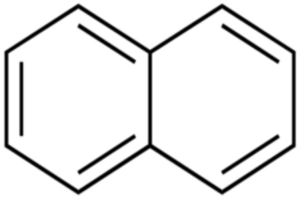
EXPERTS IN GAS ANALYSIS

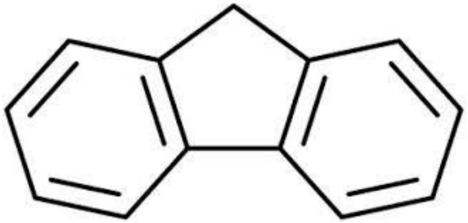
airmoSCAN XPERT solution

On-Line and In-field autoGC/FID/MS analyzer

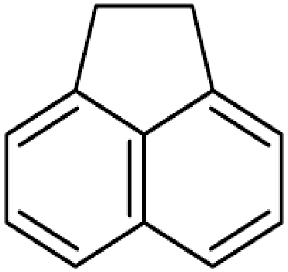
Automatic PAHs Monitoring



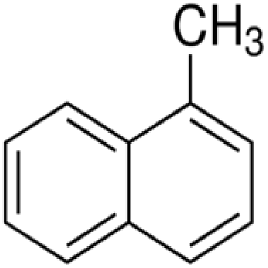
Naphthalene



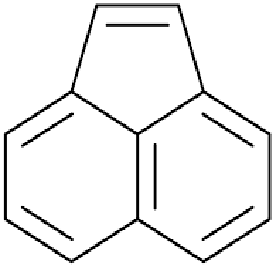
Fluorene



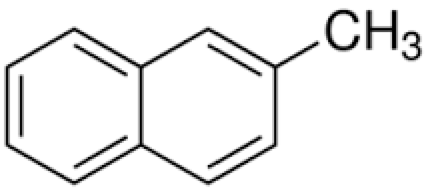
Acenaphtene



1 MethylNaphthalene



Acenaphtylene



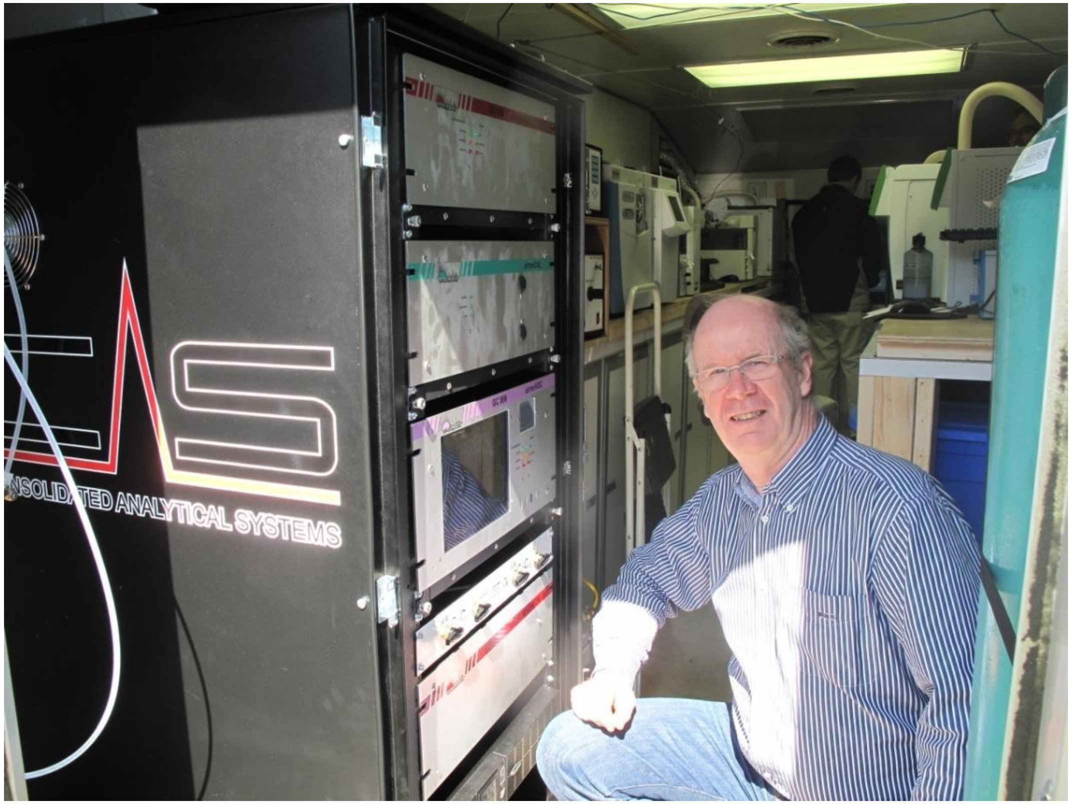
2 MethylNaphthalene

- Continuous air quality and emission gases monitoring

Main challenges :

- Ambient air is polluted by many VOCs coming from petrochemical industry, motor vehicle exhaust, industrial emissions, chemical solvents as well as biogenic emissions .
    - PAMS, Terpenes , Oxygenated, Halogenated, nitrogeneous or sulfur compounds
- Analyze precisely ambient air composition in different locations
- Continuous analysis with automatic validation of results
- More and more compounds (more than 120)
- In total compliance with government regulations

Expert analysis system



airmOzone with auto GC 866 **selected and bought** for final US EPA field tests with **Michel Robert (European WG 12 for Benzene and VOC measurement)**

Agenda

I. Polycyclic aromatic hydrocarbons (PAHs)

II. Instrument configuration with airmoSCAN XPERT solution : a trap/GC/FID/MS

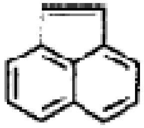
III. Advantages of the solution

IV. Industrial area study

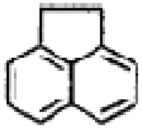
PAHs

- 100 different chemicals
  - Two or more fused benzene rings

Naphthalene



Acenaphthylene



Acenaphthene

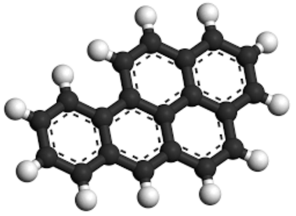
- Incomplet combustion of organic matter at high temperature
  - Anthropogenic
    - Industrial process
    - Vehicle exhausts
    - Domestic heating
  - Natural
    - Forest fires
    - Volcanoes

PAHs

- 16 PAHs selected by the US EPA
  - Mutagenicity
  - Carcinogenicity

	PAHs	Abbreviation	Chemical formula	CAS number	Number of fused benzene rings	Molar mass (g/mol)	Boiling point (°C)
1	Naphthalene	NAP	$C_{10}H_8$	91-20-3	2	128	218
2	Acenaphthylene	ACN	$C_{12}H_8$	208-96-8	3	152	280
3	Acenaphthene	ACL	$C_{12}H_{10}$	83-32-9	3	154	279
4	Fluorene	FLR	$C_{13}H_{10}$	86-73-7	3	166	298
5	Anthracene	ANT	$C_{14}H_{10}$	120-12-7	3	178	340
6	Phenanthrene	PHN	$C_{14}H_{10}$	85-01-8	3	178	340
7	Fluoranthene	FLT	$C_{16}H_{10}$	206-44-0	4	202	384
8	Pyrene	PYR	$C_{16}H_{10}$	129-00-0	4	202	390
9	Benzo(a)anthracene	BAA	$C_{18}H_{12}$	56-55-3	4	228	437
10	Chrysene	CHY	$C_{18}H_{12}$	218-01-9	4	228	448
11	Benzo(a)pyrene	BAP	$C_{20}H_{12}$	50-32-8	5	252	495
12	Benzo(b)fluoranthene	BBF	$C_{20}H_{12}$	205-99-2	5	252	481
13	Benzo(k)fluoranthene	BKF	$C_{20}H_{12}$	207-08-9	5	252	480
14	Benzo(ghi)perylene	BGP	$C_{22}H_{12}$	191-24-2	6	276	550
15	Indeno[1,2,3-cd]pyrene	ICP	$C_{22}H_{12}$	193-39-5	6	276	536
16	Dibenz(a,h)anthracene	DBA	$C_{22}H_{14}$	53-70-3	6	278	524

  - In Europe, ambient air legislation targets Benzo(a)pyrene
    - With annual target value of 1 ng/m^3



PAHs

- PAHs in the atmosphere are distributed between gas and particle phases
  - Atmospheric conditions
    - Temperature
    - Relative humidity
  - Physical properties
    - Lighter compounds tend to be in gas phase
      - 2-4 rings
    - Heavier ones almost complete association with particles
      - > 4 rings

  - Reactions contribute to the removal of gas-phase PAHs from the atmosphere:
    - ozone
    - $^{\bullet}OH$
    - $^{\bullet}NO_3$
    - photolysis at a lesser extent

L. Pozzoli, S. Gilardoni, M.G. Perrone, G. de Gennaro, M. De Rienzo, D. Vione, Ann. Chim. 94 (2004) 17.

PAHs

PAH	SINKS	ATMOSPHERIC LIFETIME
Naphthalene	$^{\bullet}OH \gg {}^{\bullet}NO_3, O_3$	6.8 daylight hours
1-Methylnaphthalene	$^{\bullet}OH \gg {}^{\bullet}NO_3, O_3$	2.8 daylight hours
2-Methylnaphthalene	$^{\bullet}OH \gg {}^{\bullet}NO_3, O_3$	2.8 daylight hours
Acenaphthylene	$^{\bullet}NO_3 > O_3 > {}^{\bullet}OH$	6 nighttime minutes 1 daylight hour
Acenaphthene	$^{\bullet}NO_3 > {}^{\bullet}OH \gg O_3$	1.2 nighttime hours 1.5 daylight hours
Fluorene	$^{\bullet}OH > {}^{\bullet}NO_3 \gg O_3$	9.1 daylight hours
Phenanthrene	$^{\bullet}NO_3 > {}^{\bullet}OH \gg O_3$	4.6 nighttime hours 11.2 daylight hours

- Light compounds are very sensitive to the amount of $^{\bullet}OH$
- The main source is the photolysis of ozone (λ < 320 nm)
  - $O_3 + h\nu \rightarrow O_2 + O\,(^1D)$
  - $O\,(^1D) + H_2O \rightarrow 2\ {\cdot}OH$
- Radicals react very rapidly
  - Negligible tropospheric concentration of •OH can be found during the night

L. Pozzoli, S. Gilardoni, M.G. Perrone, G. de Gennaro, M. De Rienzo, D. Vione, Ann. Chim. 94 (2004) 17.
B. J. Finlayson-Pitts, J. N. Pitts, Atmospheric Chemistry, Wiley, New York, 1986.

