Gas Sensor Arrays in Lab and Process Control Applications

Potential Advances in Biological and Medical Applications

AIRSENSE
ANALYTICS

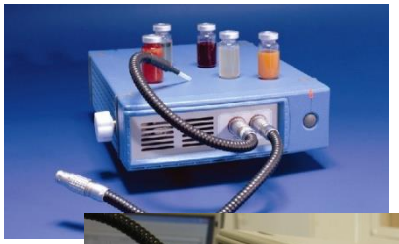
IngenieríaAnalítica
Chromatography & Spectrometry

Technology Line

I
Sensor Arrays
Electronic Nose
PEN3

iPEN

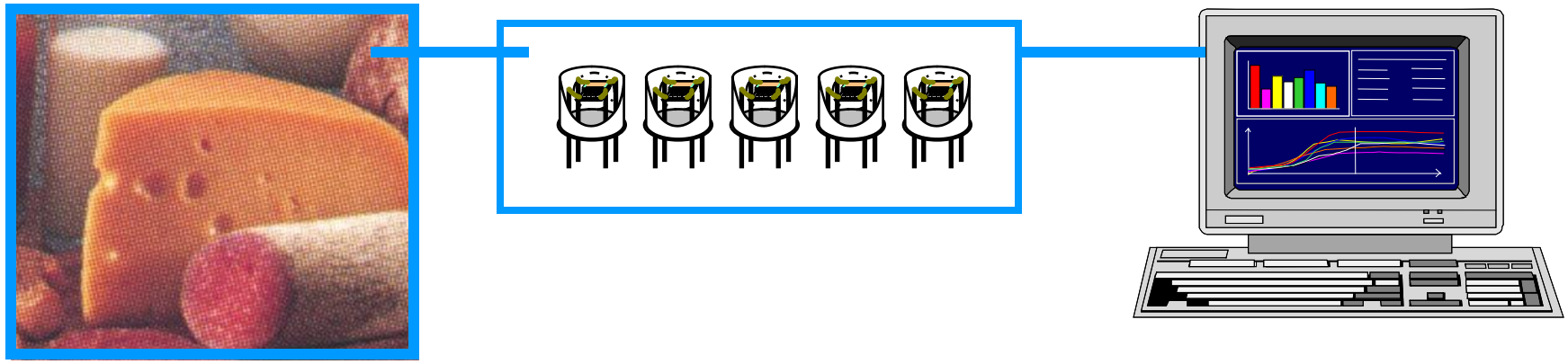
II
Trap&Thermal
Desorption
EDU3,…



Micro-TD,
EDU-GC, EDU-GD

III
Gas Detector Array
GDA
Hybrid Array

The Electronic Nose Concept



The electronic nose is an instrument, which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern-recognition system, capable of recognizing simple or complex odors (Gardner & Bartlett)

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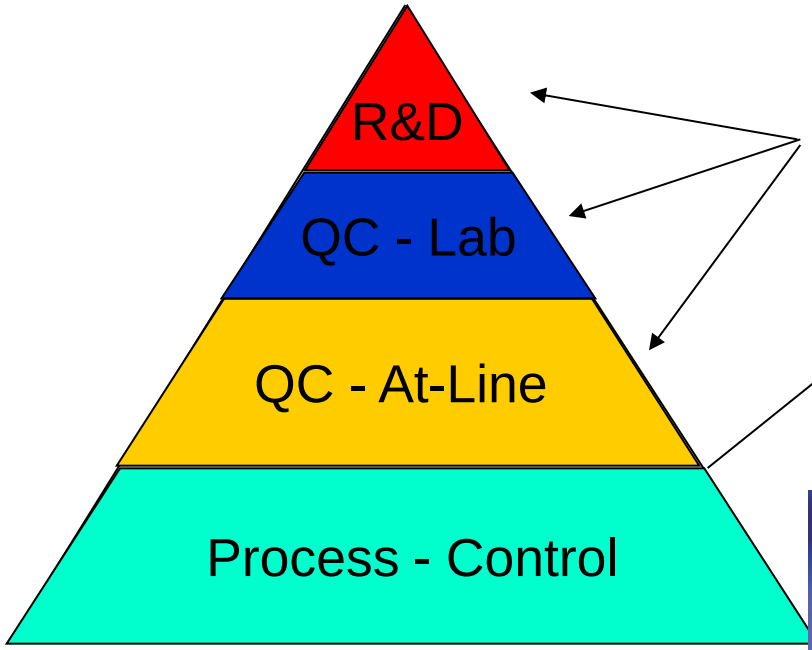
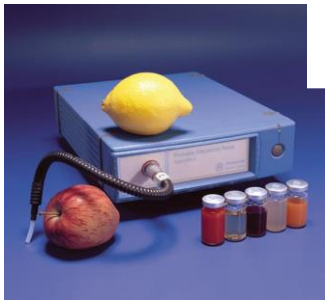
Applications and Market



PEN-



and Upgrades (EDU, HSS, ...)

iPEN

oem

Gas-Detect

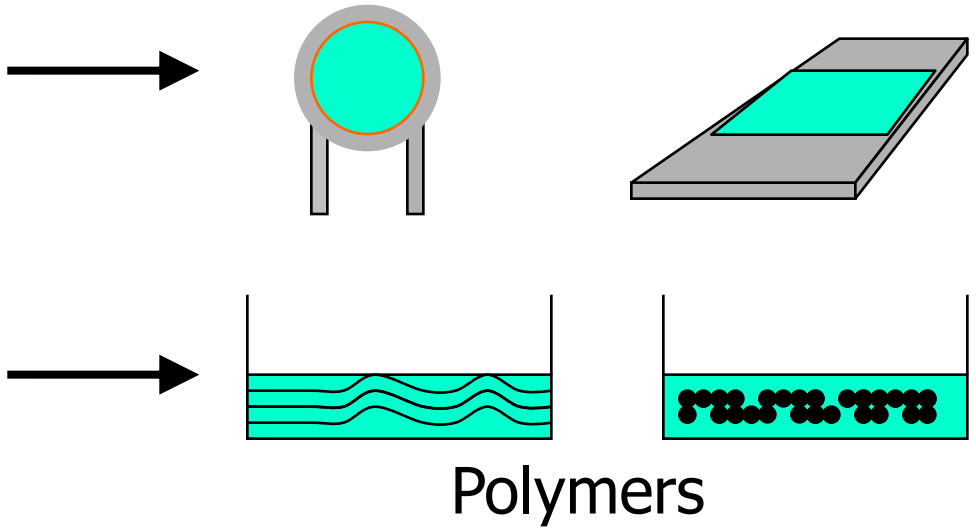
KegControl

Gas Sensors in Sensor Arrays

Cold sensors:

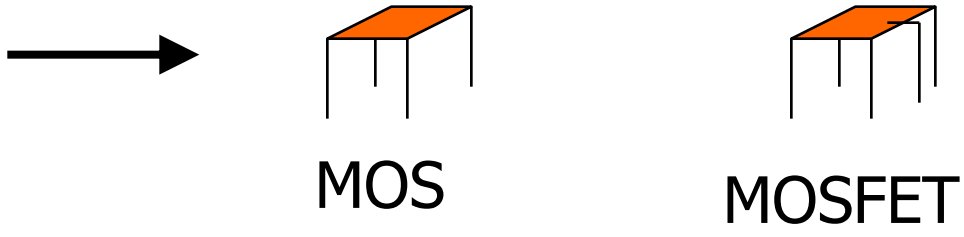
change of mass
$S = \Delta f \sim \Delta m$

change of electrical conductivity
$S = \Delta R$

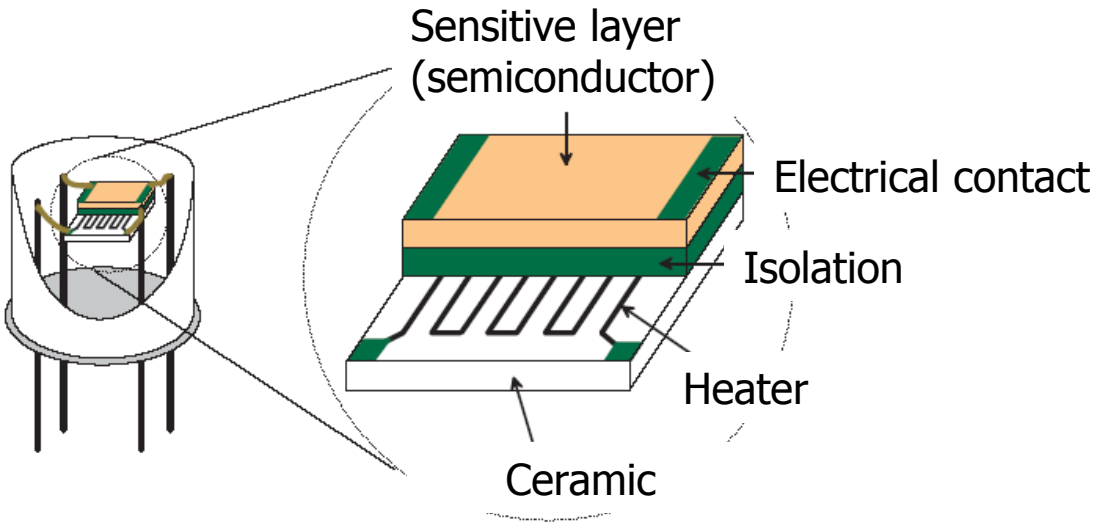


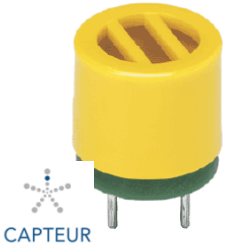
Hot sensors:

change of electrical conductivity
$S = \Delta R$



Metal Oxide Sensor (MOS)



