIP. Next to the interest in the sensitivity of the detectors, these examples indicate the general need for a further evaluation and a better understanding of the MIP system detectors and the factors that have effects on the measurements.

Therefore, a study was carried out to better identify the detector signals as a function of the concentrations. Lab tests were performed to observe the effect of different pollutants on the detector signals. Hereby, the recorded signals were compared to analytical results. Subsequently, the detectors were connected to a capillary column (MIP-GC configuration) to carry out qualitative measurements. Finally, field measurements were carried out to evaluate this MIP-GC configuration.

## 2 Description of the MIP system

The MIP allows one to obtain semiquantitative data identifying the presence of VOCs present in a vertical soil profile. Correlation of several MIP profiles allows one to delineate a VOC source zone, both in vertical and horizontal direction, with limited laboratory costs (Christy 1996; Rogge et al. 2001).

When using the MIP in the field, a heated probe, containing a semipermeable membrane, is hammered or pushed into the ground. The temperature of the probe ranges between 80°C and 121°C, and forces VOCs, present in the soil surrounding the probe, to vaporize. Subsequently, the different volatile components extracted from the soil matrix diffuse through the membrane and are carried directly to a combination of three “stand-alone” detectors. In this configuration, mainly used when MIP-probings are carried out, there is no separation of components. A continuous log of a wide range of aromatic and halogenated hydrocarbons versus depth is generated. The detector response corresponds to the sum of signals received for different individual pollutants.

The flow of the carrier gas and the temperature are set and controlled by the “MIP controller box.” The MIP itself is not a detection system, it serves as an interphase between the soil and the detectors present in the setup.

An overview of the MIP system and its components is given in Fig. 1. A detailed description of the system and its components is given by Rogge et al. (2001) and at [www.geoprobe.com](http://www.geoprobe.com).

For the detection of VOCs present in the subsurface, three detectors are present: an FID, a PID, and a DELCD. The FID detects the presence of both aliphatic and aromatic hydrocarbons. Components with an ionization potential <10.2 eV (e.g., benzene, toluene, ethylbenzene, and toluene (BTEX) and some chlorinated hydrocarbons) are recorded by the PID. The DELCD is sensitive to the presence of chlorinated and brominated components, but does not respond to fluorine- and iodine-containing components.

The detection limit for BTEX components and CAHs present in the soil and/or subsurface are reported to range from 1 to 5 ppm with respect to the FID and PID (Christy



**Fig. 1** Field set-up of the MIP system

1996; Ehle and Neuhaus 1998). For the DELCD, a detection limit of 1 ppm is mentioned by Geoprobe (Geoprobe website 2007). Ehle and Neuhaus (1998), without specifying the type of detector, provides a much lower detection limit on the order of 0.1 ppm. Other references such as Bracke (2001) indicate 0.1 to 0.5 ppm as limits for the PID–FID. The variation of these given numbers is rather confusing for the user. Neuhaus (2007) indicates that lower detection limits (on the order of 200 to 500 ppb) are feasible, but these numbers are not supported by scientific data. This identifies, also in relation to detection limits, that the need for validation (and publication of the data) is present.

Unfortunately, all the mentioned detections limits are above most soil clean-up reference values for individual parameters applied in many countries. In Table 1, soil clean-up values used in Flanders (Belgium) are given for a selection of VOCs. Consequently, the MIP system can only be used for the delineation of source zones (including pure product).

### 3 Material and methods

#### 3.1 Semiquantitative measurements

MIP measurements were carried out using one component and mixed solutions. Detectors were configured as “stand-alone,” meaning that the MIP gasflow is going directly to these detectors (not via a column).

Tetrachloroethylene (PCE), trichloroethylene (TCE), *trans*-1,2-dichloroethylene (*t*-1,2-DCE), and toluene were selected for the measurements because they regularly occur at polluted sites. An overview of the used solutions is given in Table 2. The solutions were put into a cylinder in which the MIP probe was placed during 45 s (Fig. 2).

In this set-up, the nitrogen carrier gas (i.e., MIP gasflow) had a constant flow rate of 38–45 ml/min. Using a trunkline of 45 m (150 ft), the travel time of the components, from the membrane to the detectors, was approximately 42–47 s. Detector sensitivity was set on high modus.