PAHs

- PAH concentrations in ambient air

	PAHs	Abbreviation	Chemical formula	CAS number	Concentration (ng/m3)	% Tot PAH
1	Naphthalene	NAP	$C_{10}H_8$	91-20-3	201.29	91.47
2	Acenaphthylene	ACN	$C_{12}H_8$	208-96-8	5.08	2.31
3	Acenaphthene	ACL	$C_{12}H_{10}$	83-32-9	7.61	3.46
4	Fluorene	FLR	$C_{13}H_{10}$	86-73-7	-	-
5	Anthracene	ANT	$C_{14}H_{10}$	120-12-7	1.19	0.54
6	Phenanthrene	PHN	$C_{14}H_{10}$	85-01-8	-	-
7	Fluoranthene	FLT	$C_{16}H_{10}$	206-44-0	2.12	0.96
8	Pyrene	PYR	$C_{16}H_{10}$	129-00-0	1.67	0.76
9	Benzo(a)anthracene	BAA	$C_{18}H_{12}$	56-55-3	0.1	0.05
10	Chrysene	CHY	$C_{18}H_{12}$	218-01-9	0.32	0.15
11	Benzo(a)pyrene	BAP	$C_{20}H_{12}$	50-32-8	0.12	0.05
12	Benzo(b)fluoranthene	BBF	$C_{20}H_{12}$	205-99-2	-	-
13	Benzo(k)fluoranthene	BKF	$C_{20}H_{12}$	207-08-9	-	-
14	Benzo(ghi)perylene	BGP	$C_{22}H_{12}$	191-24-2	0.35	0.16
15	Indeno[1,2,3-cd]pyrene	ICP	$C_{22}H_{12}$	193-39-5	0.17	0.08
16	Dibenz(a,h)anthracene	DBA	$C_{22}H_{14}$	53-70-3	0.03	0.01

Measurements of Ambient Naphthalene and Other Polycyclic Aromatic Hydrocarbons, South Coast Air Quality Management District

PAHs

- Measurements of ambient naphthalene in the South Coast Air Basin

Period of Measurement	Location	[Naphthalene] ng/m^3 (day)	[Naphthalene] ng/m^3 (night)
1986 (late winter, high NOx episode)[1]	Torrance	3315	2875
1986 (summer, smog episode)[2]	Glendale	3100	4300
1987 (spring)[3]	Reseda	750	1300
1993 (fall, smog episode)[4]	Los Angeles	6000	
1995[5]	Redlands	348 to 715	
2001 to 2002[6]	Southern CA	200 to 575	
2002 (summer)[7]	Los Angeles	~ 350	~ 140
2002 (summer)[7]	Riverside	~ 225	~ 40
2003 (winter)[7]	Los Angeles	~ 1400	~ 1000
2003 (winter)[7]	Riverside	~ 500	~ 150

[1] Arey et al, 1987 ; [2] Arey et al, 1989 ; [3] Atkinson et al, 1994 ; [4]Fraser, 1998 ; [5]Gupta, 1995 ; [6] Calvert et al, 2002 ; Eiguren-Fernandez et al, 2004 ; [7] Reisen, 2003

PAHs

- Very toxic
- Produced naturally and by human activities
- Gaseous or solid
- Lifetimes of light compounds in the gaseous phase is short
- To control their emissions and effects on people's health
  - Need to monitor continuously PAHs
  - Time between measurements < 1 hour
    - Vehicle exhaust
    - Industrial process
  - Naphthalene needs to be monitored
    - Most abundant PAH
    - Mainly gaseous
- Gaseous phase represent more than 96% of the total PAH amount

Agenda

I. Polycyclic aromatic hydrocarbons (PAHs)

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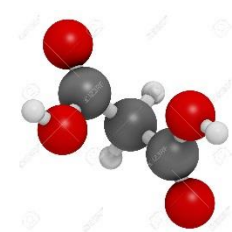
III. Advantages of the solution

IV. Industrial area study

Why do we need auto TDGC-FID/MS for PAHs monitoring

What does the customer want?

- Analytical system fully automatic
- No need to send samples to laboratories
- No possible mistake for compounds identification
- No Engineer needed to operate the system
- Increase process performances



Why do we need auto TDGC-FID/MS for PAHs monitoring

What does the system do

Automatic validation of results

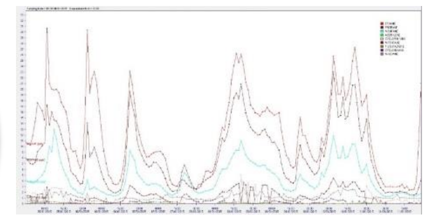
Automatic trends

Direct sampling on-site

No possible mistake for compounds identification

Automatic calibration check

Quantify and identify with two detectors



airmoSCAN $_{\text{XPERT}}$ PAHs configuration

airmSCAN XPERT PAH configuration

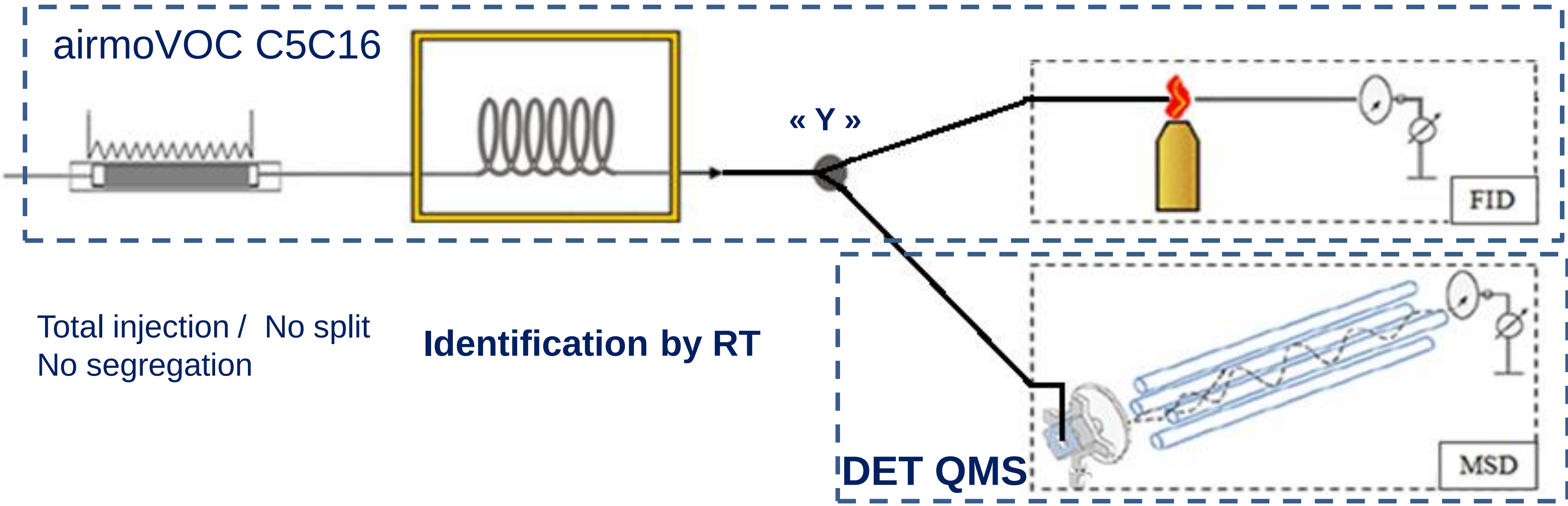
airmoC5C15 with Process MS

- airmoVOC C5-C16 5U
- Process Mass spectrometer (0-300 amu) 10U
- 1U rack with mouse and key board
- Hydroxychrom (H2 generator) 4U
- airmoCAL MFC in option
- airmoPURE (zero air generator)
- Sampling pumps included

auto GC FID and MS General operation

MFC for volume sampling calculation

Chromatographic metallic column



Total injection / No split
No segregation

Identification by RT

TRAP for

pre-concentration

GC for Speciation

« Y » and MS multiplexer

Double Detection
MS & FID
by auto GC 866

Agenda

I. Polycyclic aromatic hydrocarbons (PAHs)

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Specialty of the solution

- Combination of two technologies for Very high sensitivity

1. **Auto GC 866 with µ-FID**
   - Compounds concentration using a **trap** for **Low ppt and ppq**
   - Compounds speciation with pure hydrogen First identification by RT
   - Automatic quantification certified by different organisms
     - mCERTs 2013 ; worlwide expertises recognized by national institutes...
     - US EPA selected in 2014

Specialty of the solution

➢ Combination of two technologies : Very high sensitivity

2. Auto GC FID 866 with Mass Spectrometer

- Highly sensitive universal detector (ppt – ppb)

- Selective detector

- Identification by mass analysis : certification of the identification (from ppt level)
- Automatic quantification in MID mode (ppt or ppb level)

- Allows deconvolution of chromatographic peaks: automatic quantification of coeluted compounds

- Identification of unknown compounds by library in SCAN mode

Why two detectors used after speciation ?

- Quantification with GC-MS :
- Response factors = RF are determined experimentally
  - Drift of source conditions require frequent calibration
  - **Calibration must be done on all compounds**

- Quantification with GC-FID :
  - Theoretical response (ECN)[1] factors verified experimentally
  - **Response Factors = RF relative to Benzene or Naphthalene**
  - **Calibration can be done on only one compound**
  - airmoVOC is mCERTs certified and selected by US EPA

[1] Scanlon, J.T., and Willis, D.E., *J. Chromatogr. Sci*. 23, 333-340 (1985)

Why two detectors used after speciation ?