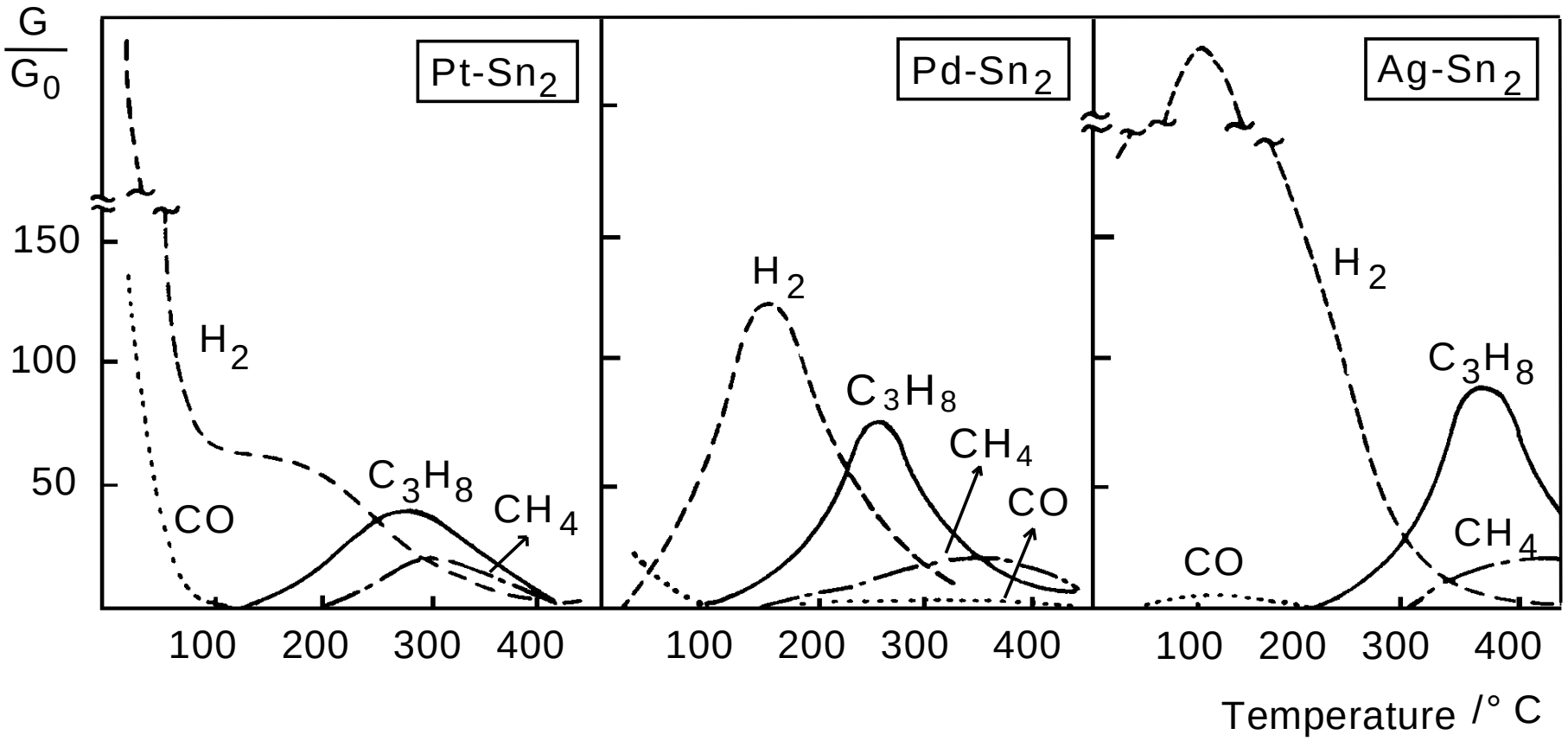


Change of electrical conductivity due to oxidation/reduction reactions

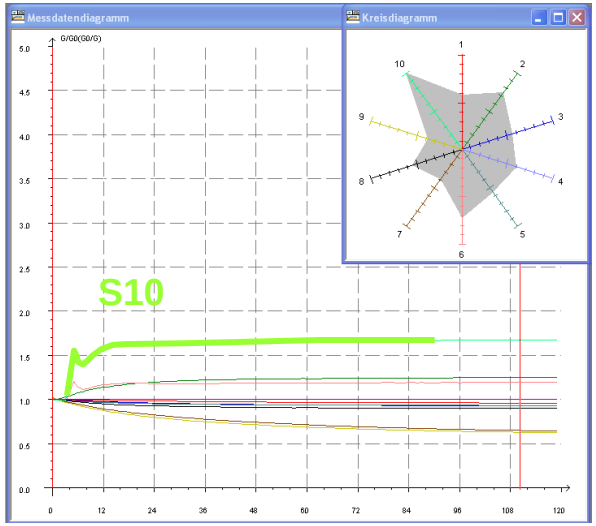
Broad range sensitivity (VOC, CO, NH_3, H_2, H_2S)

Sensitive layers of commercial systems:
SnO_2, WO_3, $Cr_xTi_yO_z$ & mixtures

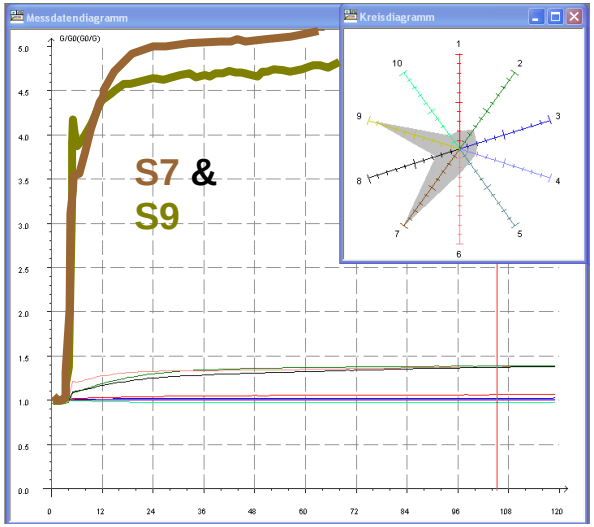
Effect of Temperature and Dopands on the Selectivity



Sensitivity and Selectivity of the Sensors

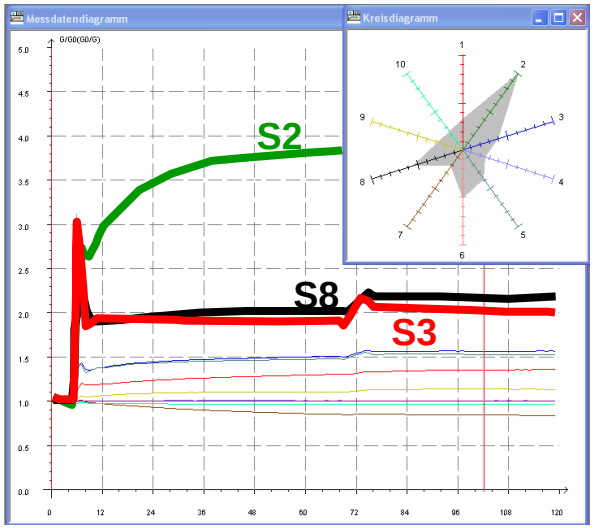


10ppm CH_4

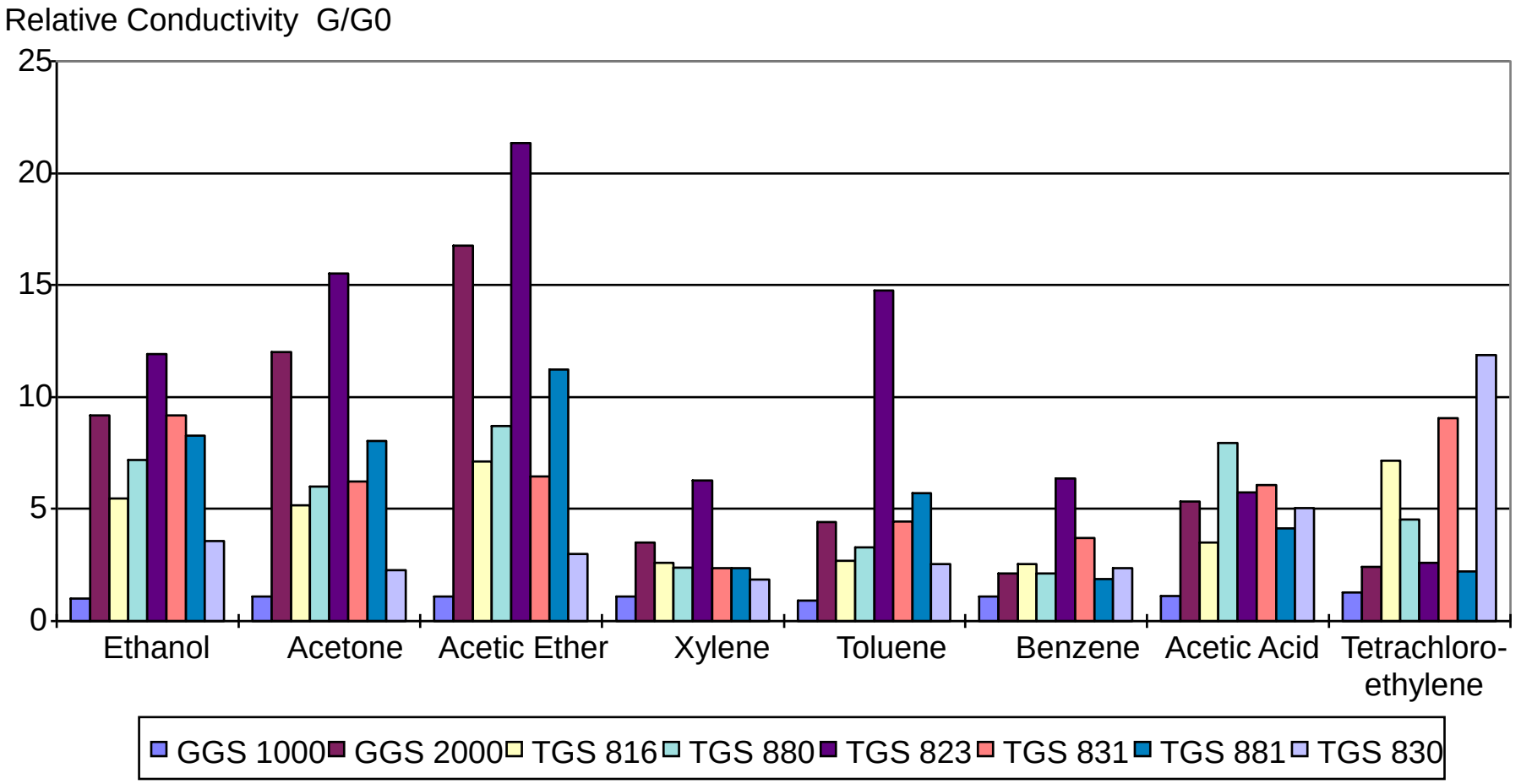


1ppm H_2S

10ppm C_6H_6



Different Pattern of an Array of Eight MOS Sensors



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Pattern Recognition

1. Phase: Training & Verification

"Learning" through measuring known compounds
Saving of the reference vectors and testing of the pattern

2. Phase: **Recognition**

Measurement of the actual unknown compound

Identification by comparing the reference vector with the actual unknown vector

Quantification of the identified compound with the stored calibration file

Euklidic Distance
Mahalanobis Distance
Coefficient of Correlation

PCA
LDA
DFA
PLS

Neural Networks: ???

Portable Electronic Nose PEN-3

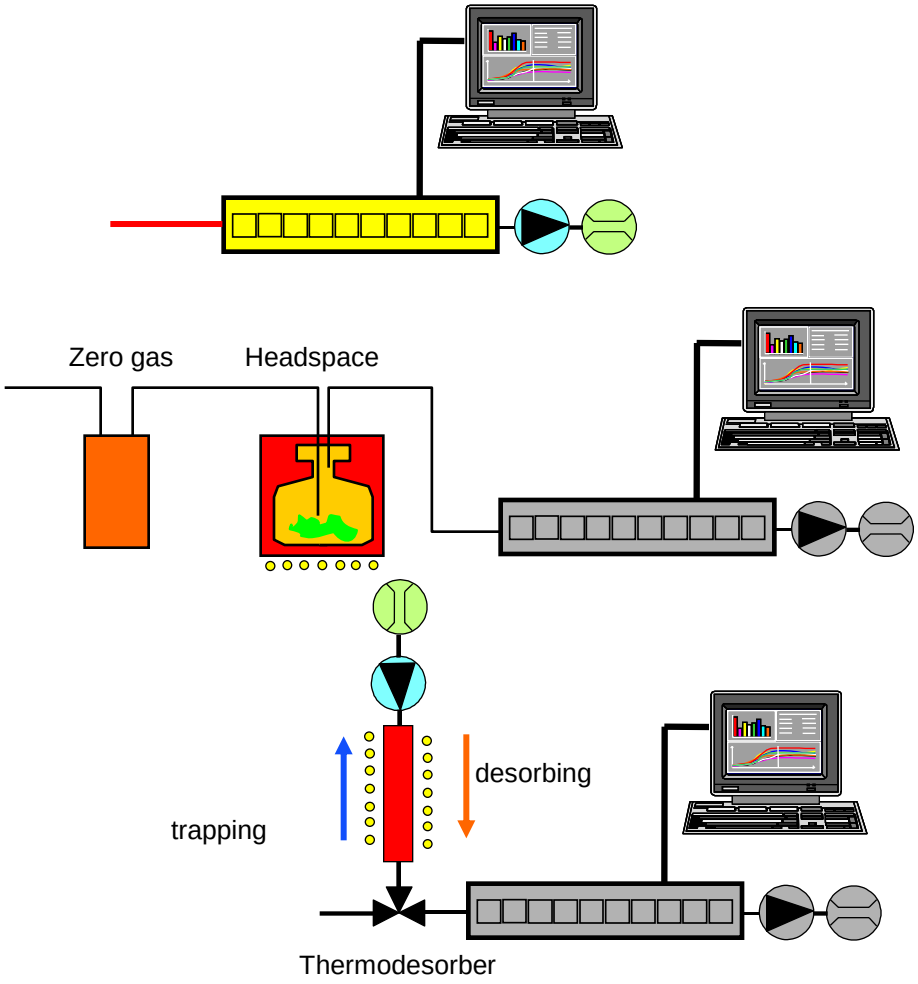
- small
- portable
- low cost
- Auto-Ranging
- Stand-Alone Operation