To compare the concentrations of the prepared solutions and the corresponding MIP signal, a sample of the solution was taken at the same moment the MIP probe was placed in the cylinder. The water samples were then analyzed by headspace GC/MS (HS-GC/MS). After each measurement, the probe was cleaned. New measurements were only carried out after the detector response had reached the background values.

#### 3.2 Qualitative analyses

Since the MIP system configured with the detectors “stand-alone” does not allow the detection of individual parameters, a combination of the MIP system with a gas chromatograph (GC; Rogge et al. 2001) or with a direct sampling ion trap mass spectrometer (DSITMS; EPA 2005a, b) can be used. According to these studies, the combination of an MIP-GC or an MIP-DSITMS system is promising, but improvements are necessary. Unfortunately, no clear information related to the detection limits is given.

In our study, a sample loop or a purge and trap concentrator together with a capillary column (Restek MXT-1) was installed prior to the detectors. A schematic view of the configuration used is given in Fig. 3. As identified in this figure, MIP gas (N<sub>2</sub> + volatile components from the contamination) is flowing to detectors: (1) flow direction “A” indicates MIP gas going straight to the three detectors, first PID and then FID and DELCD (= “detectors stand alone”); (2) in flow direction “B” there are several possibilities: (1) MIP gas can be diverted to an external sampling device (path actually shown in the figure), this

**Table 1** Groundwater clean-up values used in Flanders for a selection of VOCs

Parameter	ppb (ug/l)
Benzene	10
Toluene	700
Dichloromethane (DCM)	20
Trichloromethane (TCM)	200
Tetrachloromethane	2
Trichloroethylene (TCE)	70
Tetrachloroethylene (PCE)	40
1,1-Dichloroethane	330
1,2-Dichloroethane	30
1,1,1-Trichloroethane	500
1,1,2-Trichloroethane (TCA)	12
<i>Cis</i> + <i>trans</i> -1,2-dichloroethylene (DCE)	50
Vinylchloride (VC)	5

**Table 2** Used solutions and observed detector signals

Parameter(s)	Concentration		Detector signal		
	ppm (mg/l)		FID	PID	DELCD
	Theoretical <sup>a</sup>	Measured <sup>b</sup>	mV		
<b>Individual components</b>					
PCE	5	4	–	–	–
	10	8	–	–	62
	53	31	–	27	315
	110	93	3	65	930
	158	140	6	80	1,236
<i>Trans</i> -1,2 DCE	5	4	–	32	120
	10	10	3	75	246
	50	52	14	315	1,232
	96	89	18	502	1,959
TCE	200	203	48	992	3,162
	5	3	–	–	57
	10	7.5	1	36	166
	50	40	5	116	553
	100	85	9	197	1,055
Toluene	200	100	13	302	1,554
	300	260	22	468	2,834
	5	4	–	26	–
	14	12	4	61	–
Mixtures	53	55	13	227	–
	100	90	21	354	–
	196	179	41	644	–
	507	310	81	1,266	–
	PCE	1.2	1	–	29
TCE	1.3	1			
<i>Trans</i> -1,2 DCE	1.1	1			
Toluene	1.3	1			
PCE	3.2	2	3	56	335
TCE	3.4	3			
<i>Trans</i> -1,2 DCE	3.0	2			
Toluene	3.5	3			
PCE	7.4	7	6	120	707
TCE	7.9	7			
<i>Trans</i> -1,2 DCE	6.8	7			
Toluene	7.9	8			
PCE	12.9	6	9	177	1,100
TCE	13.7	10			
<i>Trans</i> -1,2 DCE	11.9	11			
Toluene	13.9	10			
PCE	27.3	24	15	319	1,967
TCE	29.0	28			
<i>Trans</i> -1,2 DCE	25.1	25			
Toluene	29.3	29			

– no detector signal observed

<sup>a</sup>Theoretical concentration of the solution made<sup>b</sup>Measured concentration using HS-GC/MS

has not been used in the study presented; (2) MIP gas is diverted to a 2-ml loop after which the gas is diverted to a column before it reaches the detectors (= “2 ml sample loop”); (3) MIP gas is trapped (using an absorbent) and

later released through a column before it reaches the detectors (= “purge and trap”)

In case of the qualitative analyses, the performance of both setups (2 ml sample loop, and purge and trap) was tested first in the laboratory. Subsequently, the combination of “purge and trap” was evaluated in the field.