- Quantification with GC-FID is used automatically for all compounds because of bellow reason:
  - long term stability (several years)
  - linearity of FID detectors FID
    - **More precise: GC-FID expert for quantification on peak area**
- Identification is done by GC-FID and confirmed automatically by GC-MSD
  - **GC-MSD expert for identification on mass**
- Quantification with GC-MSD is done automatically on all compounds and is used when: GC-MS：
  - Correlation between RT of FID and MSD is not good
  - Correlation between concentration of FID and MSD is not good
  - Drift of Retention Time
  - Co elution
  - Signal saturation
  - Compounds with bad response factor to FID

Automatic quantification

- Identification and quantification done by FID and MS simultaneously
  - Automatic identification and quantification of all compounds by GC FID:
    - Substance table on airmoVOC C5C16
  - Automatic identification and quantification of all compounds by GC MS in **MID mode**
    - Ion list and window of retention time for C5C16 MS coupling
    - Quantification is done on ion peak height
- Identification and quantification of unknown compounds (not in the list) in **SCAN mode**
  - 1st Comparison with embedded CHROMATOTEC library
  - If not in CHROMATOTEC library the mass spectrum can be sent to CHROMATOTEC for identification by R&D department
    - Comparison with NIST library and confirmation by injection of the pure compounds in airmoSCAN XPERT

Quantification of co-elutions with Vistachrom MS module

- Coeluted compounds
  - GC-MS records all data and inform user of coelutions automatically
  - MS quantify automatically all coeluted compounds
- Retention times recorded by:
  - GC-FID Vistachrom
  - GC-MS software
- GC-MS records all RT even with very important RT modification
  - Easy data reprocess even with large number of molecules

Quantification of co-elutions with Vistachrom MS module

- Automatic Communication between instruments
  - Complementary information
  - Alarm systems for co-elution and modification of retention times

Automatic data validation with internal calibration

CHROMATOTEC QC

Cross verification with Permeation tubes & cylinders from different companies

Instruments are tested for 2 weeks with different standards

⇒**> 120 different compounds   120**

⇒More compounds in option

•GC-FID

- Relative response factors to Benzene
- Calibration
- Peak speciation

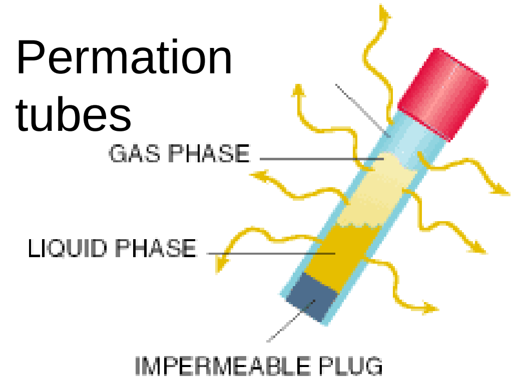
•GC-Mass Spectrometer

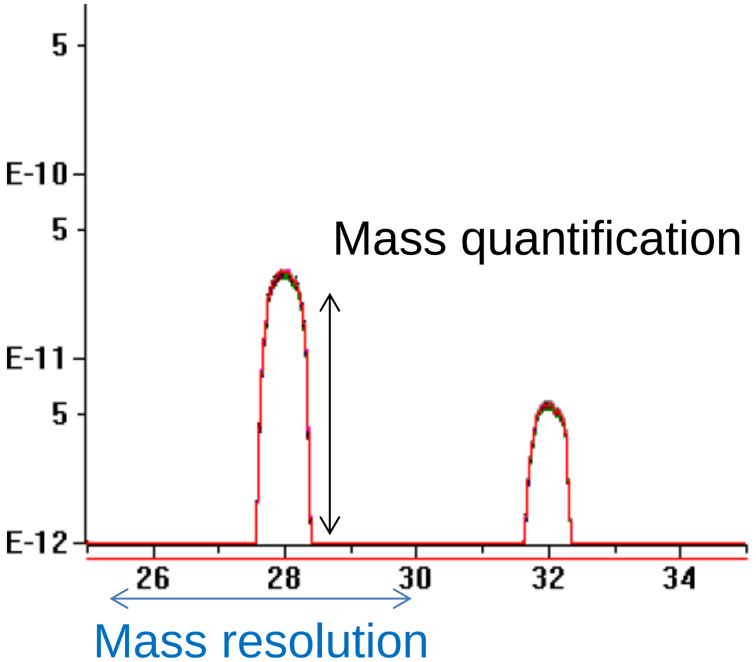
- Calibration
- Targeted Ion list for automatic identification and quantification
- Library for fragmentation patterns used to identify unknown compound

Automatic validation/Calibration using permeation tubes

- For quantification
  - GC-FID

  Automatic **validation** (mCERTS)
  - GC-MS
    - Auto-correction
    - Mass quantification
    - Daily calibration validation
- For mass scale resolution
  - MS
    - Automatic daily validation with CALIB
    - Validation by user
    - Need to be checked once a year





All-in-one solution with embedded supervisor

- Embedded computer including VISTACHROM software used for management of:
  - The analyzers:
    - C5C16
    - Process Mass spectrometer
  - The peripherals
    - Air & Hydrogen generators,
    - Calibrator
    - Streams multiplexer

  - Data acquisition management with Real-Time Data Base (RTDB)
  - Warnings & alerts of all parameters and data stored in RTDB
  - Remote access for easier maintenance

auto GC FID and MS automatic management of the data: analysis

Vista MS 2.0 → Data transfer → Comparison RT and C° with GC-FID

Automatic calculation of :
-Concentration for each compounds
-Retention time for each compounds

Automatic transfer of the data between Vista MS on DET QMS supervisor and MathModule software on airmoVOC supervisor
Data available on RTDB

Automatic comparison:

-between FID RT and MSD RT
-between FID concentration and MSD concentration
Automatic emission of comparison report

Done by VistaMS 2.0 software on DET QMS supervisor

Done using LAN connection between the 2 supervisor

Done by MathModule software on airmoVOC supervisor

auto GC FID and MS automatic management of the data: analysis

140704-MSGC-SynchroAlarm - Bloc-notes

Fichier Edition Format Affichage ?

```
05:09   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
05:09   BENZENE found in MS, not found in GC [MS : 1 / GC : 0]
05:09   TOLUENE found in MS, not found in GC [MS : 1 / GC : 0]
05:09   M_P_XYLENE not found in GC results [Result]
05:09   ##### Synchronization for results : KO####
05:39   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
05:39   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
05:39   M_P_XYLENE not found in GC results [Result]
05:39   ##### Synchronization for results : KO####
06:09   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
06:09   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
06:09   M_P_XYLENE not found in GC results [Result]
06:09   ##### Synchronization for results : KO####
06:39   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
06:39   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
06:39   M_P_XYLENE not found in GC results [Result]
06:39   ##### Synchronization for results : KO####
07:09   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
07:09   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
07:09   BENZENE retention time difference is too high [MS : 270 / GC : 264.86669921875]
07:09   M_P_XYLENE not found in GC results [Result]
07:09   ##### Synchronization for results : KO####
07:36   ##### Process results for #20730509.Results.AMBMSQU.CALIB30M ####
07:36   ##### Synchronization for results : KO####
08:06   ##### Process results for #20730509.Results.AMBMSQU.CALIB30M ####
08:06   ##### Synchronization for results : KO####
08:39   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
08:39   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
08:39   BENZENE found in MS, not found in GC [MS : 1 / GC : 0]
08:39   TOLUENE found in MS, not found in GC [MS : 1 / GC : 0]
08:39   M_P_XYLENE not found in GC results [Result]
08:39   ##### Synchronization for results : KO####
09:09   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
09:09   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
09:09   M_P_XYLENE not found in GC results [Result]
09:09   ##### Synchronization for results : KO####
09:39   ##### Process results for #20730509.Results.AMBMSQU.AMB-30HT ####
09:39   MS Result file was not relevant for the substance  (0 or 1 was expected instead of INI)
09:39   M_P_XYLENE not found in GC results [Result]
09:39   ##### Synchronization for results : KO####
```

Outline

I. Instrument configuration

II. Advantages of the solution

III. Industrial area study

   I. Phase 1: Laboratory tests

   II. Phase 2: On-site tests

Phase 1

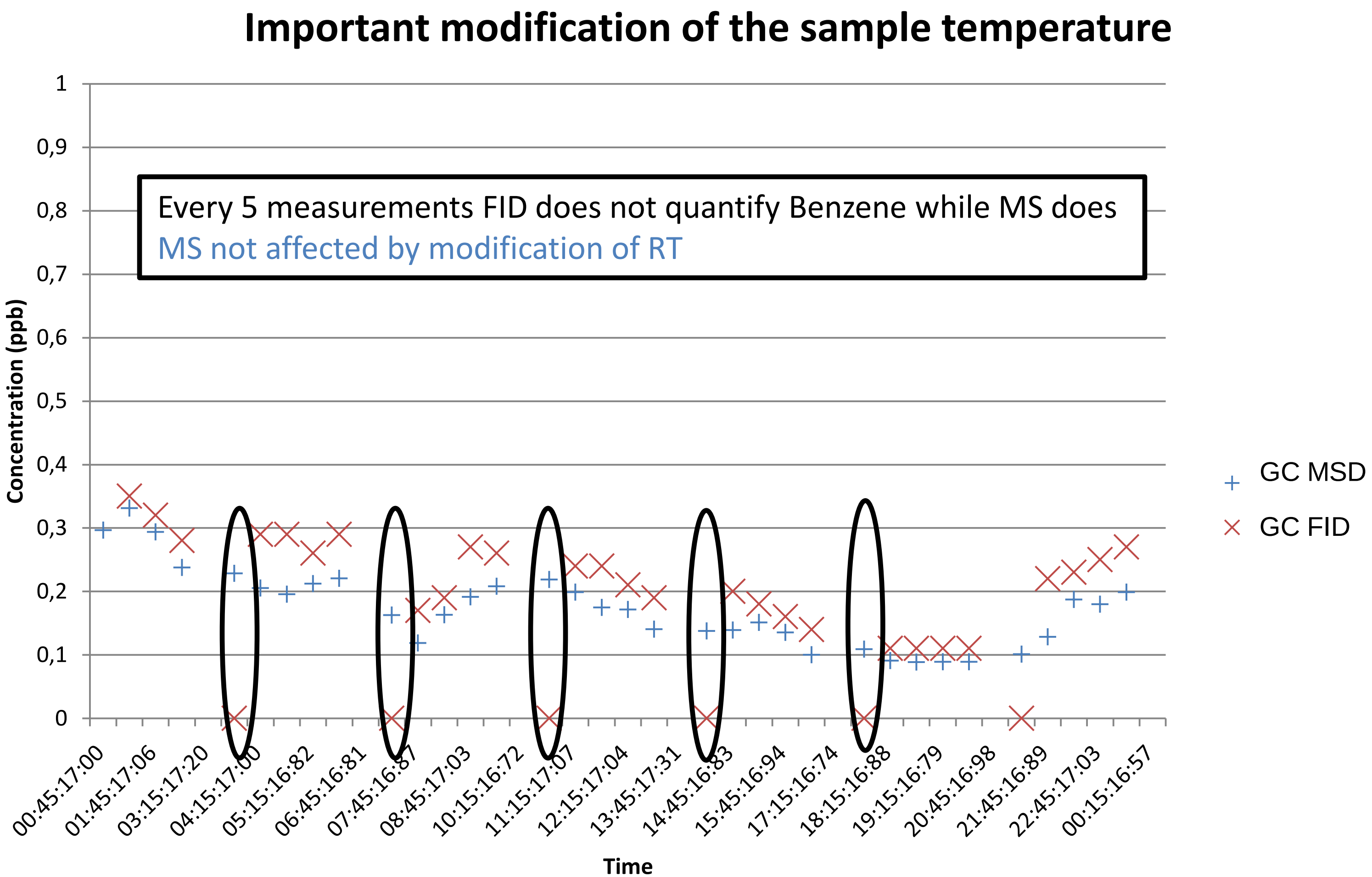
Solution for problems which can happen with instruments in field environment