Industrial Sensor Array: the i-PEN Series

- Same MOS Array Technology
- designed for industry
- remote operation
- stand alone unit
- optional trap available

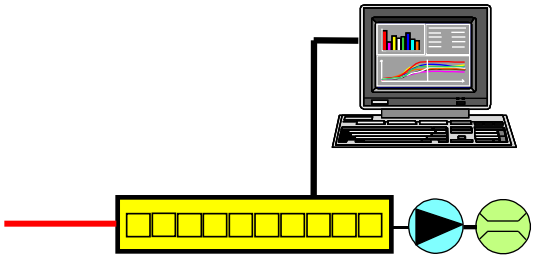
Sampling Methods with an Electronic Nose

Sampling must be
well defined and
repeatable

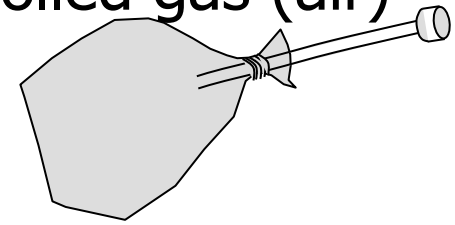


Sampling -Direct

- Direct (passive & active): simple, most common, dependency on ambient parameters



- Sampling Bags: transport of sample to the instrument, controlled gas (air)

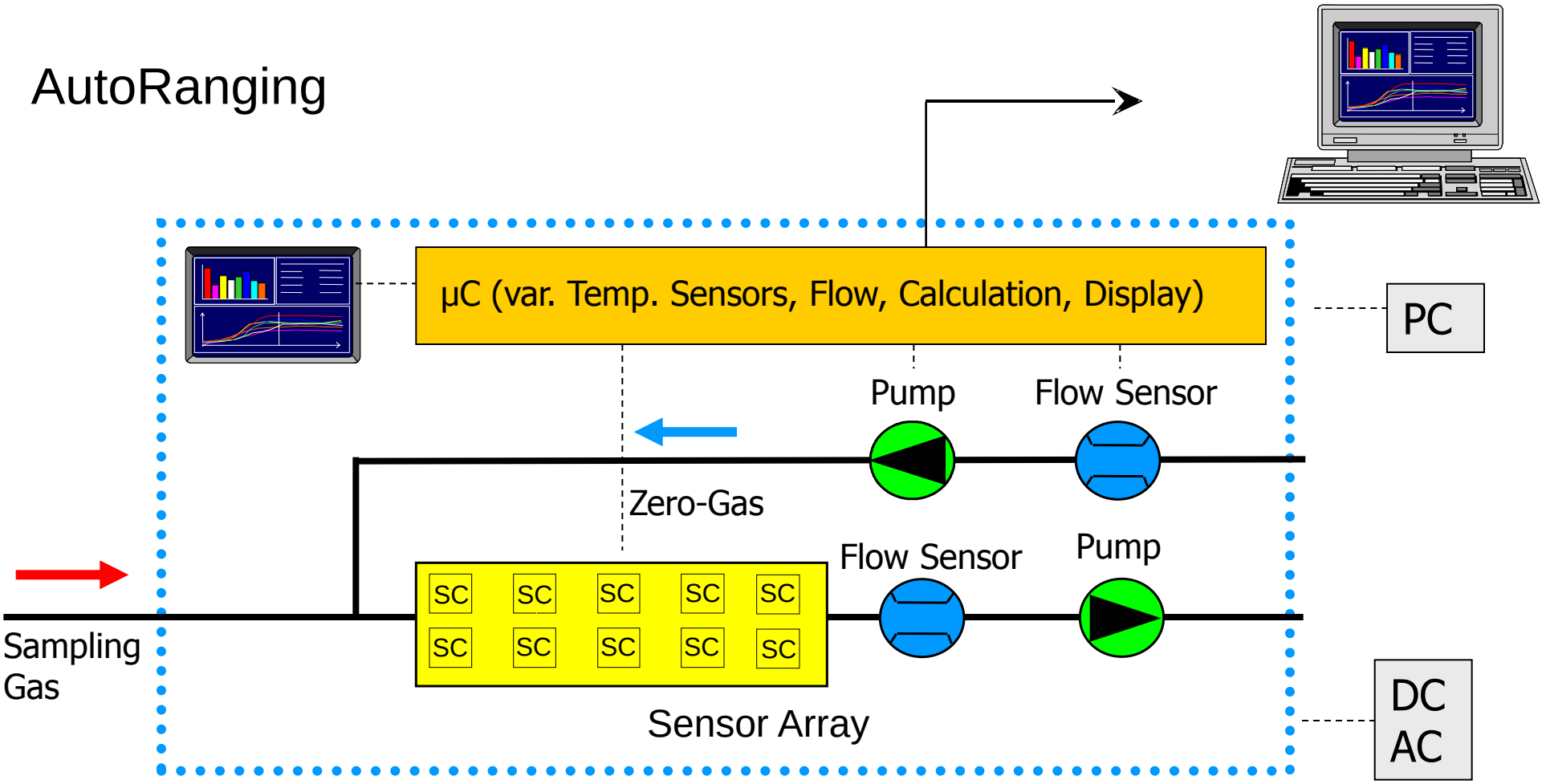


T_{max} =200°C, roasting bags

PET-Polyethylenterephthalate (Nalophan)