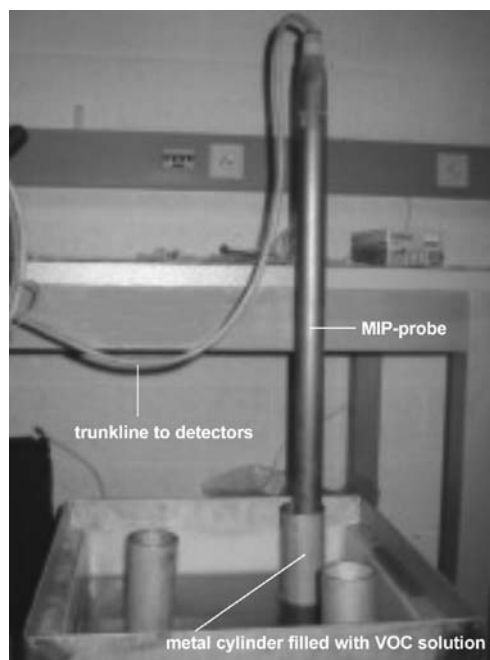
### 3.2.1 Sample loop

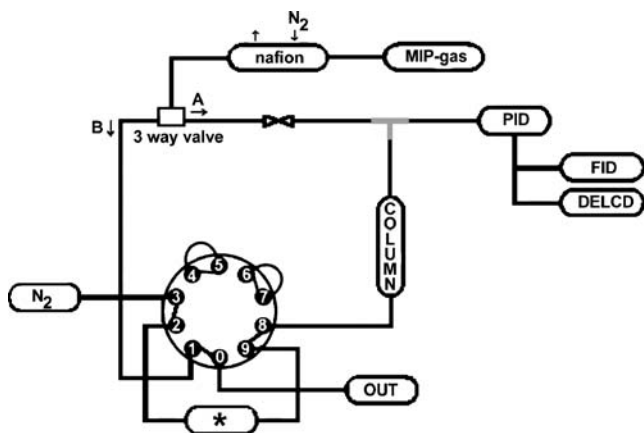
When using the sample loop, the MIP gas is collected in a 2-ml loop and then, by switching the valve, is separated from the main gas flow. The collected gas then flows through the column which is installed before the detectors. The column used is a Restek MXT-1, with a length of 15 m, internal diameter of 0.53 mm, and a film thickness of 5 μm. The separated components can be identified using the different detectors. Before allowing the gas to flow to the detectors, a certain time to “clean” the loop is applied.

### 3.2.2 Purge and trap

In case of the purge and trap, the MIP gas is trapped on tenax adsorbents. It is very important, depending on the concentrations present in the gas that a certain time is taken to allow the compounds to be trapped. After changing the gas flow direction, the trap is heated, and the compounds are released into the column. When reaching the detectors, the individual compounds can be identified.

The software program “Peak Simple,” which can be downloaded from the SRI website (SRI 2007), was used to

**Fig. 2** Laboratory set-up



**Fig. 3** View of the MIP-GC system; **a** gas flow “stand-alone” detectors; **b** gas flow loop/trap configuration; *asterisk* loop or trap; numbers indicate possible routes of the gas flow; more explanation see Section 3.2

control the gas flow, to define time and temperature events, and to interpret the detector signals.

### 3.3 Field test

The use of the purge and trap setup to carry out qualitative analysis was evaluated in the field. At a site characterized by high concentrations of monoaromatic and chlorinated aliphatic hydrocarbons present in the soil and in the groundwater, a MIP measurement was carried out.