- Important variations of external conditions
  - Temperature
  - Vibration
  - Shelter power off
- Important variation of sample concentration and matrix
  - Humidity
  - High increase of concentration
  - New Unknown compounds and or co-elution

Problems on GCs：

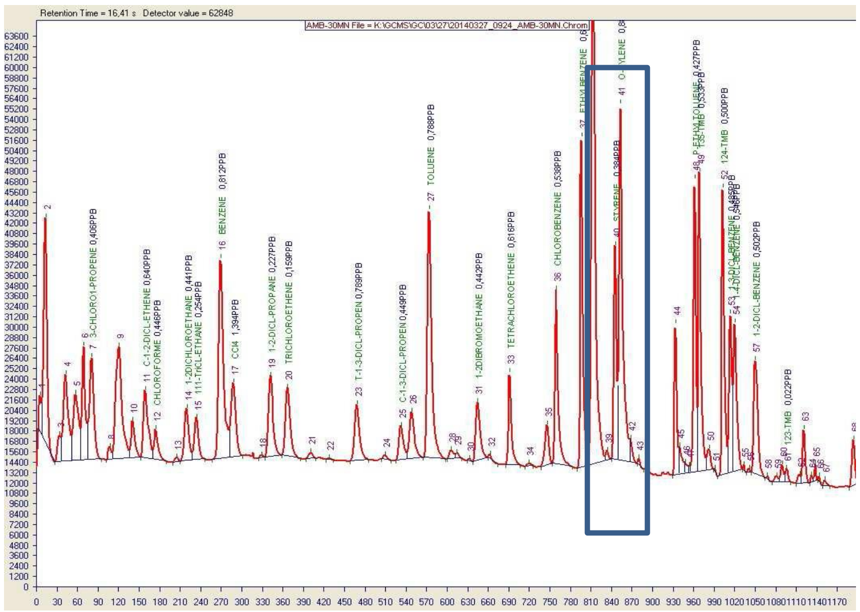
- Modification of retention times
- Signal saturation
- Over-estimation of signal due to co-elution