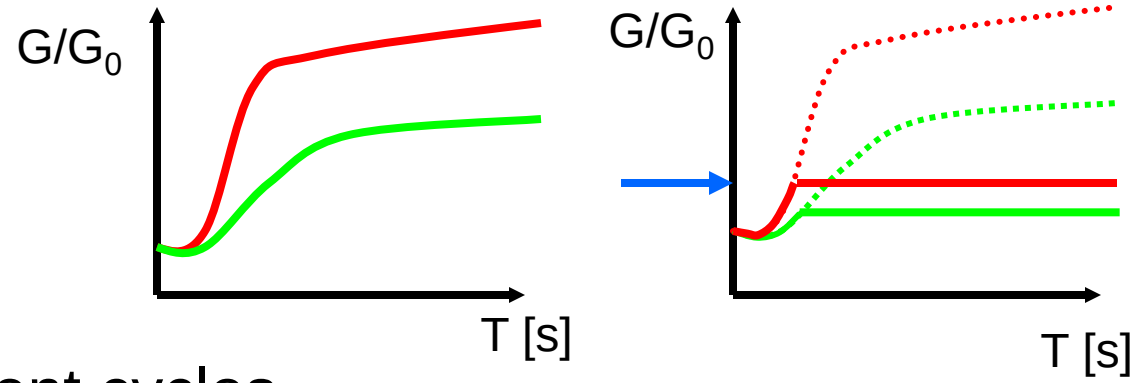
PEN3: Sample Flow & Dilution

AutoRanging

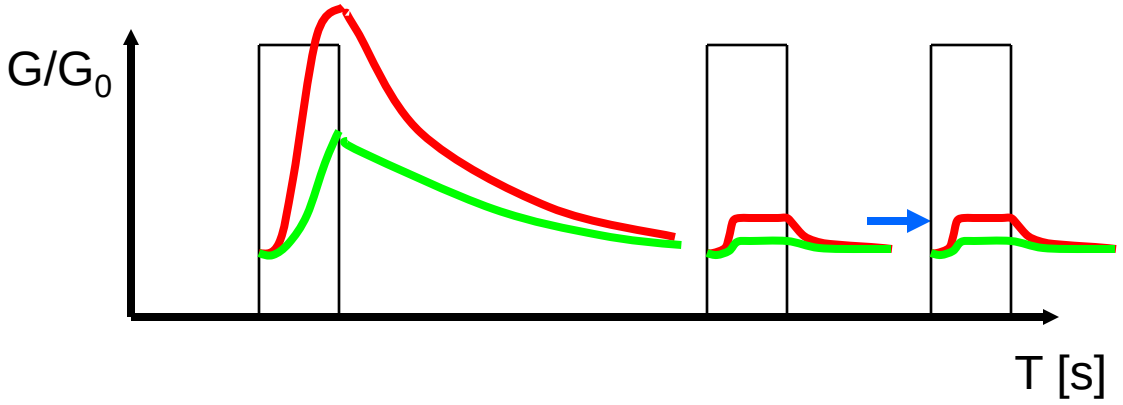


Autoranging

- better lifetime

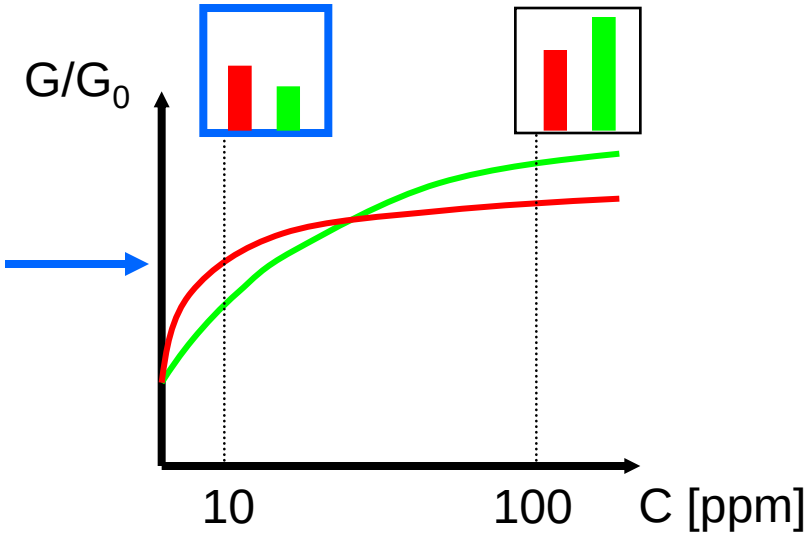


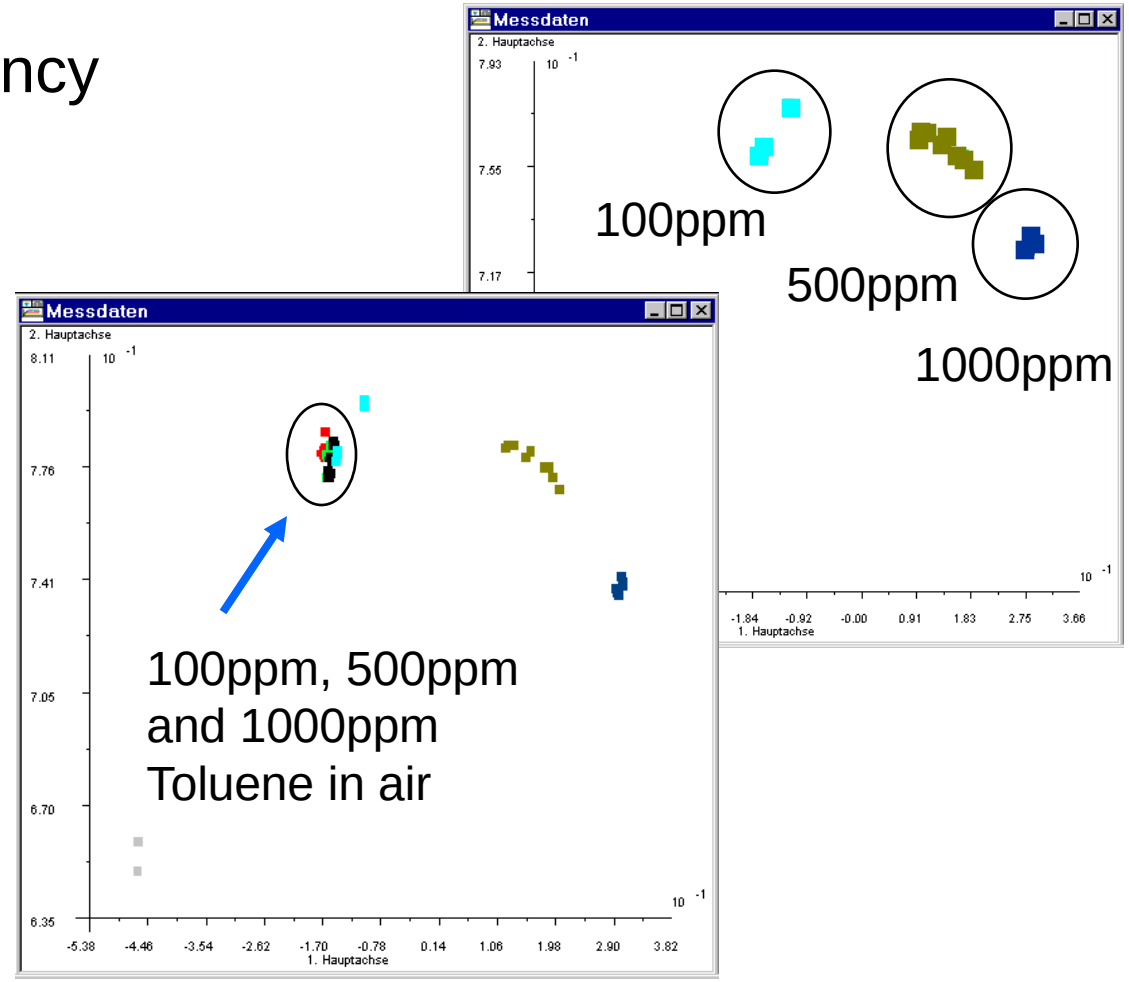
- faster measurement cycles



Autoranging

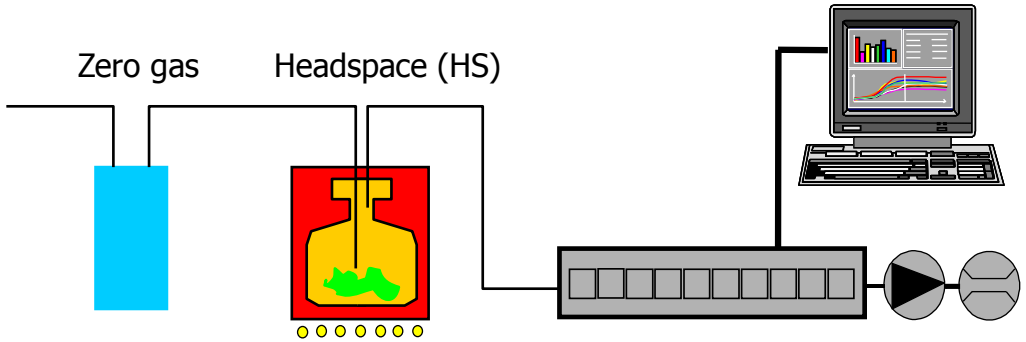
- Pattern without dependency on the concentration



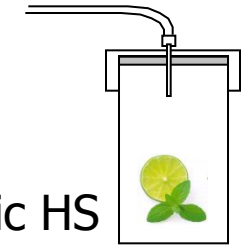


Sampling : Headspace

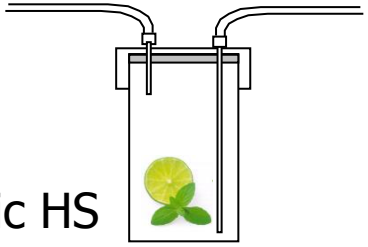
Headspace, Autosampler: better reproducibility due to controlled temperature, time and carrier gas (air)



Static HS



Dynamic HS



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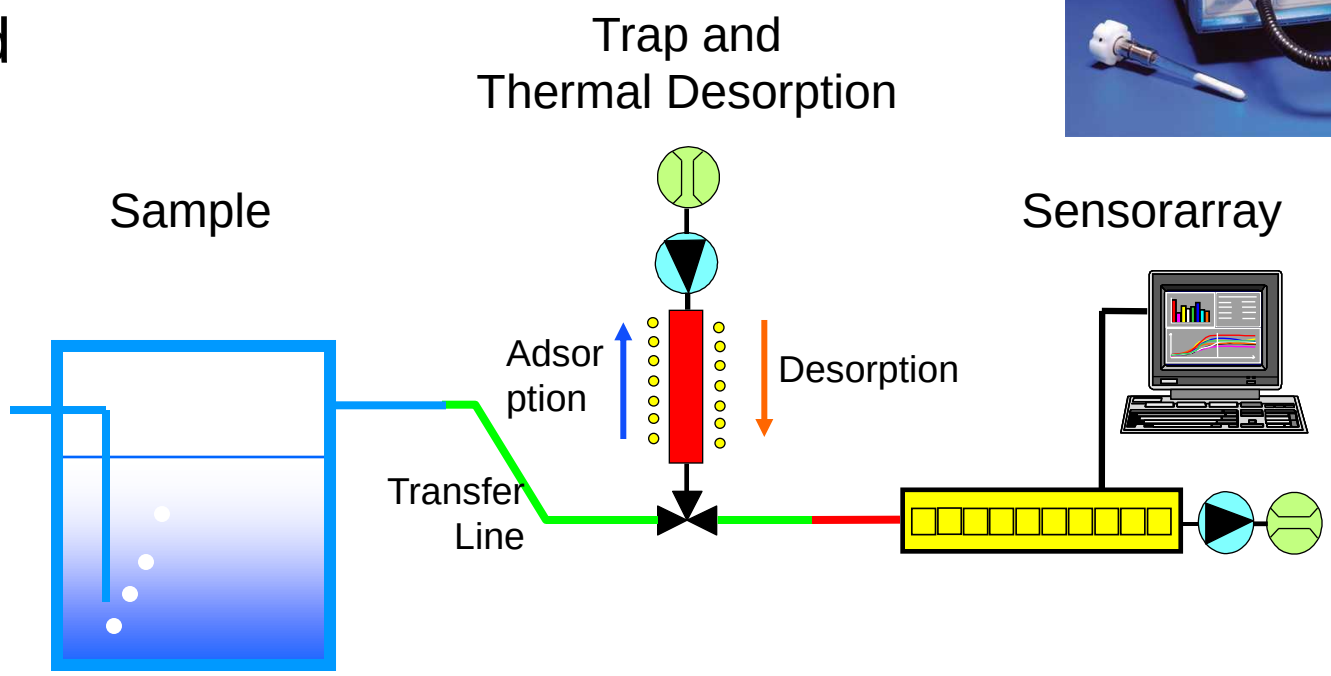
Enrichment & Desorption Unit EDU2 with the PEN2

- new technology:
  Automatic trapping and desorption
- increase in selectivity
- lower detection limits (100 x)
- µP-controlled

Enrichment and Desorption

- lower detection limits (100…1000)
- Enhanced selectivity
- on-line / remote controlled



Breakthrough Volumes

- BV [L/g]

BV \ T	20°C	80°C	180°C	220°C
CH_3	0.006	<0.001	<0.0001	
EtOH	1.80	0.055	<0.001	
Toluene	400	12.5	0.015	0.003
Phenol	1630	17	0.02	0.005
Geosmin	6300	30	0.011	<0.01
H_2O	0,065	0,01	0,001	0

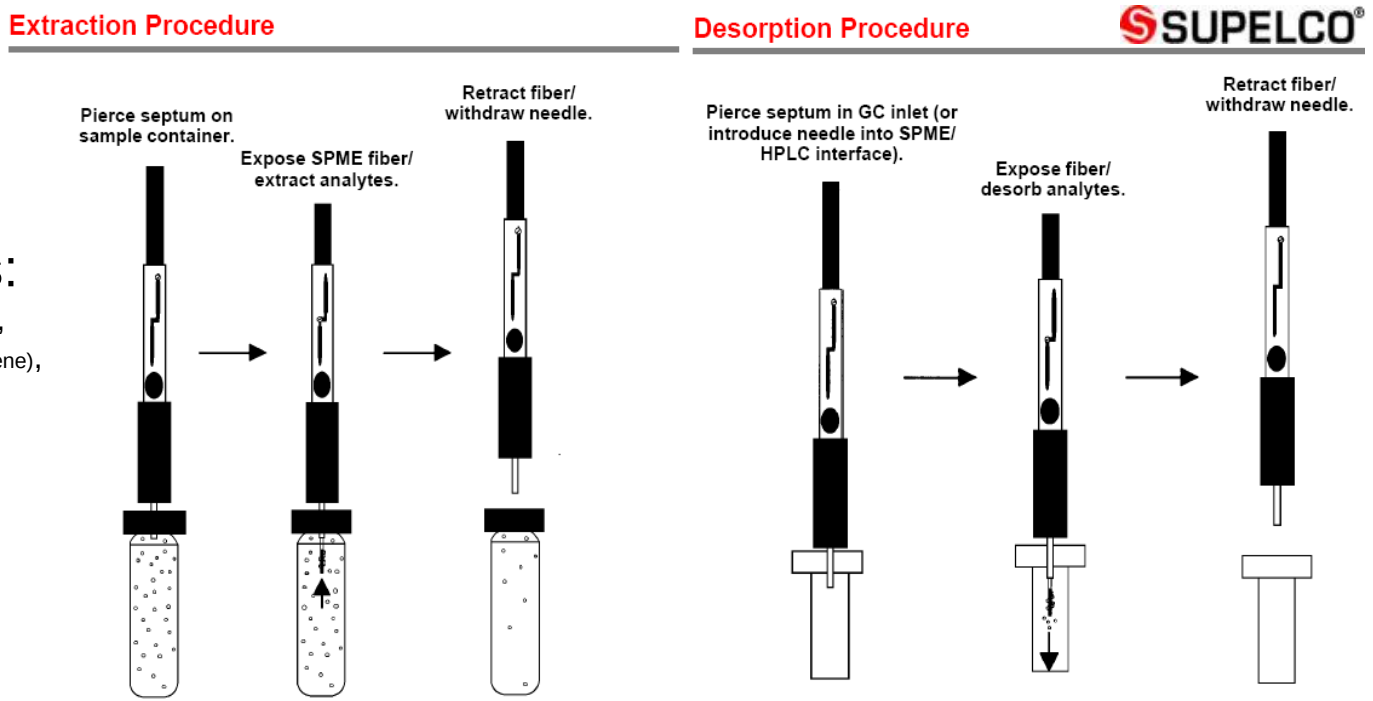
- Discrimination of highly volatile compounds / Water
- High enrichment factors achievable by increasing the sampling time