## 4 Results and discussion

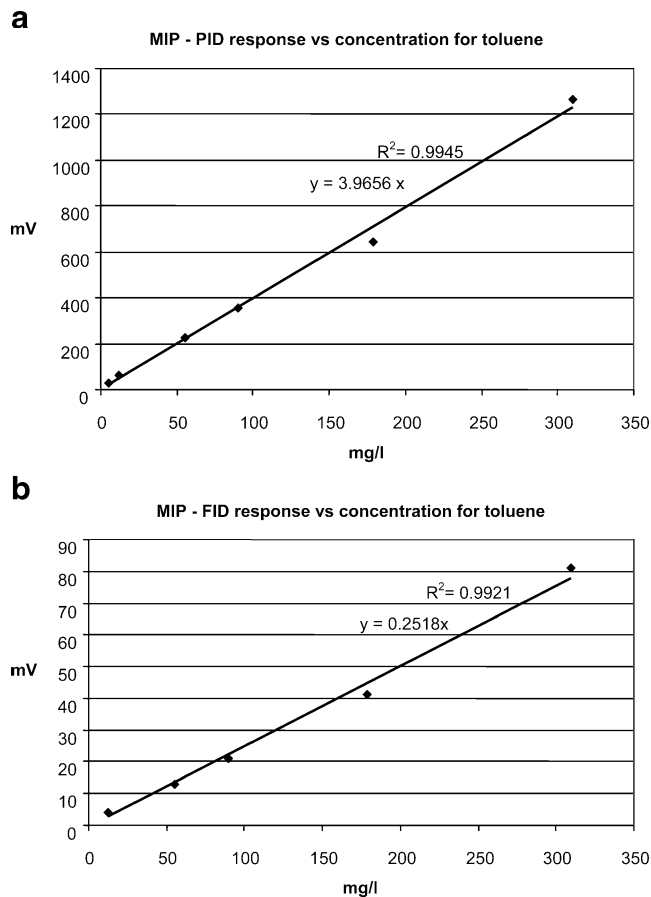
### 4.1 Semiquantitative measurements

The measurements confirm that high DELCD signals are observed for CAHs, that the aromatic components are best indicated by the PID, that the FID has a relatively low sensitivity for both parameter groups, and that the intensity of the recorded signals increases with increasing concentrations. There is a linear relationship between FID and PID signal and concentration (see example of toluene in Fig. 4a, b), but a quadratic relationship for the DELCD response (see example of *trans*-1,2-DCE in Fig. 5).

It has to be mentioned that the intensity of the MIP signals is also related to the membrane used. The variation of the MIP signal as a function of different membranes was not considered during the laboratory experiments.

It was also observed that no significant signals were detected for solutions having concentrations lower than those given in Table 2.

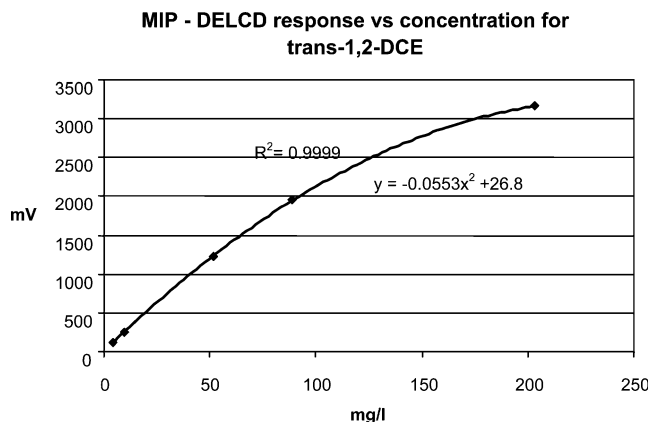
Thus, for each individual parameter, the lowest concentration for which a signal was observed, has to be



**Fig. 4** Relationship between FID and PID signal and concentration of toluene

considered as a detection limit for the MIP “stand-alone” configuration (Table 3).

Next to the determination of detection limits, tests were carried out to determine the concentration at which maximum signals (5 V) were reached (see Table 3). The maximum intensity of the MIP-DELCD and the MIP-PID signal was only reached for very high concentrations



**Fig. 5** Relationship between DELCD response and concentration of *trans*-1,2-DCE



**Table 3** Summary of the laboratory measurements

Detector	Parameter	DL ppm (mg/l)	Conc.—5 V ppm (mg/l)
DELCD	TCE	3	>300
	<i>Trans</i> -1,2-DCE	3	>250
	PER	10	Pure product
PID	Toluene	~4	Pure product
	TCE	10	
	<i>Trans</i> -1,2-DCE	~4	>400
FID	PER	50	
	Toluene	~10	
	TCE	~10	
	<i>Trans</i> -1,2-DCE	~10	
	PER	~10	

DL detection limit, i.e., lowest concentration for which a MIP-signal was observed (for individual components), *Conc.—5 V* concentration for which a maximum signal of 5 V was reached (for individual components)

(>250 ppm) or pure product. The MIP-FID signal never reached a maximum intensity.