Phase 1

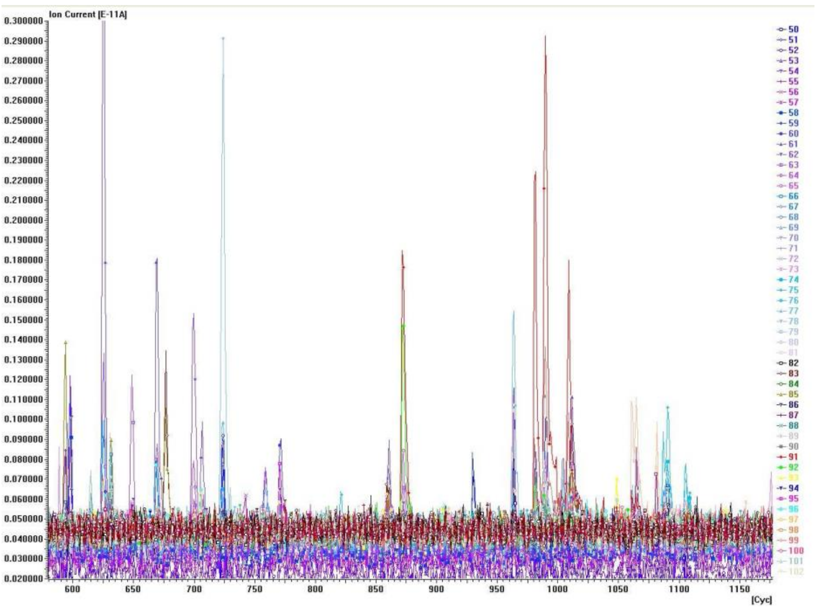


One concentration not measured by the GC-FID

MS Quantification of co-elutions



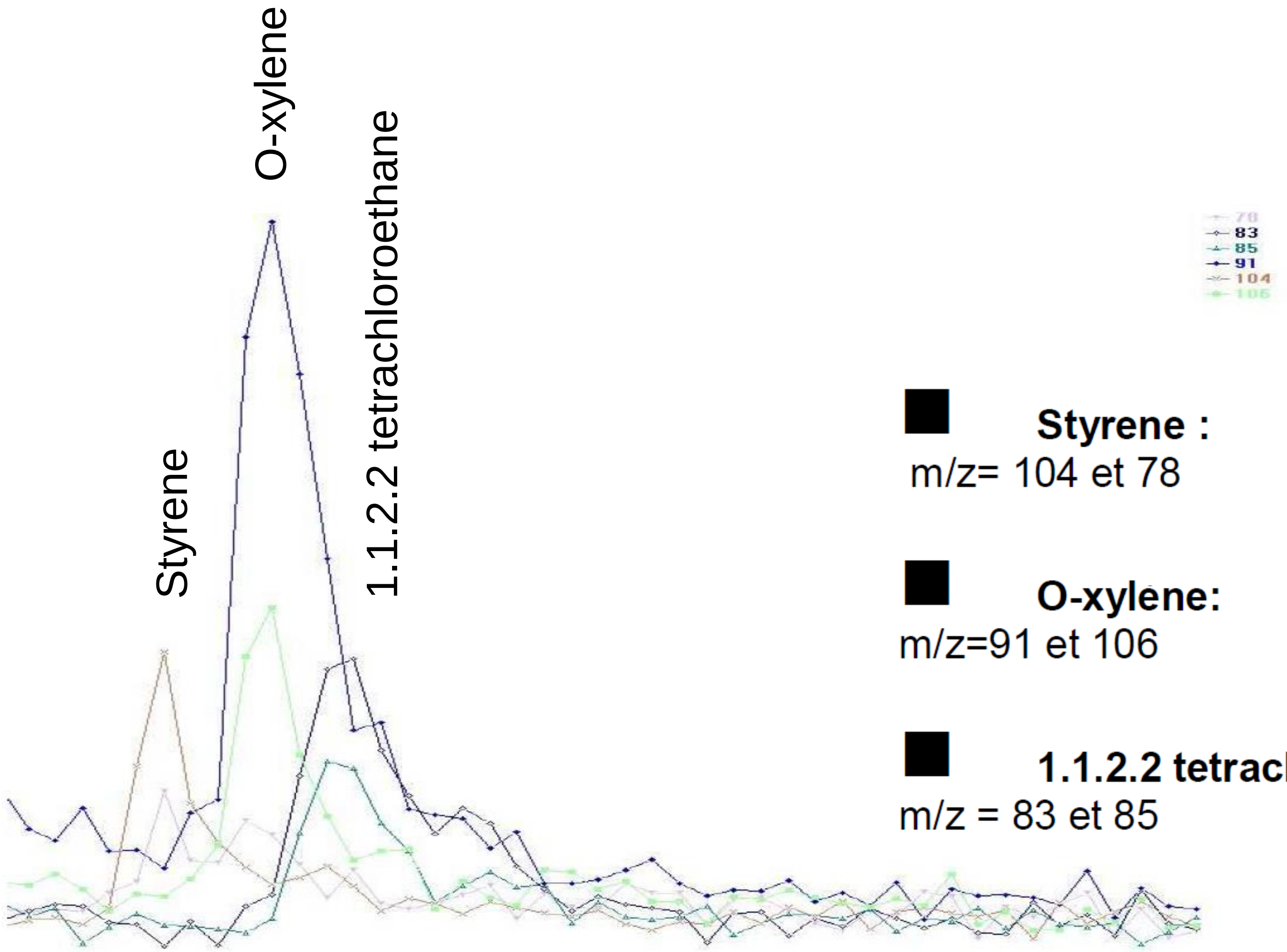
GC-FID



One color by mass

GC-MS

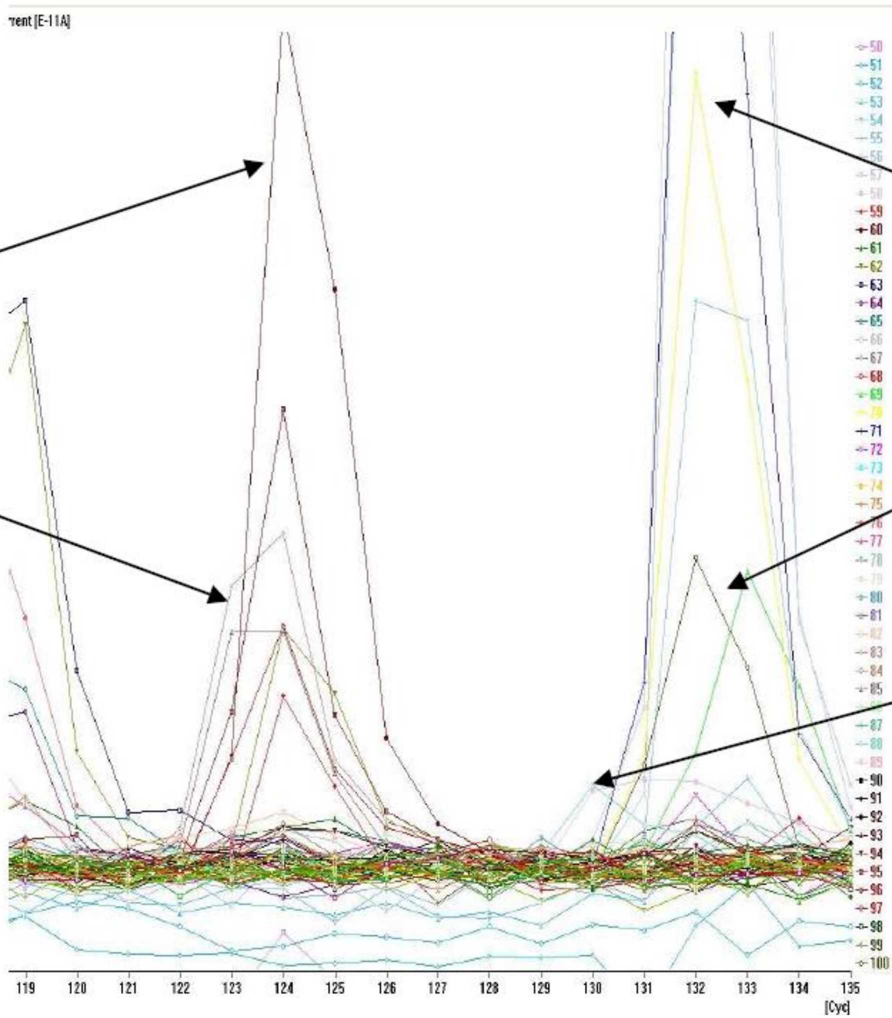
MS Quantification of co-elutions



- **Styrene :** m/z= 104 et 78
- **O-xylene:** m/z=91 et 106
- **1.1.2.2 tetrachloroethane** m/z = 83 et 85

Quantification of co-elutions

TO15

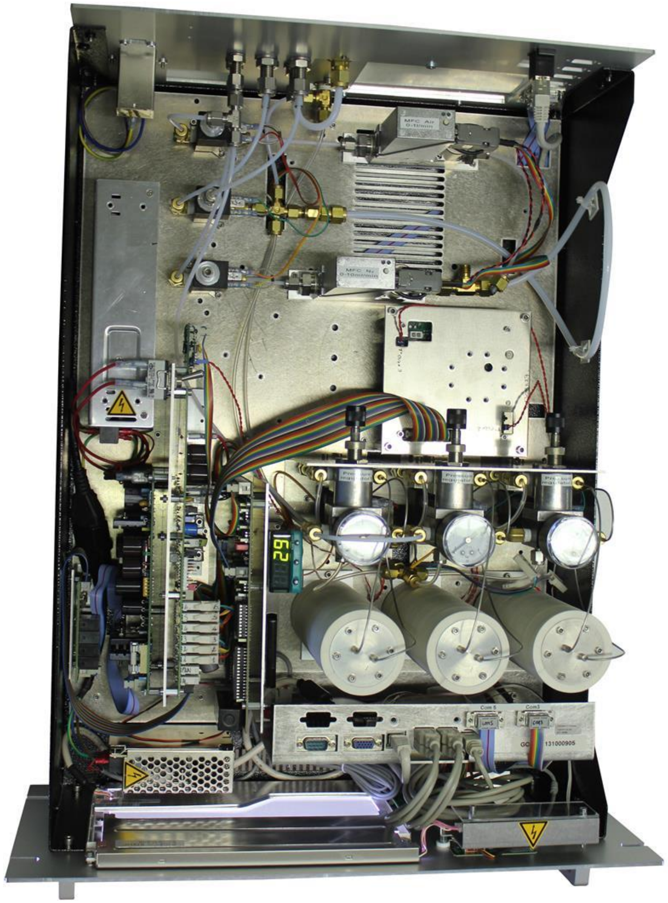


Laboratory tests

Naphthalene in air

- Permeation tubes
  - 20 ng/min
  - 60 °C

- Analytical conditions
  - Sampling times
    - 300 s – 1200 s
    - At 3 ppb (naphthalene)
  - Concentrations

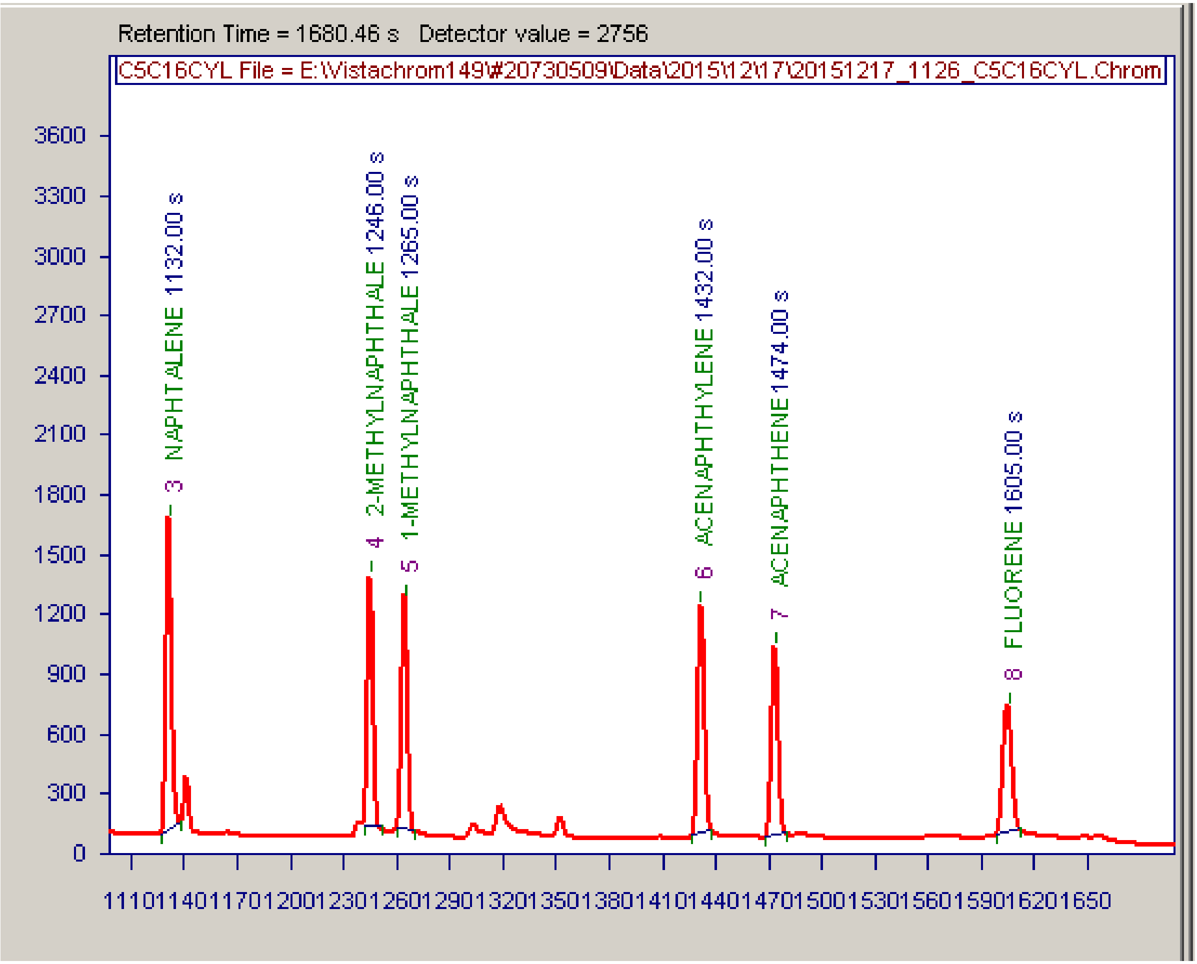


Laboratory tests

- Sample
  - SV Calibration Mix (Restek)
    - 18 components
    - 2 mg/ml in methylene chloride

Acenaphthene (83-32-9)
Acenaphthylene (208-96-8)
Anthracene (120-12-7)
Benz(a)anthracene (56-55-3)
Benzo(a)pyrene (50-32-8)
Benzo(b)fluoranthene (205-99-2)
Benzo(ghi)perylene (191-24-2)
Benzo(k)fluoranthene (207-08-9)
Chrysene (218-01-9)
Dibenz(a,h)anthracene (53-70-3)
Fluoranthene (206-44-0)
Fluorene (86-73-7)
Indeno(1,2,3-cd)pyrene (193-39-5)
1-Methylnaphthalene (90-12-0)
2-Methylnaphthalene (91-57-6)
Naphthalene (91-20-3)
Phenanthrene (85-01-8)
Pyrene (129-00-0)