Sampling, SPME

Adsorption Tubes, SPME: modification of selectivity, better detection limits, transport of sample to the instrument

SPME materials:

PDMS (Polydimethylsiloxane),
PDMS / DVB (Divinylbenzene),
PDMS / Carboxen,
CW (Carbowax)/ DVB,
Polyacrylate



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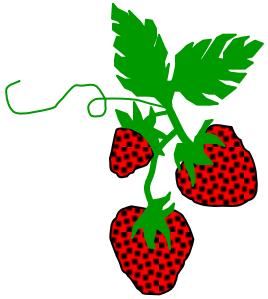
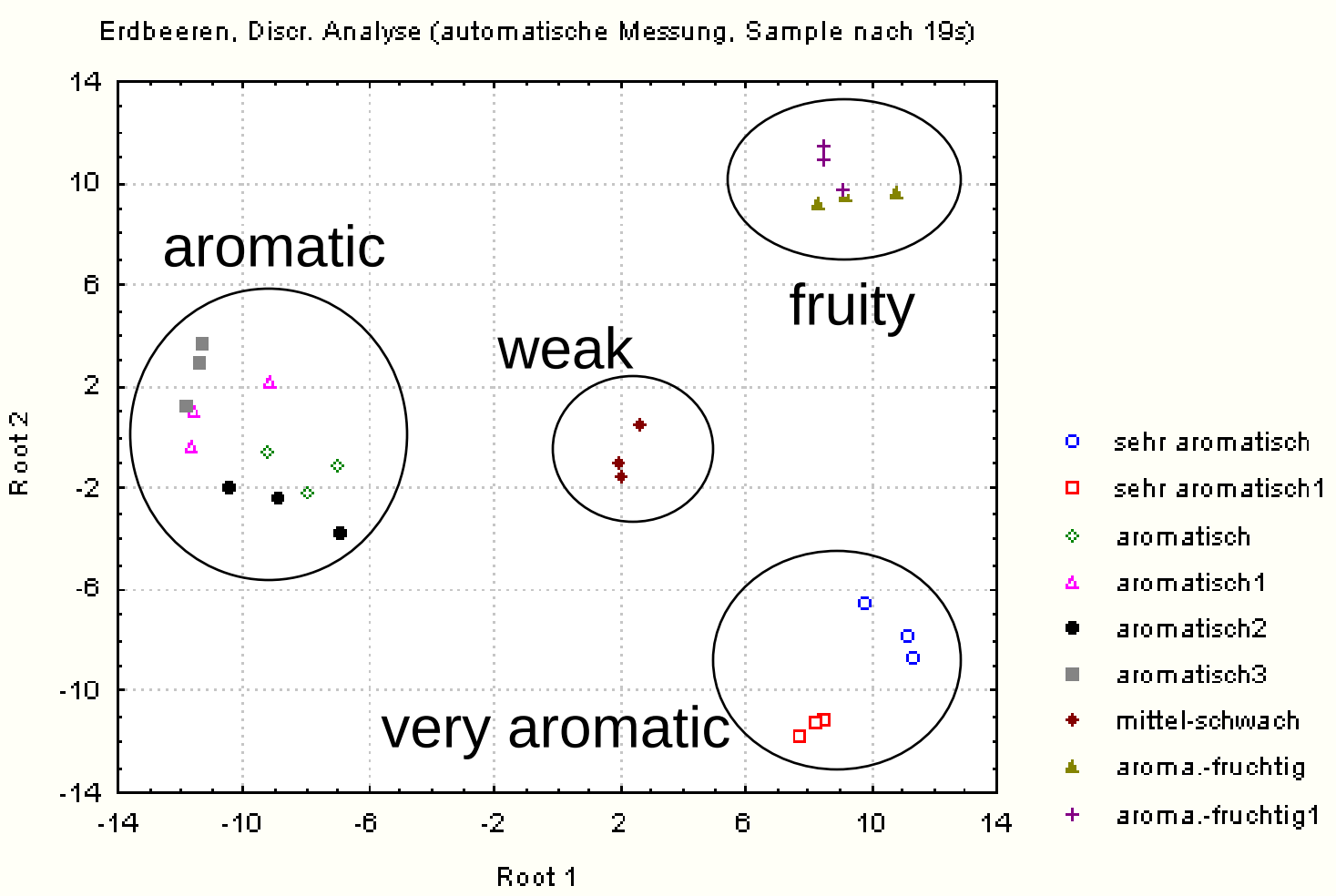
Applications

- Quality control:
  Food (rancidity, freshness, off flavor, contamination)
- Safety: work place areas,
  storage places (natural gas)
- Environment: dispersion of air
  pollutants, supervision of filters
  (compost plants, sewage plants)
- Medicine (identification of fungi, bacteria,
  flavor in diagnosis)
- Process control:
  polymers (packing material, automobiles)

Differentiation of Food

- Food
(aroma of strawberries)

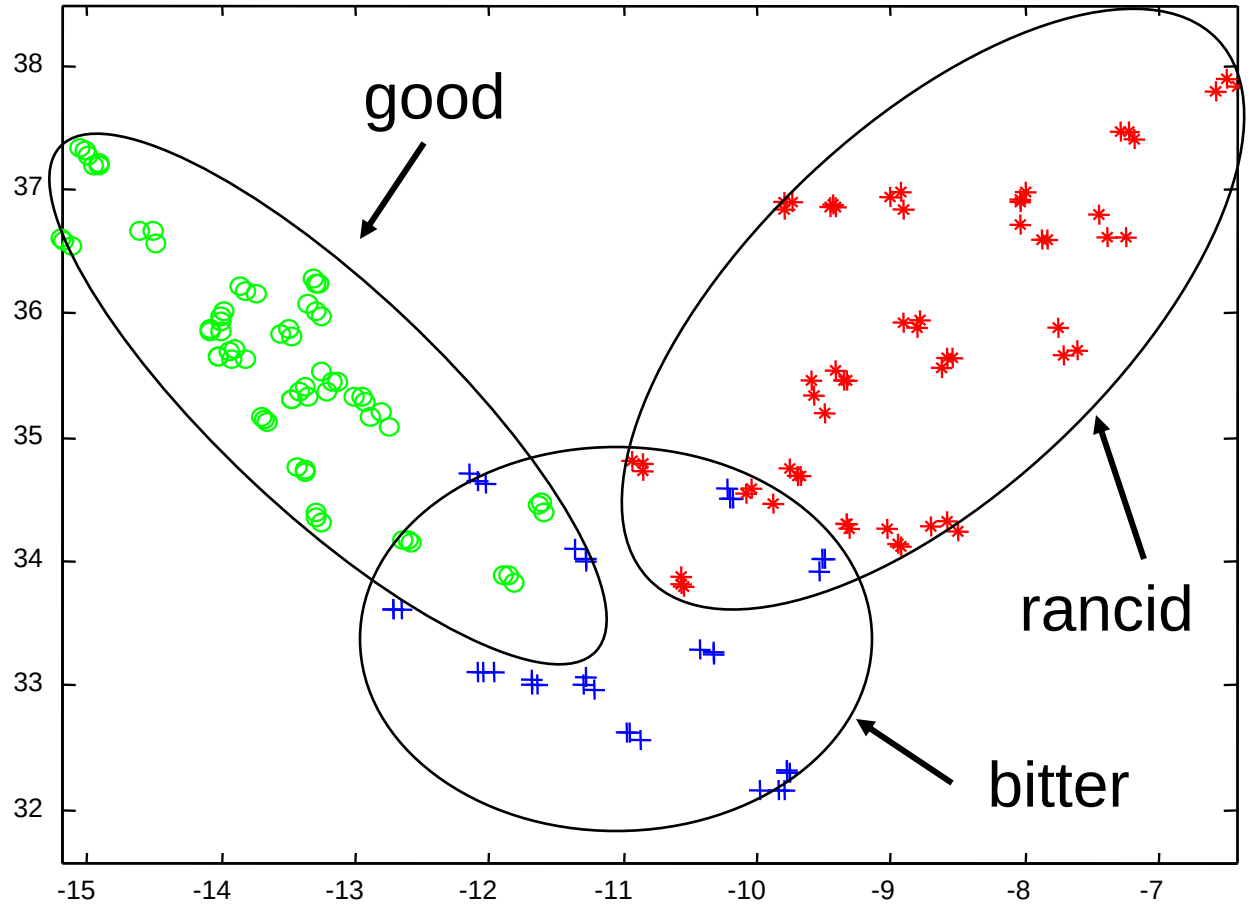




Fast Rancidity Detector

- Walnuts: rancidity

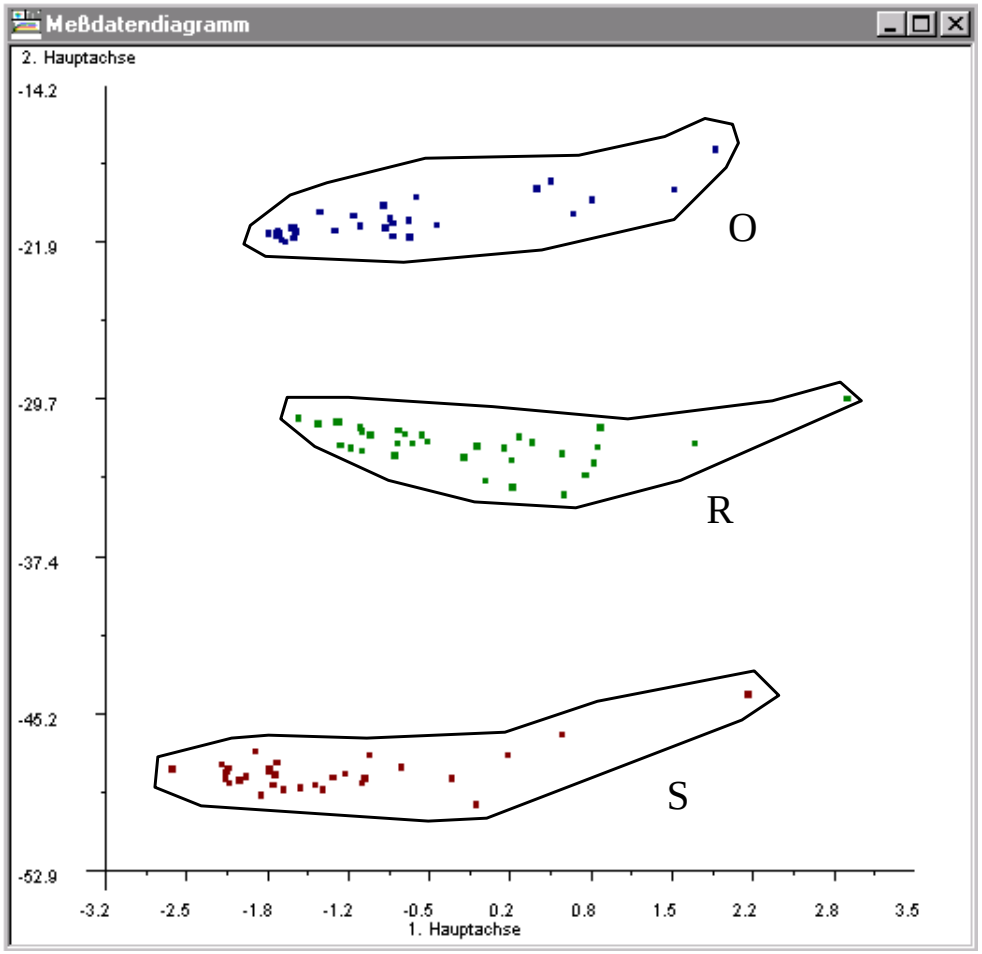
(Application tested over 6 months with the same pattern. Probability that a rancid sample will be identified as a good one is less than 0,5%)