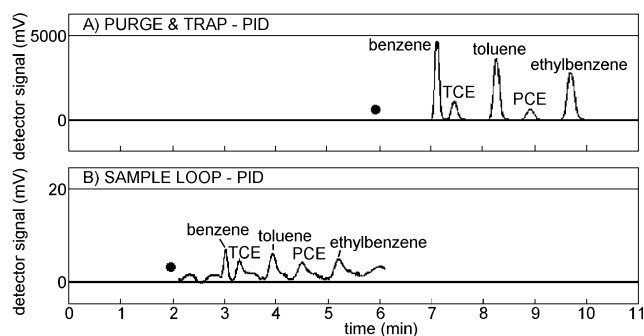
The evaluation method used is simple and relatively easy to execute, allowing MIP operators to determine the minimum concentrations for which MIP signals can be observed in the field. When comparing the observed detection limit (see Tables 2 and 3) to those found in the literature, it can be concluded that the latter are lower (i.e., more optimistic). Furthermore, it is advised to give detection limits for each parameter in relation to the type of the detector used. As a result, the MIP user will be able to define when to use the MIP and how to interpret the data collected during field work. Finally, the latter will lead to a better understanding of the observed pollution.

#### 4.2 Qualitative analyses

Different solutions were made and brought into a metal cylinder (see Fig. 2). The MIP probe was then introduced, and the measurement started. Each measurement was carried out three times. To identify the different compounds, the retention time and surface area were determined for each peak. In Fig. 6, PID chromatograms of a standard gas containing benzene (1 ppm), ethylbenzene (1 ppm), toluene (1 ppm), PCE (1 ppm), and TCE (1 ppm), obtained for both the loop and the trap system, are given.

##### 4.2.1 Sample loop

For the sample loop application, the detection limits found in the literature for GC measurements with direct injection of a sample are 1 ppm for the FID and 10 ppb for the PID and DELCD. Since the working principle of the MIP-probe



**Fig. 6** Comparison of the analysis of a standard gas containing benzene, toluene, ethylbenzene, trichloroethene and tetrachloroethylene using purge and trap (a) and the sample loop (b); filled circles release into the capillary column. Data were collected using a 15 m, 0.53 mm ID, 5  $\mu$ m Restek MXT-1. Oven temperature: 40°C (hold 8.8 min.) to 150°C at 10°C/min

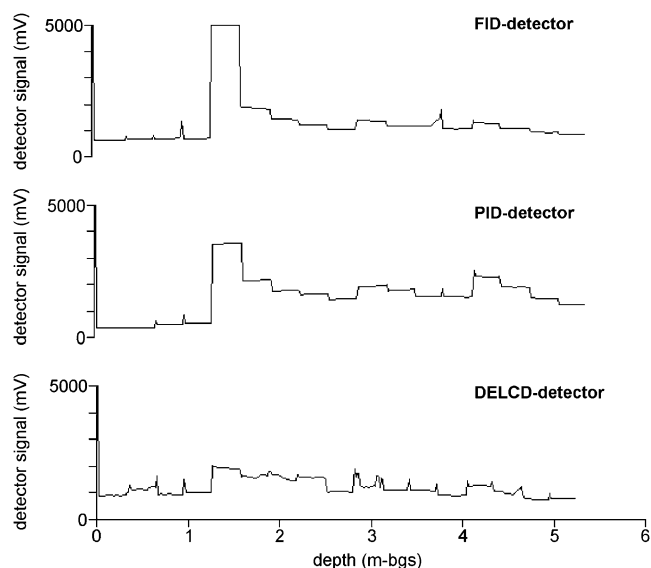
is based on vaporization of contaminants, the amount of components actually entering the column is mainly a function of the contaminant's boiling point and Henry's coefficient. To identify detection limits for the loop system, different measurements have been carried out. First, the ideal measurement conditions were determined using different event programs. To identify the sensibility of the capillary column, special attention was given to the effect of change in temperature rise. Next, measurements were carried out using one component and mixed solutions.