Laboratory tests



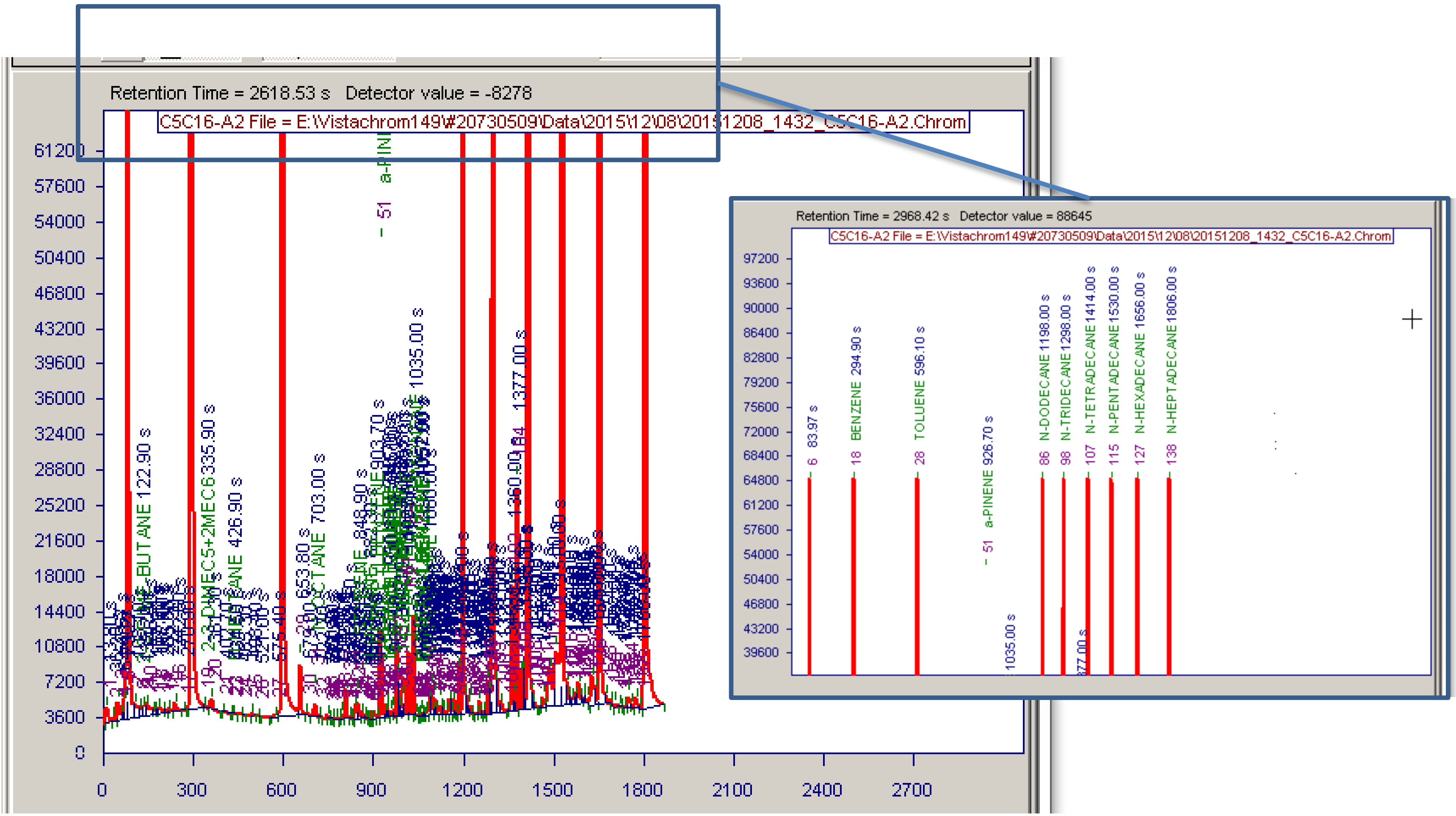
6 first PAHs are analyzed

Laboratory tests

- Mass spectrometer can identify and quantify
  - Automatic identification and quantification without reprocess
  - Index of toxicity can be automatically calculated at each analysis

- Analysis by GCMS of 6 PAHs
  - Naphthalene
  - 1 MethylNaphthalene
  - 2 MethylNaphthalene
  - Acenaphtylene
  - Acenapthene
  - Flurorene
    - Straight Alkane can be measured also up to C17

Straight alkane analysis



Compound from benzene to C17 analyzed

Outline

I. Instrument configuration

II. Advantages of the solution

III. Industrial area study

    I. Phase 1: Laboratory tests

    II. Phase 2: On-site tests

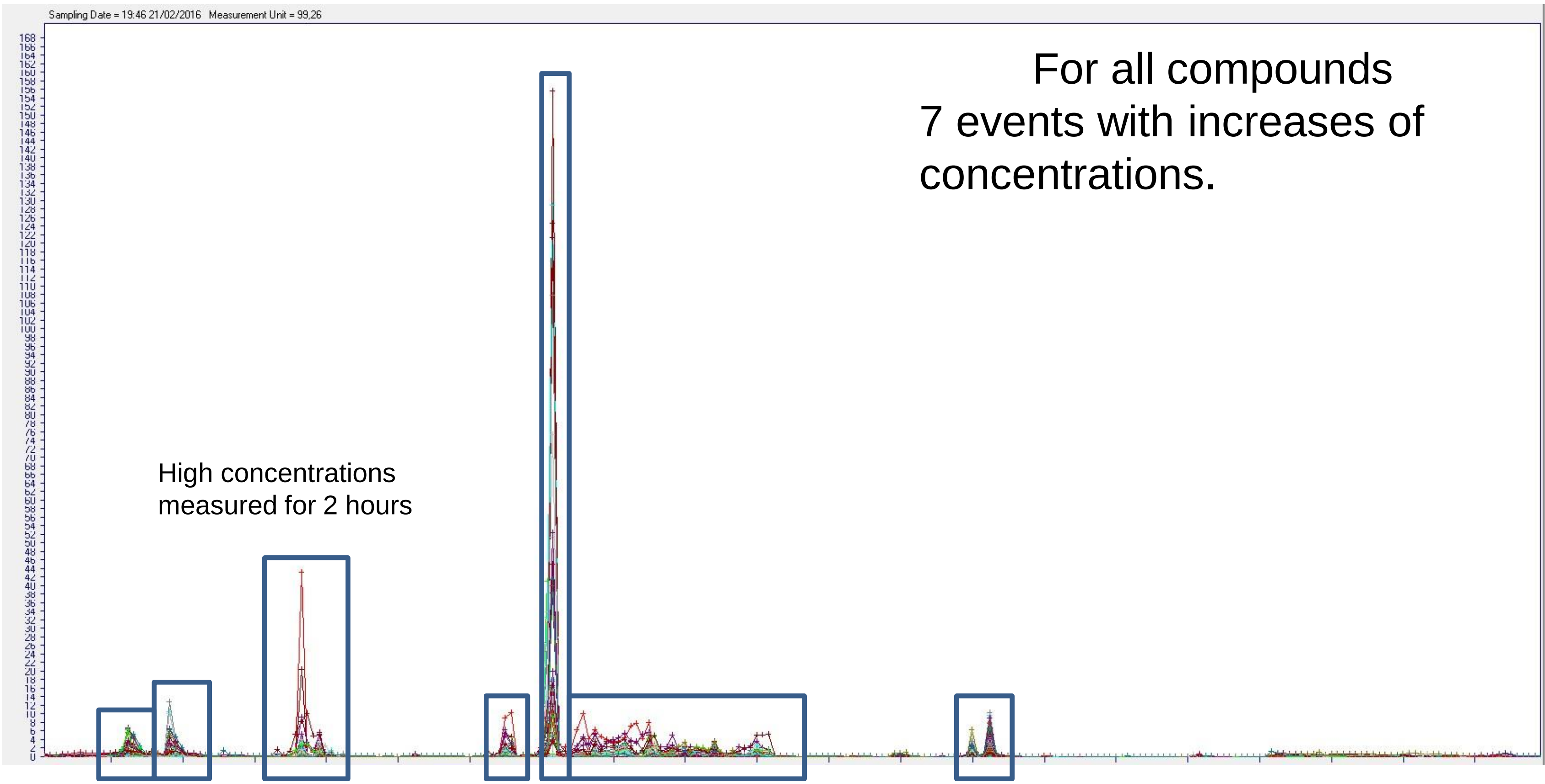
Field tests

- Continuous monitoring of C5-C16 and 6 first PAHs
- Location
  - South of France
- Industrial site
- Collaboration with South France Air Quality Management district
  - air languedoc roussillon

Monitored compounds	
1-PENTENE	I-PROPYLBENZENE
N-PENTANE	A-PINENE
2-2-DIME-BUTANE	N-PROPYLBENZENE
2-ME-PENTANE	M-ETHYLTOLUENE
3-ME-PENTANE	P-ETHYLTOLUENE
2-ME-1-PENTENE	135-TMB
1-HEXENE	O-ETHYLTOLUENE
N-HEXANE	B-PINENE
ME-CYCLOPENTANE	124-TMB
2-4-DIME-PENTANE	1-3-DICL-BENZENE
BENZENE	N-DECANE
CYCLOHEXANE	1-4-DICL-BENZENE
2-3-DIMEC5+2MEC6	123-TMB
3-ME-HEXANE	LIMONENE
224-TME-PENTANE	M-DIETHYLBENZENE
N-HEPTANE	P-DIETHYLBENZENE
ME-CYCLOHEXANE	N-UNDECANE
234-TME-PENTANE	NAPHTALENE
TOLUENE	N-DODECANE
2-ME-HEPTANE	N-TRIDECANE
3-ME-HEPTANE	2-METHYLNAPHTHALE
N-OCTANE	1-METHYLNAPHTHALE
ETHYLBENZENE	N-TETRADECANE
M&P-XYLENES	ACENAPHTHYLENE
STYRENE	N-PENTADECANE
O-XYLENE	N-HEXADECANE
N-NONANE	