Differentiation with Trap & Thermal Desorption

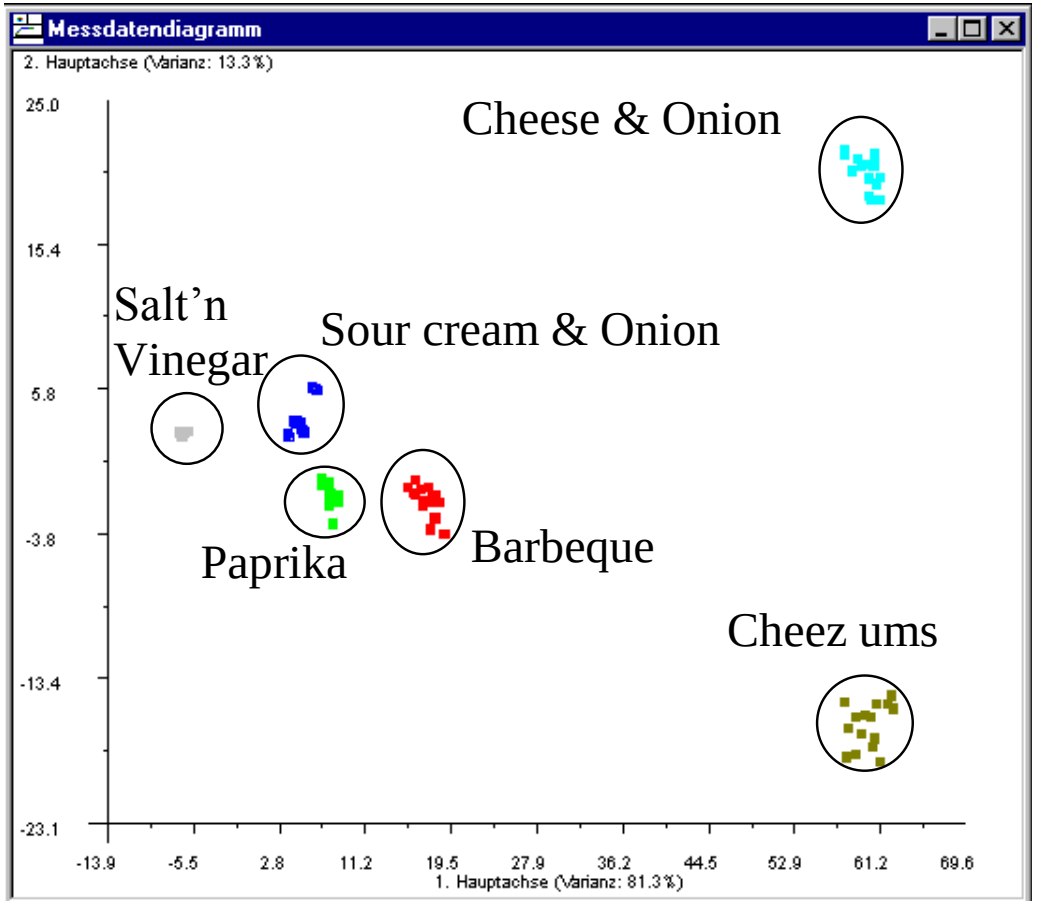
- Food:
  vinegar

(no differentiation possible without selective enrichment)



Headspace Analysis of Food

- Differentiation of spices for potato chips

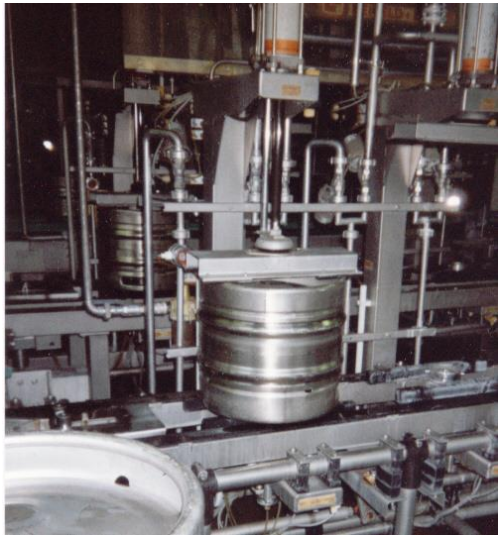


iPEN KegControl®

contaminated beer barrels

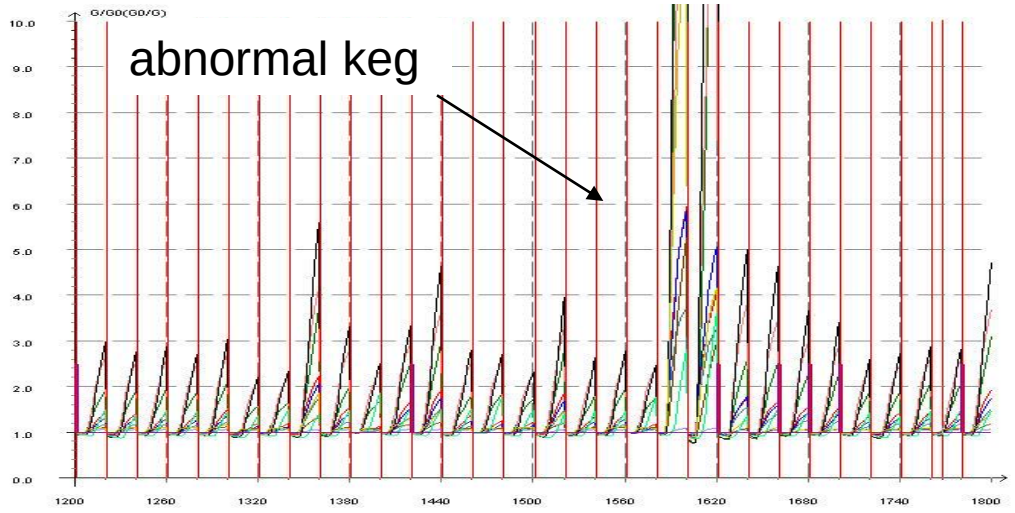
Recycling of containers
(water, beer)

- Detection of solvents and off odors
- Low detection limits
- Fast analysis

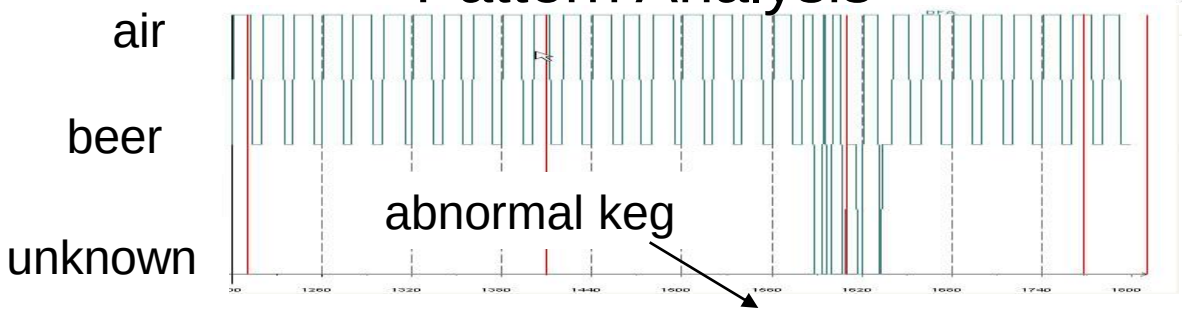


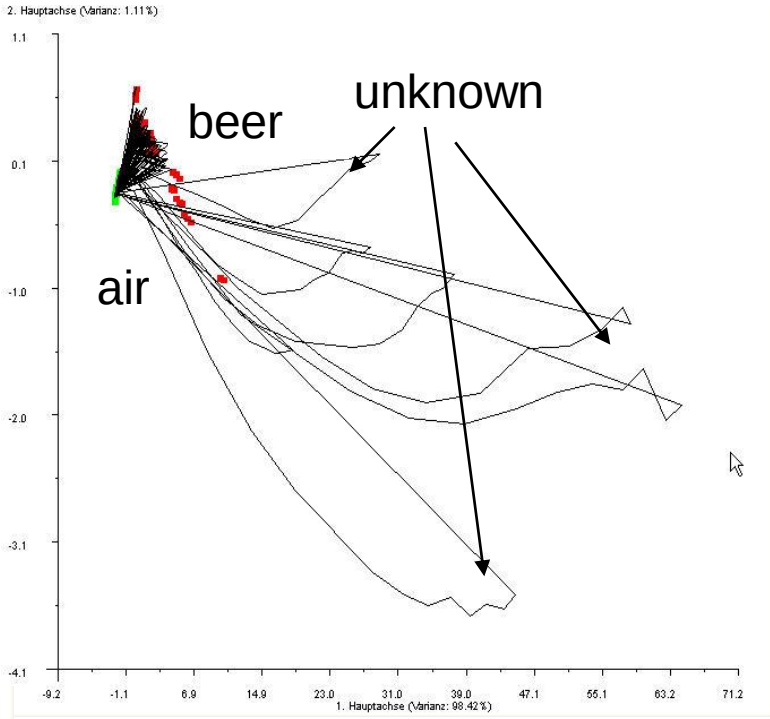
iPEN: KegControl

Raw Data



Pattern Analysis



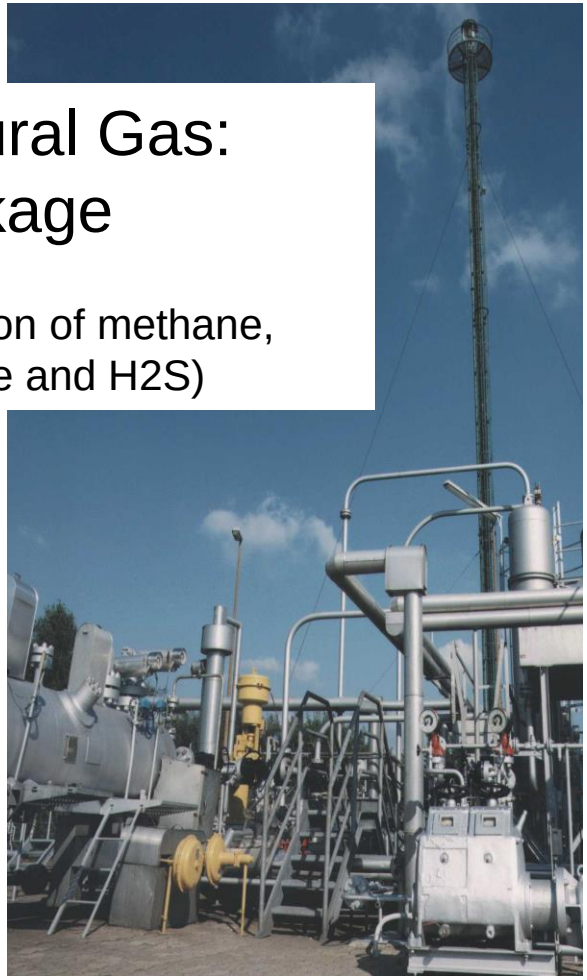


PCA of the complete series (500 meas.)