The detection limits obtained for a selection of compounds are given in Table 4. These limits, which are higher than the theoretical limits given for the detectors, have to be interpreted as an indication of the real limit. The relatively high values can be explained by the fact that only 2 ml of gas (i.e., volume of the loop) is actually entering the column. To be able to measure a signal for the components present in 2 ml of gas, it is necessary that high concen-

**Table 4** Detection limits observed for a selection of compounds using the sample loop

Parameter	DL ppm (mg/l)	Parameter	DL ppm (mg/l)
MTBE	25	1,1,2-trichloroethane	20
Dichloromethane	1	Toluene	30
<i>Trans</i> -1,2 dichloroethene	1	Octane	400
Hexane	250	Tetrachloroethene	30
1,2-Dichloroethane	5	Chlorobenzene	50
1,1,1-Trichloroethane	5	Ethylbenzene	50
Benzene	5	<i>m</i> -Xylene	50
Tetrachloromethane	5	<i>p</i> -Xylene	50
Trichloroethene	5	<i>o</i> -Xylene	100
Heptane	300	1,2,4-Trimethylbenzene	100

DL Detection limit, i.e., lowest concentration for which a MIP-signal was observed



**Fig. 7** Signals for a MIP measurement using the detectors “stand-alone”

trations are present both in the gas entering the loop as well as in the soil.

#### 4.2.2 Purge and trap

When applying the purge and trap method, the crucial point for an optimal use of the trap is the “flushing time” (corresponding to a certain volume of gas) required to allow sufficient adsorption. This time is not only a function of the type and concentration of compounds present in the solution or in the soil, but also of the composition of the trap itself. Therefore, the flushing time has to be determined for each

measurement campaign, this depending on the field conditions (concentrations and type of compounds).

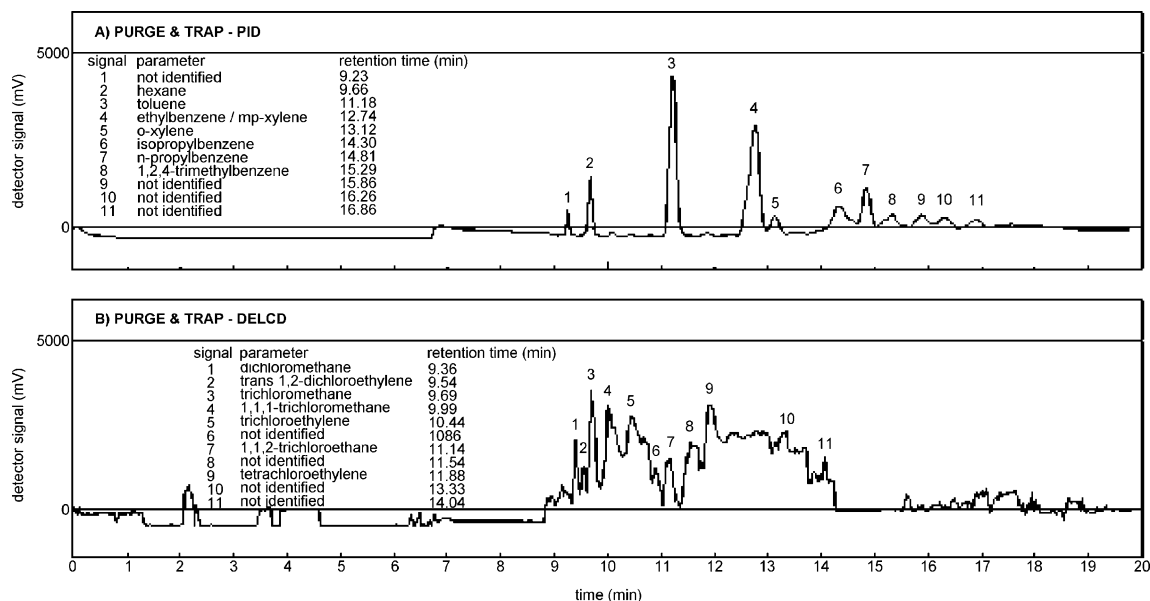
Measurements carried out using a 10-ppm solution of *trans*-1,2-dichloroethene indicated that the tenax adsorbents was almost completely saturated after a flushing time of 6 min (or ca 240 ml).

From Fig. 6, it is clear that a better resolution is obtained compared to the configuration with the sample loop when using the purge and trap. Furthermore, also signals for lower concentrations are detected. The difference in retention time observed for the two chromatograms is caused by different event programs used for the loop and the purge and trap.

#### 4.2.3 Field test

A “classic” MIP profile, with the detectors in stand-alone mode, was generated up to 5.2 m depth below ground surface (m-bgs). The results of the classic MIP are given in Fig. 7. Since the FID and the PID detector show a similar profile, the presence of monoaromatic hydrocarbons is indicated. According to the peak signals of maximum intensity (5 V), pure product may be present between 1.3 and 1.6 m-bgs. The absence of significant signals on the DELCD profile means that there are no CAHs present or only in concentrations below the detection limit.