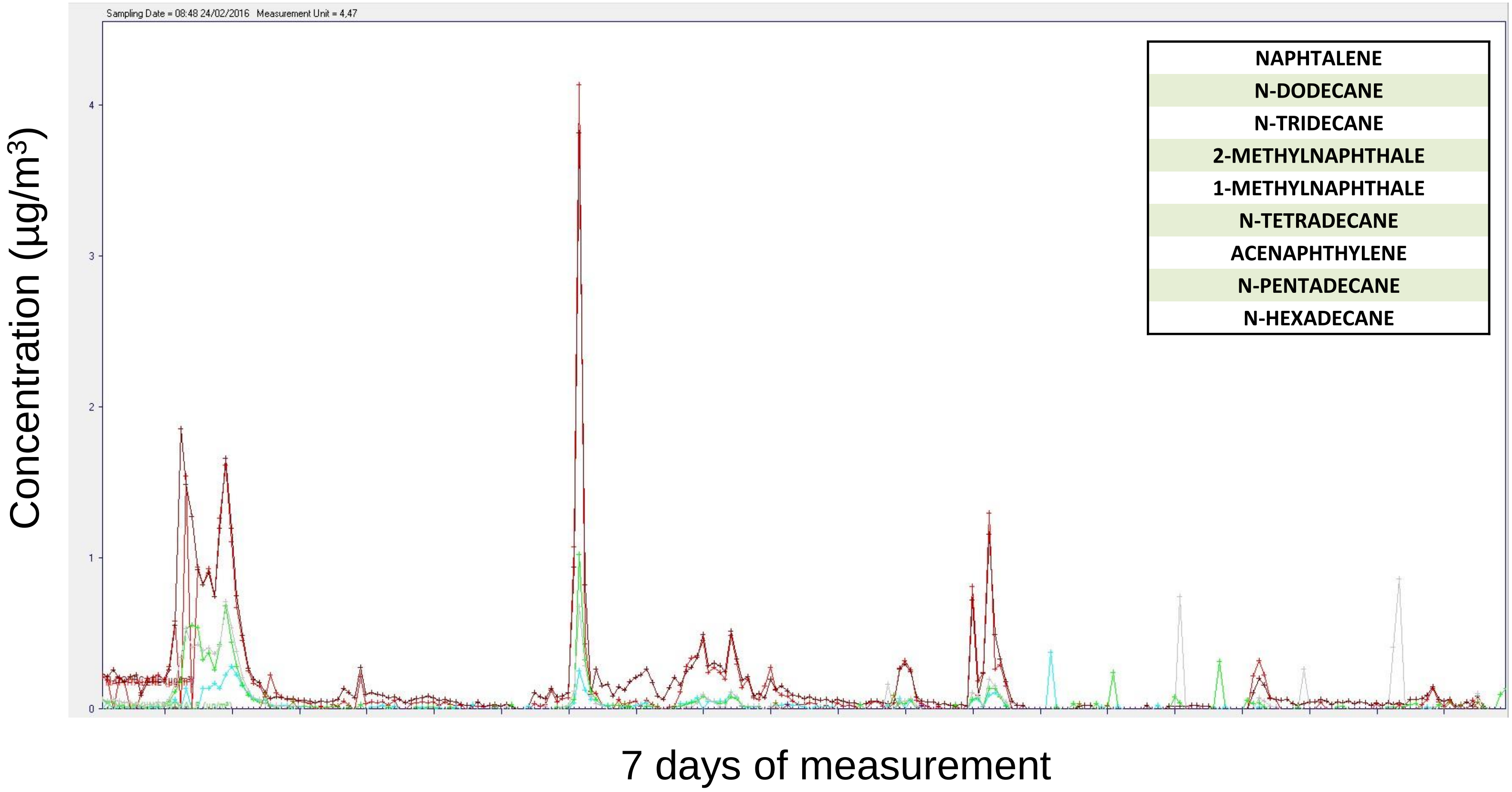
Field tests

Concentration (µg/m^3)

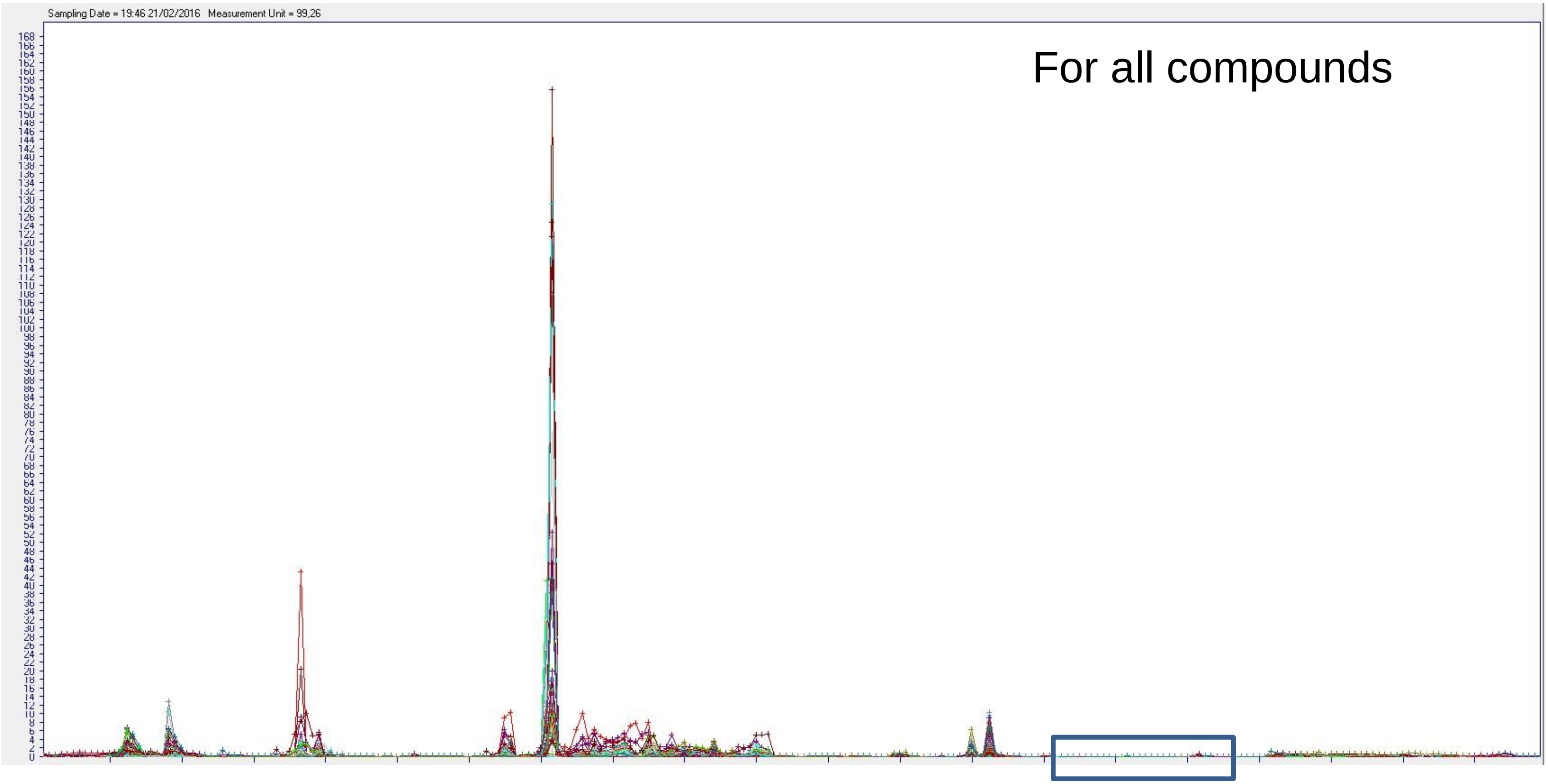


7 days of measurement

Field tests


Sampling Date = 08:48 24/02/2016 Measurement Unit = 4,47
Concentration (µg/m3)
NAPHTALENE
N-DODECANE
N-TRIDECANE
2-METHYLNAPHTHALE
1-METHYLNAPHTHALE
N-TETRADECANE
ACENAPHTHYLENE
N-PENTADECANE
N-HEXADECANE
7 days of measurement

Field tests

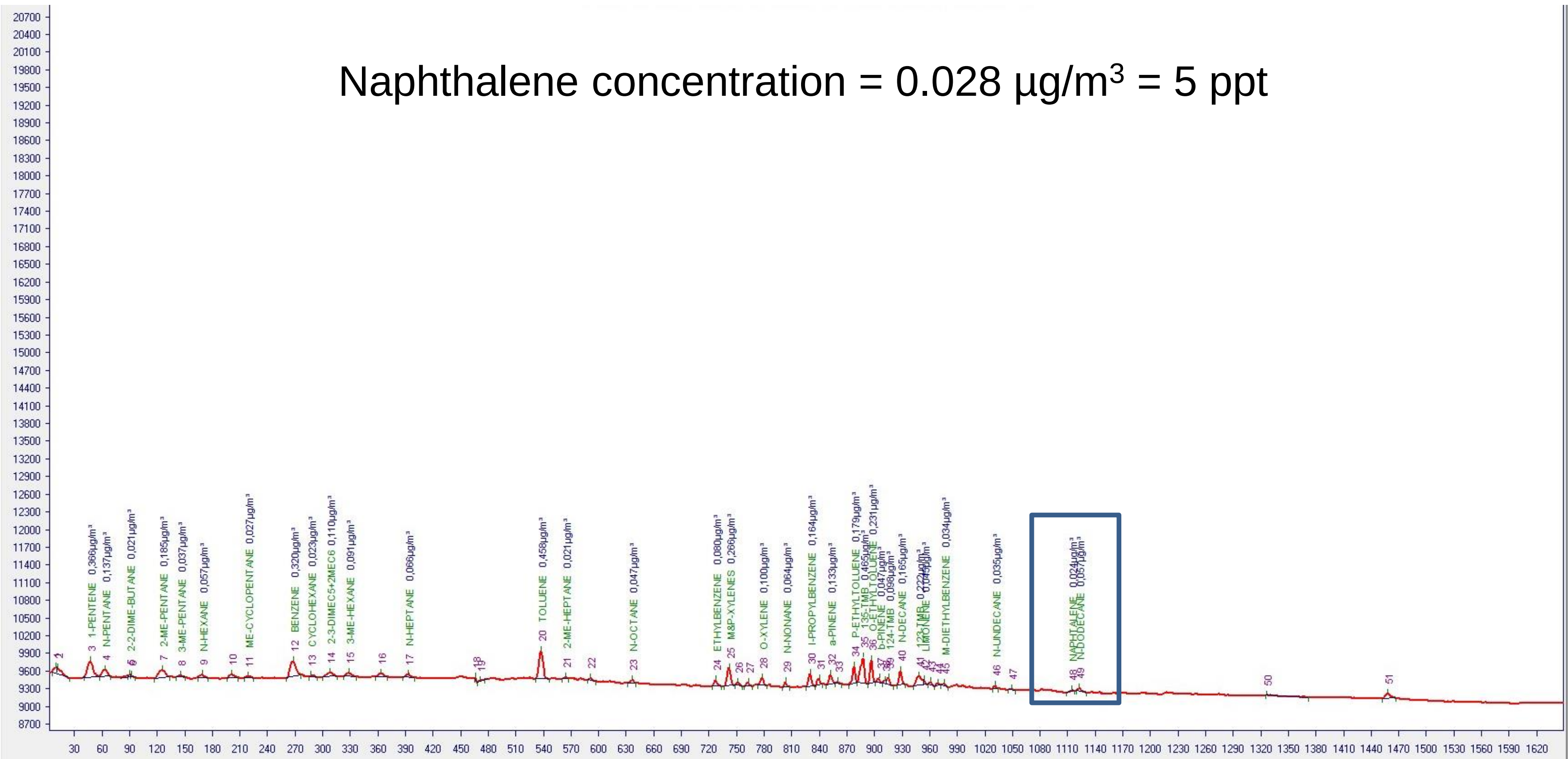


Concentration (µg/m³)