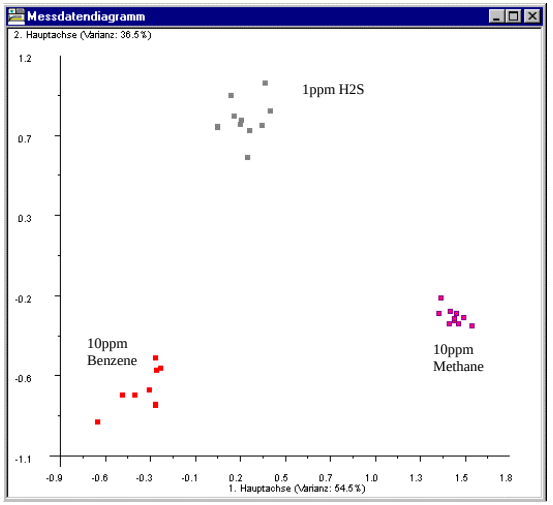
PEN: Leakage of Sour Gas

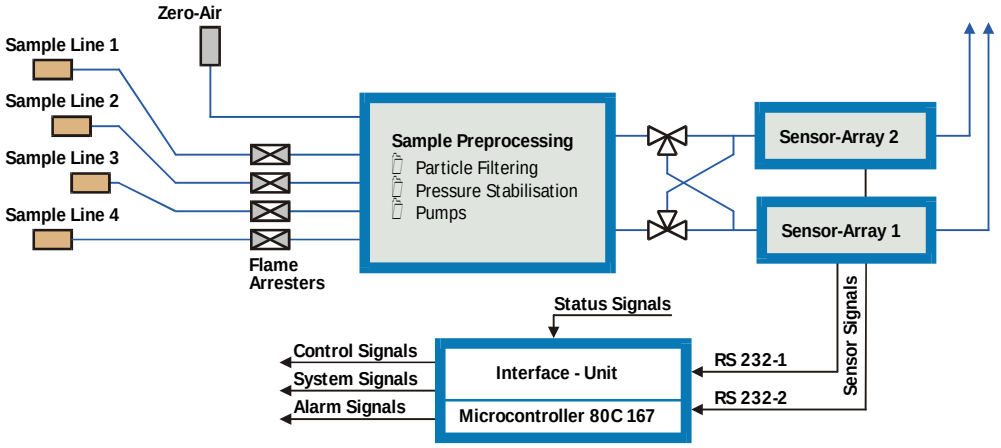
- Natural Gas: Leakage

(detection of methane, benzene and H2S)



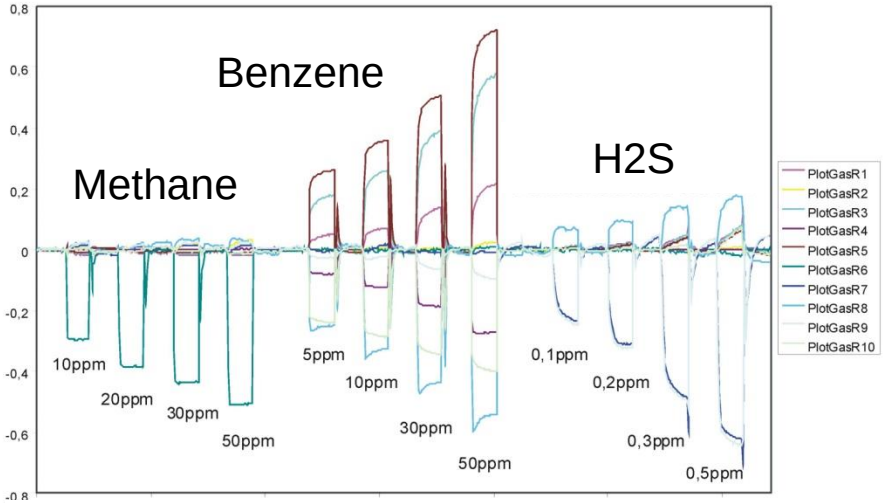
Variation (PCA) between sensor arrays

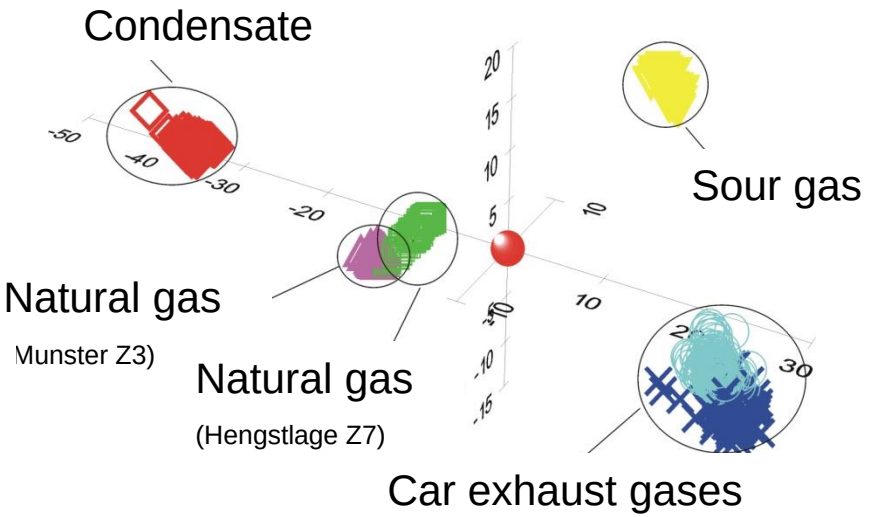




iPEN: Leakage Control

Detection device with dual sensor array

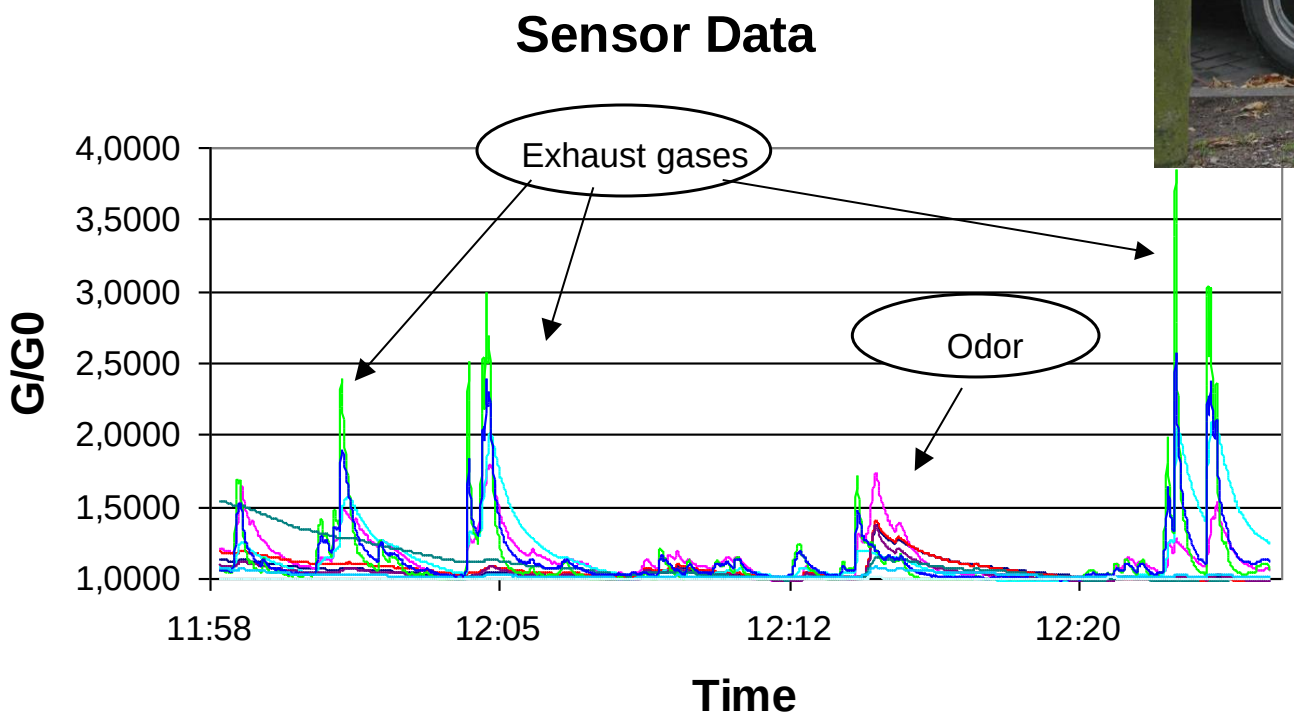




Monitoring of Biofilters

- Odor complains at a shopping center:

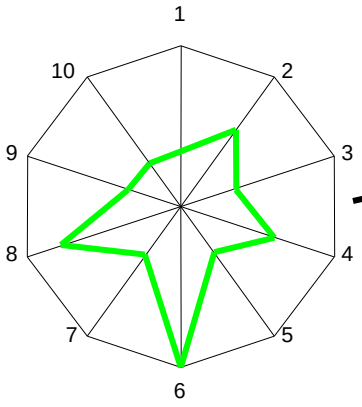
  Monitoring of sporadic releases of odors from a subterraneous biofilter of a sewage duct