After interpreting the “classic” MIP data, another probing was carried out parallel to the first one, using the trap in combination with a capillary column. This allows one to determine the type of compounds present in the soil. At five different depths (i.e., 1.8, 2.5, 3.0, 4.2, and 5.2 m-bgs), a GC analysis was carried out. To avoid contamination of the



**Fig. 8** MIP-GC profiles obtained during an in-situ field test **a** PID profile; **b** DELCD profile. Data were collected using a 15 m, 0.53 mm ID, 5  $\mu$ m Restek MXT-1. Oven temperature: 40°C (hold 8.8 min) to 150°C at 10°C/min. **a** PID profile; **b** DELCD profile

**Table 5** Soil analytical results, using HS-GC/MS

Parameter	Concentration	
	ppm (mg/kg) 1.00–1.50 <sup>a</sup>	ppm (mg/kg) 2.00–2.20 <sup>a</sup>
Benzene	<0.05	<0.05
Toluene	42	14
Ethylbenzene	17	8,3
M+p-Xylene	84	23
O-Xylene	12	4,6
1,2,4-Trimethylbenzene	8.1	2.6
1,3,5-Trimethylbenzene	<0.05	1.1
Dichloromethane	<1.0	<1.0
Trichloromethane	<0.1	<0.1
Tetrachloromethane	<0.1	<0.1
Trichloroethylene	<0.2	<0.2
Tetrachloroethylene	99	26
1,1-Dichloroethane	<0.1	0.64
1,2-Dichloroethane	<0.1	<0.1
1,1,1-Trichloroethane	<0.1	<0.1
1,1,2-trichloroethane	<0.2	<0.2
Cis-1,2-Dichloroethylene	60	34
Trans 1,2-Dichloroethylene	<0.1	<0.1
Vinylchloride	<0.5	<0.5

<sup>a</sup> Sample depth (in meters below the surface)

system, no analysis was done in the top soil section where the presence of pure product is expected.

In Fig. 8, the results of an MIP-GC analysis represent the qualitative determination of volatile soil contaminants present at a depth of 1.8 m-bgs. Although it was not possible to identify every individual signal, several monoaromatic and chlorinated aliphatic hydrocarbons were identified on the basis of the retention times of the observed peaks in the PID and DELCD chromatograms. According

to the analyses on soil, given in Table 5, more compounds were identified when interpreting data received by the MIP-GC system.

## 5 Conclusions

The measurements carried out using the MIP with detectors stand-alone or in combination with a loop or trap, connected to a column, confirmed that this instrument is very useful when knowing and understanding its performance. This relates mainly to the detection limits of the detectors. For a selection of parameters, such limits have been determined (see Tables 3 and 4). Table 6 summarizes the detection limits for different types of pollutants. The values obtained seems to be more realistic than those found in the few references giving detection limits.

The configuration of the MIP system with the built-in capillary column and, respectively, the 2-ml sample loop or the purge and trap preconcentrator is useful to carry out on-site qualitative analyses in combination with vertical screening of the pollution.

When using the purge and trap, a better resolution will be obtained, and pollutants present in lower concentrations will be detected. It is advised to determine the optimal flushing time and the detection limit of the expected pollutants in advance.

## 6 Recommendations and perspectives

This study indicates that care has to be taken when interpreting results from the MIP measurements. There is discussion on the detection limits among users and

**Table 6** Summary of the detection limits (concentration in soil) obtained for the different MIP configurations

<b>Detectors stand-alone</b>			
Parameter	FID ppm (mg/l)	PID ppm (mg/l)	DELCD ppm (mg/l)
Toluene	4	10	–
CAH	10	4–50	3–10
<b>2 ml sample loop</b>			
Parameter	FID/PID/DELCD ppm (mg/l)		
MAH	5–100		
CAH	1–50		
Alkanes	250–400		
MTBE	25		
<b>Purge and trap</b>			
Parameter	FID/PID/DELCD		
MAH	Function of concentration in the soil and flushing time		
CAH	Function of concentration in the soil and flushing time		

CAH chlorinated aliphatic hydrocarbons, MAH monoaromatic hydrocarbons



providers indicating that there is still a need for further measurements and discussion.