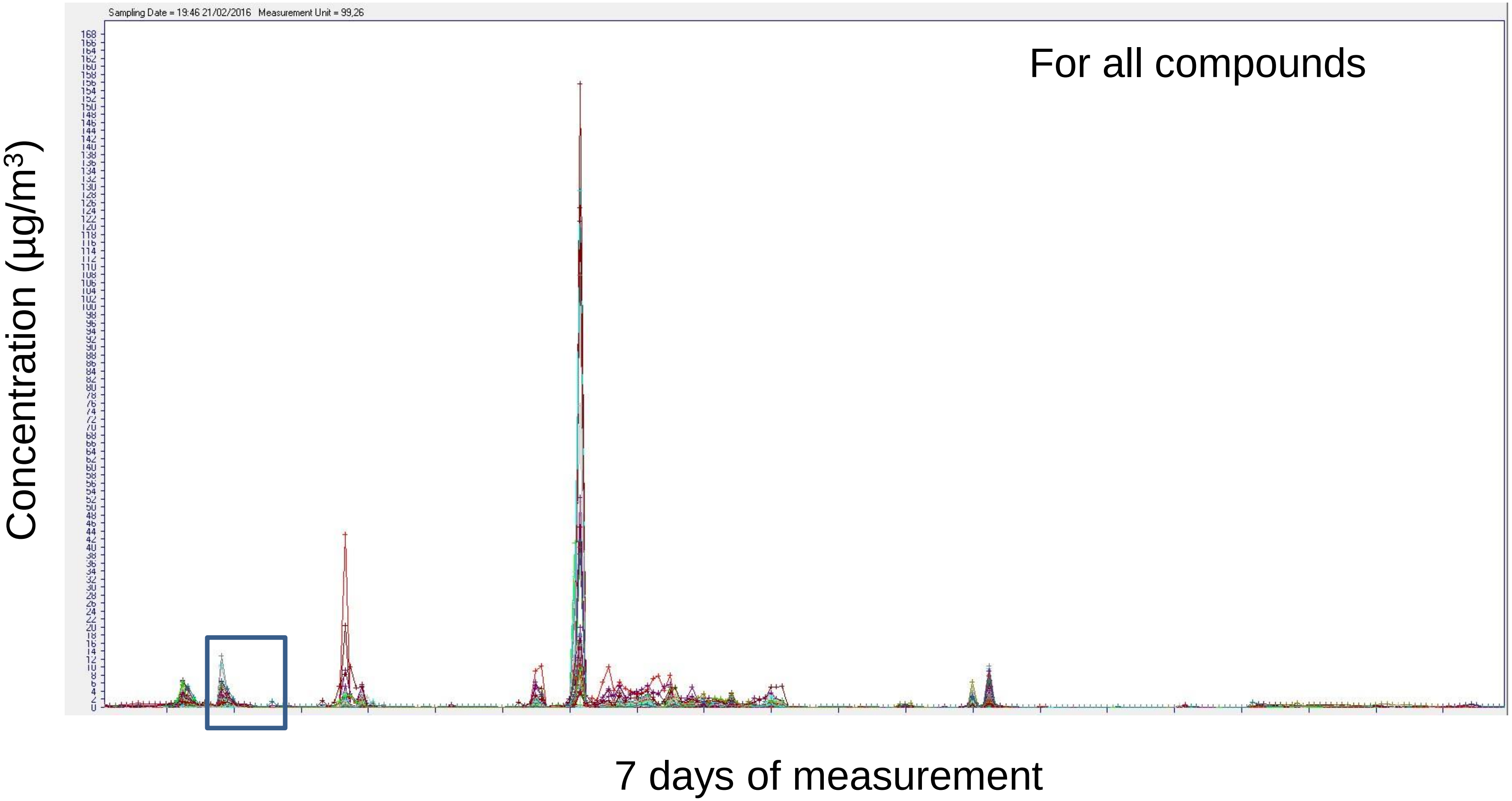
7 days of measurement

Field tests

Low concentration profile

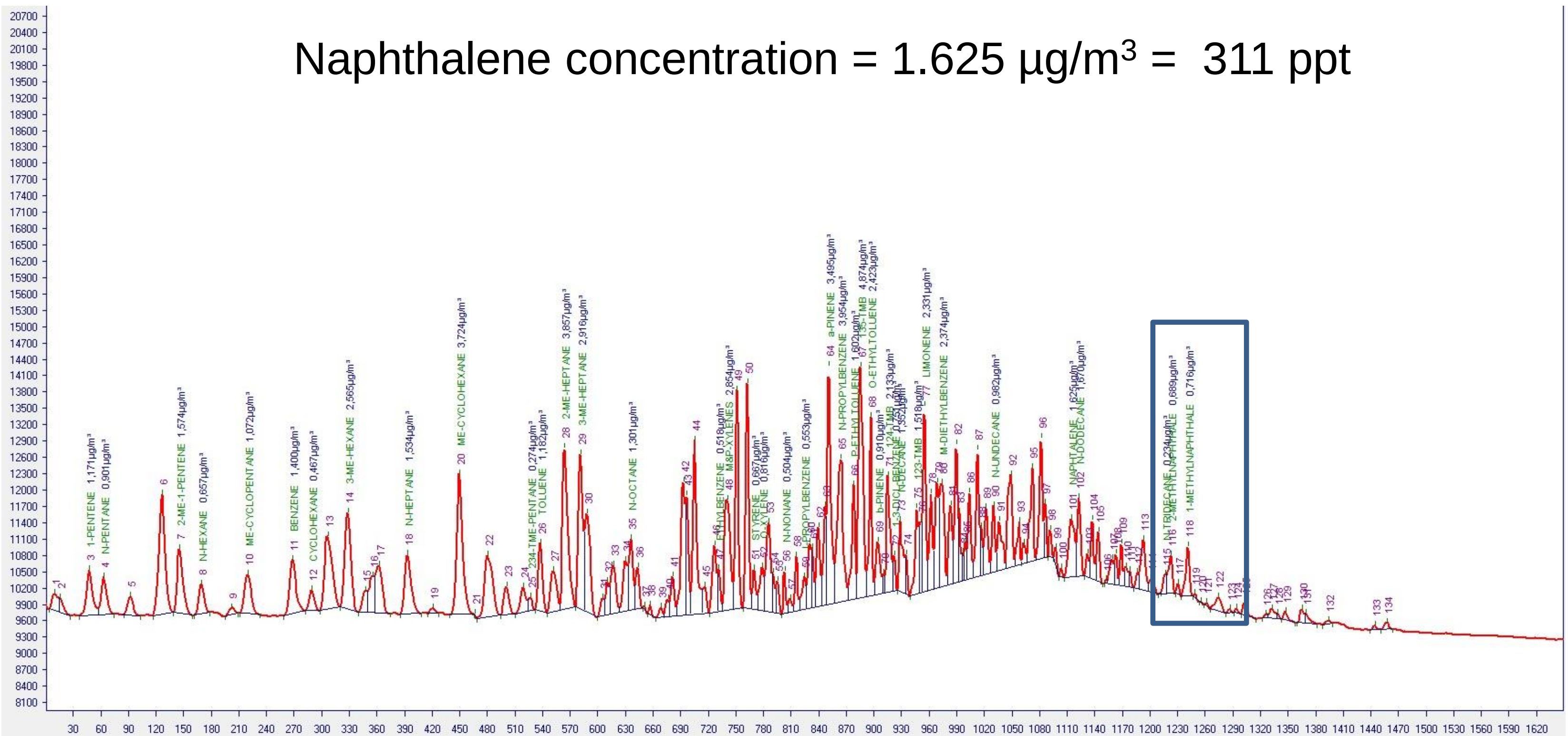


Field tests



Sampling Date = 19:46 21/02/2016 Measurement Unit = 99,26
For all compounds
Concentration (µg/m3)
7 days of measurement

Field tests



Field tests

- Analysis of VOCs and PAHs
  - From C5 – C16 for straight alkanes / alkenes and aromatic hydrocarbons
  - From Naphthalene to Fluorene for PAHs
- Continuous monitoring allows the measurement of short increases of concentrations

Conclusion

- AirmoSCAN XPERT PAH Composed by airmoC5C16 and Process MS
  - Continuous system
  - 1 hour cycle
  - Automatic validation by process MS
  - Analyze 6 first PAHs
  - System restart in one hour

Conclusion

- Double identification & quantification of all chemicals compounds from C5 to C16 thanks to the autoGC/FID/MS
  - Concentrations from **ppt,** ppb, ppm to %
  - Embedded supervisor with RTDB
- Automatic data validation using embedded permeation tubes
- Flexible & evolutive system
  - airmVOC C5C16 upgrade with MS
  - Easy to use for non-chemists
  - **mCERTs certified for working 24h/24, 7d per week**

    > 3 month without operator intervention

Current status & Perspectives

- Other compounds
  - Aldehydes ; Sulfur (HCHO ; Mercaptans)
  - **CH4 / NMTHC / THC and VOC up to Naphthalene**
  - Odors
- MS coupled with auto GC FID 866
  - VOC ; OVOC ; halogenated compounds

    VOC， OVOC
  - **PAH's in particulate phase from C17 to c22 & PAC's, PCB's / DIOXINES**

Sales Contact

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Thank you for your attention !