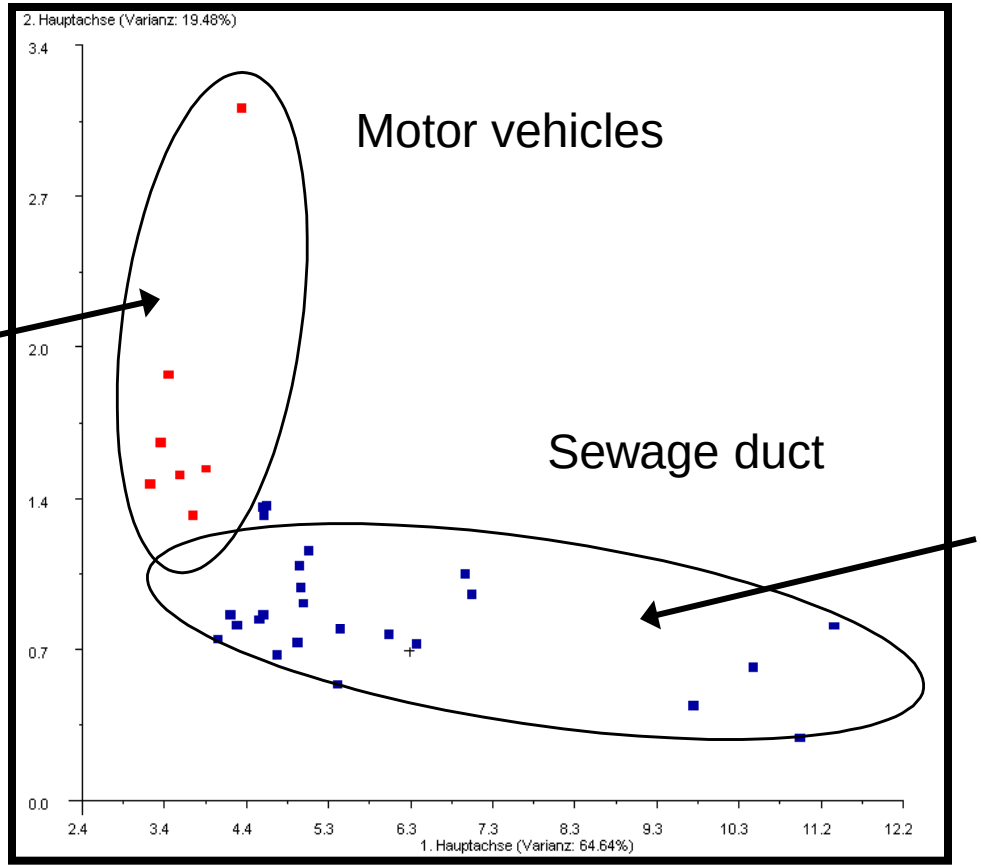


Monitoring of Biofilters

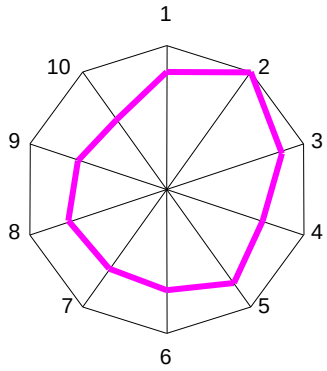
- Principal Component Analysis

exhaust gases



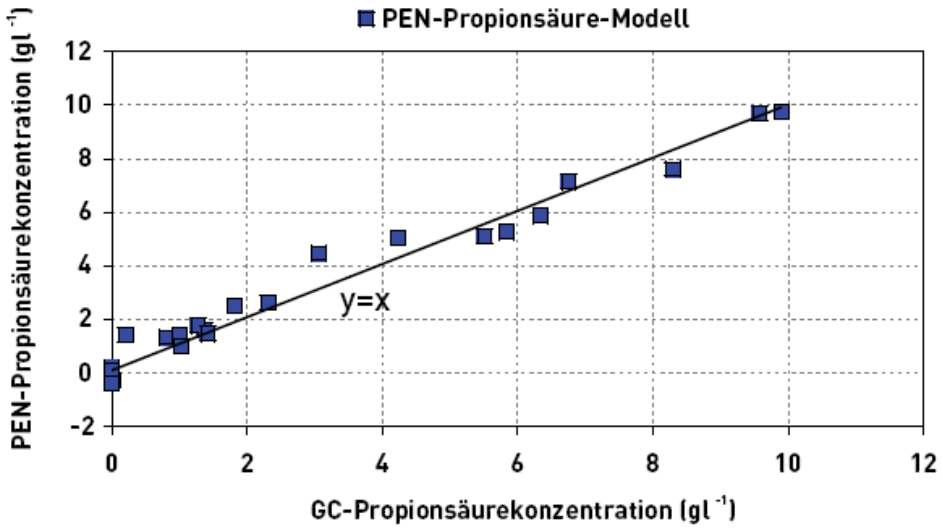


odor



PEN3: Biogas Generation

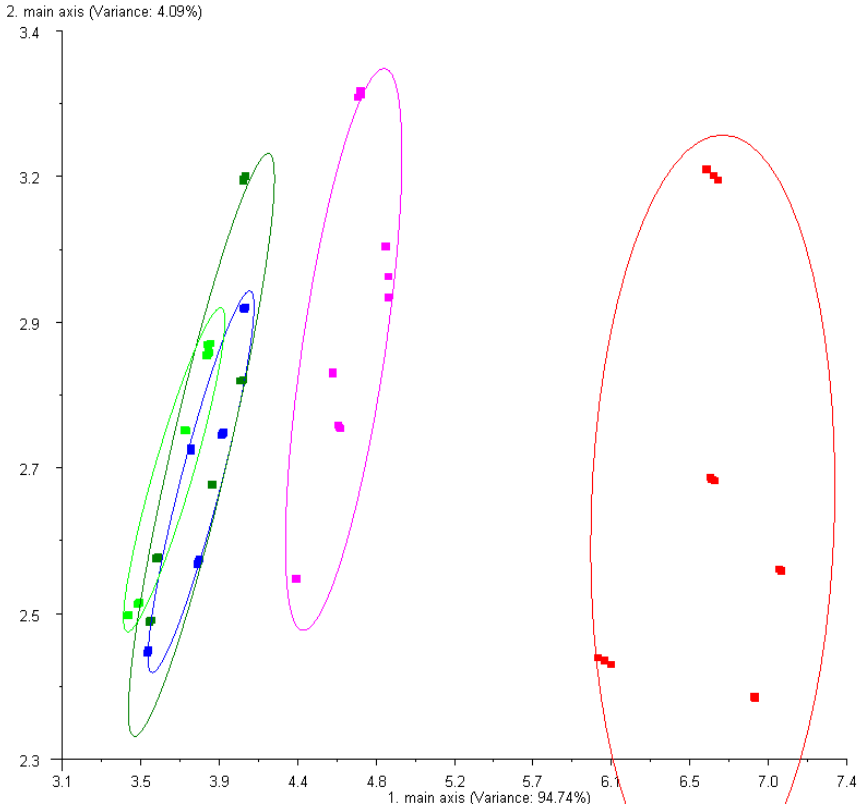
- PLS - descriptor
- quantification on Propionic Acid in Fermenter



PEN3: Fungi in Grain Storage

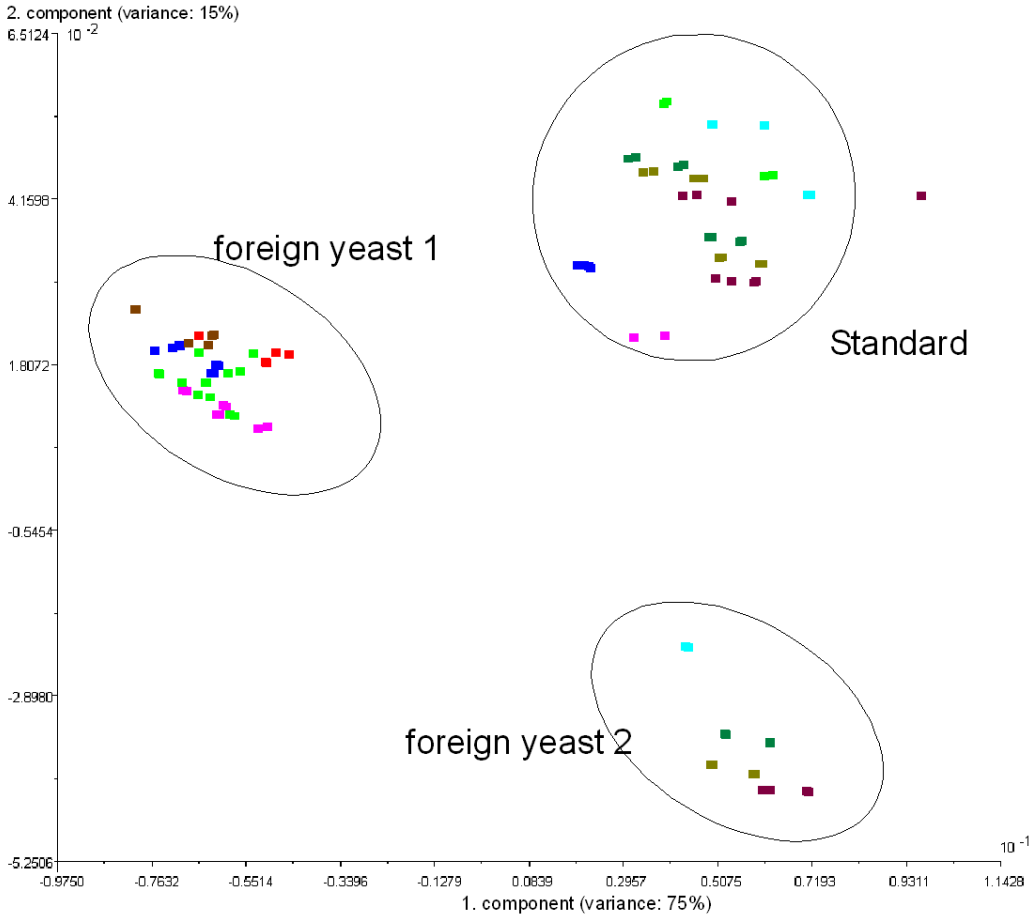
- Test samples containing different Fungi, Aspergillae

- Compounds of interest
  1 Butanol
  2 Octen -3- ol
  Dimethyldisulfid



PEN3: Foreign Yeast in Joghurt

- Early detection of potential spoilage before delivery
- Yeast tested:
  (JB20.11.-2)
  (QMa29.11.-1)
- Special sampling tool



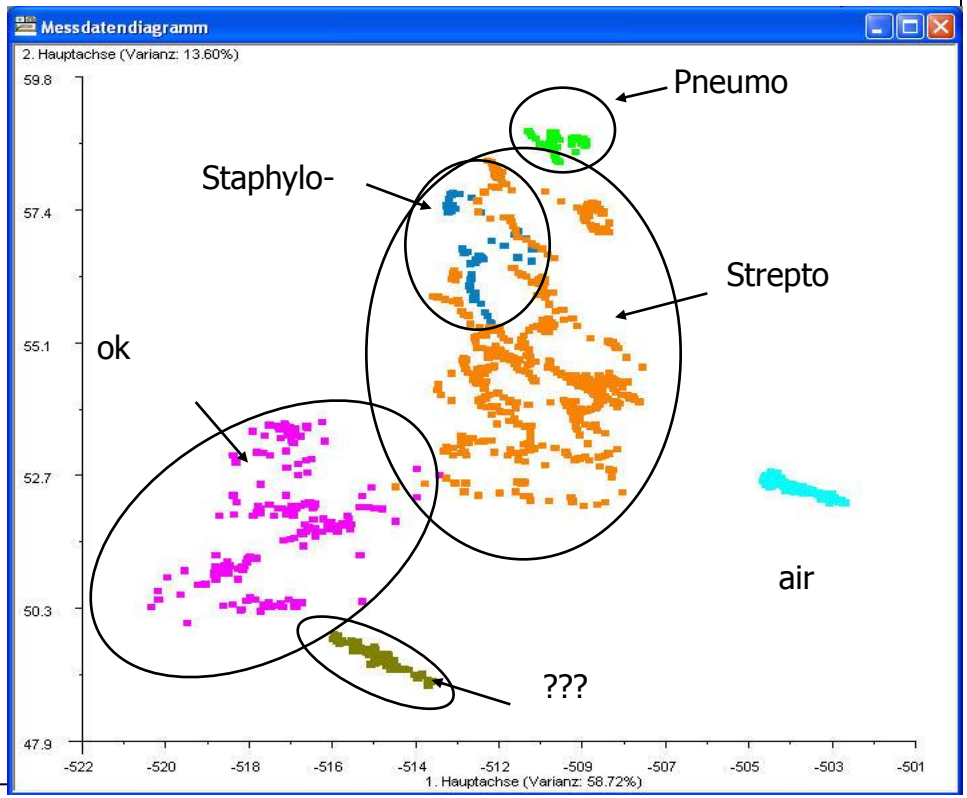
PEN2: Otitis media

- Differentiation of Infectia for enabling a specific treatment

Many lab samples and patients have been investigated within 6 months

Strepto- Staphylo, Pneumokokkae H. influenzae

PCA Analysis
Normalization



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Finally

Sensor Array Technology offers an affordable quality supervision

Enoses have a huge field of applications

Sampling Set Ups have too be optimized

Medical applications are widely in Research State