The major goal of this paper and of recommended additional observations should finally result in a better interpretation of the collected field data, thus allowing correct conclusions and define better remedial actions.

## References

- ASTM (2007) Standard practice for direct push technology for volatile contaminant logging with the membrane interphase probe (MIP). ASTM standard D7352-07
- Bracke R (2001) The application of direct-push technology with respect to geomonitoring and construction issues. *Ecos Umwelt-technische und -wissenschaftliche Publikationen, ECOS Umwelt GmbH., Germany*, (in German: Der Einsatz von DP-Verfahren für Geomonitorings und baugrundtechnische Fragestellungen)
- Christy TM (1996) A permeable membrane sensor for the detection of volatile compounds in soil. Paper presented at the National Ground Water Association's Outdoor Action Conference, Las Vegas, Nevada, [www.geoprobe-di.com](http://www.geoprobe-di.com)
- Christy TM, Gillespie G (1996) Proceedings of the Direct Push Days Workshop, Salina
- Ehle N, Neuhaus M (1998) Application of direct push technology and membrane interphase probe (in German: Standortuntersuchung mit Drucksondentechnik und Membrane Interphase Probe). *TerraTech* 5:36–39
- EPA (2005a) Sensor technologies used during site remediation activities—selected experiences. EPA 542-R-05-007. [www.clu-in.org](http://www.clu-in.org)
- EPA (2005b) Groundwater sampling and monitoring with direct push technologies. EPA 540/R-04/005. [www.epa.gov](http://www.epa.gov)
- Geoprobe website (2007) Direct Image. [www.geoprobe-di.com](http://www.geoprobe-di.com)
- Griffin TW, Watson K (2002) A comparison of field techniques for confirming dense non aqueous phase liquids. *Ground Water Monit R* 22(2):48–59
- Lookman R, Rogge M (2000) Delineation of large soil pollution with volatile compounds using probing techniques. 300–301 In: Proceedings of the 7th FZK/TNO Conference on Contaminated Soil, Leipzig
- McAndrews B, Heinze K, Diguiseppi W (2003) Defining TCE plume source areas using the membrane interface probe (MIP). *Soil Sediment Contam* 12:799–813
- Neuhaus M (2007) In-situ investigation of contaminated soil and groundwater with MIP- and ROST<sup>tm</sup>—CPT. *Italian Journal of Engineering and Environment, Special Issue 1*. 59–63. Casa Editrice Universita La Sapienza
- Rogge M, Christy TM, De Weirdt F (2001) Site contamination fast delineation and screening using the membrane interface probe. In: Breh W et al (ed) *Field screening Europe*. Kluwer Academic Publishers, Dordrecht, pp 91–98
- SRI (2007) SRI Instruments. Peak simple download. [www.srigc.com/peaksimple.htm](http://www.srigc.com/peaksimple.htm)
- Touchant K, Lookman R, Bronders J, Van Keer I, Smolders R, Van Houtven D, Wilczek D (2004) Militair domein Brustem: Bijkomend onderzoek (Kerosine). VITO/2004/IMS/R/147 (VITO report in Dutch)
- Van Keer I, Habtie A, Bronders J, Wilczek D, Smolders R (2003a) Validatie en toepassing van de 'Membrane Interphase Probe (MIP)'. Deel 2: Testsite 1: evaluatie van sonderingen uitgevoerd met de Membrane Interphase Probe (MIP) op een voormalig Texacoterrein verontreinigd met BTEX, te Gent. VITO/2003/IMS/R/011 (VITO report in Dutch)
- Van Keer I, Habtie A, Bronders J, Wilczek D, Smolders R (2003b) Validatie en toepassing van de 'Membrane Interphase Probe (MIP)'. Deel 2: Testsite 3: evaluatie van sonderingen uitgevoerd met de Membrane Interphase Probe (MIP) ter hoogte van een voormalige leerlooierij, verontreinigd met VOCl's te Zulte. VITO/2003/IMS/R/078; (VITO report in Dutch)
- Van Keer I, Bronders J, Touchant K, Verhack J, Wilczek D (2008) Detection and measurement techniques to identify the presence of NAPLs in the field. In: Annable MD et al (ed) *Methods and techniques for cleaning-up contaminated sites*. Springer, Dordrecht, pp 59–69 NATO Science for peace and security series—C: environmental security