# Applying the electronic nose in the environment

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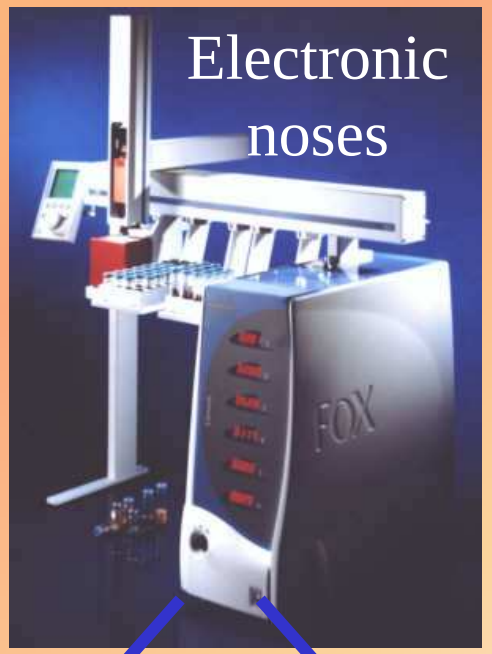
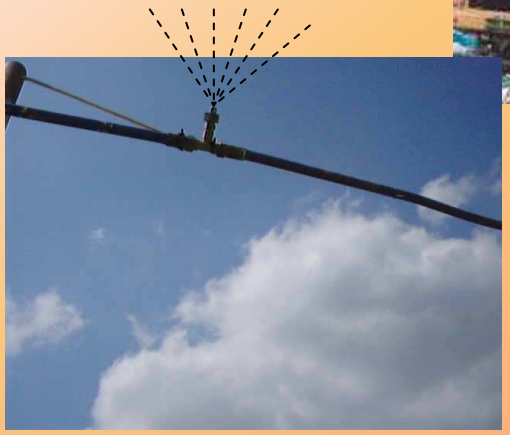
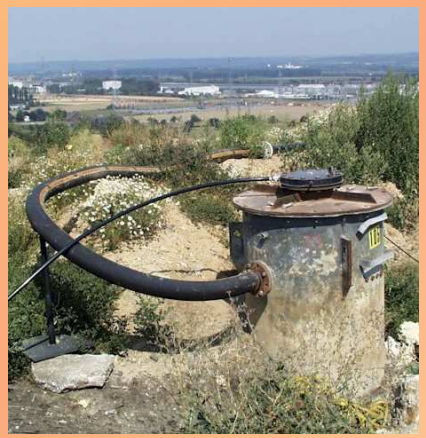



Recognising gaseous ambiences in the environment

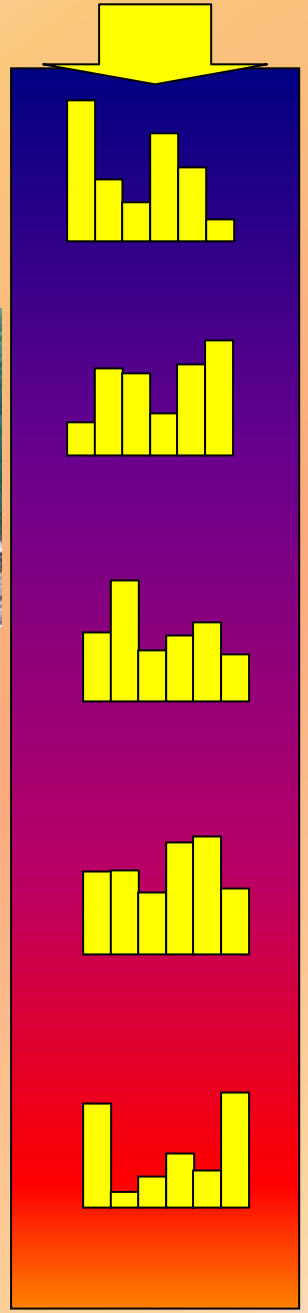
Monitoring

# Recognising gas ambiences





Signal patterns from an array of sensors



fresh waste

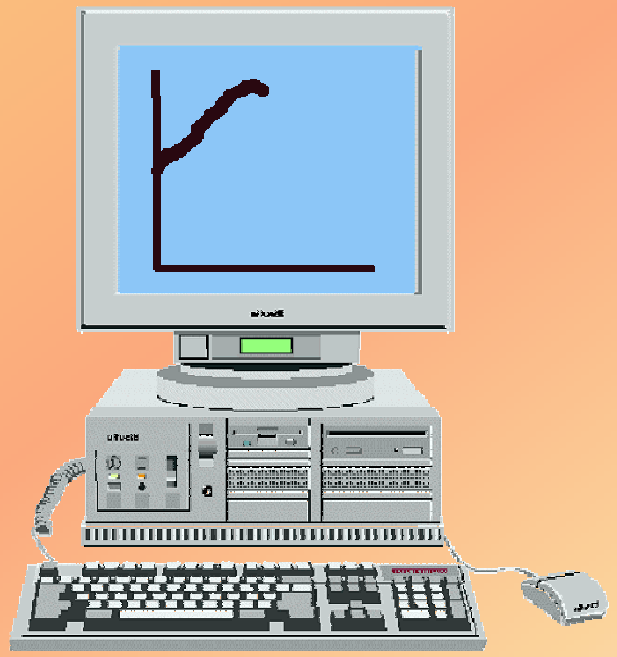
engine exhaust gas

odour neutralizer

landfill gas

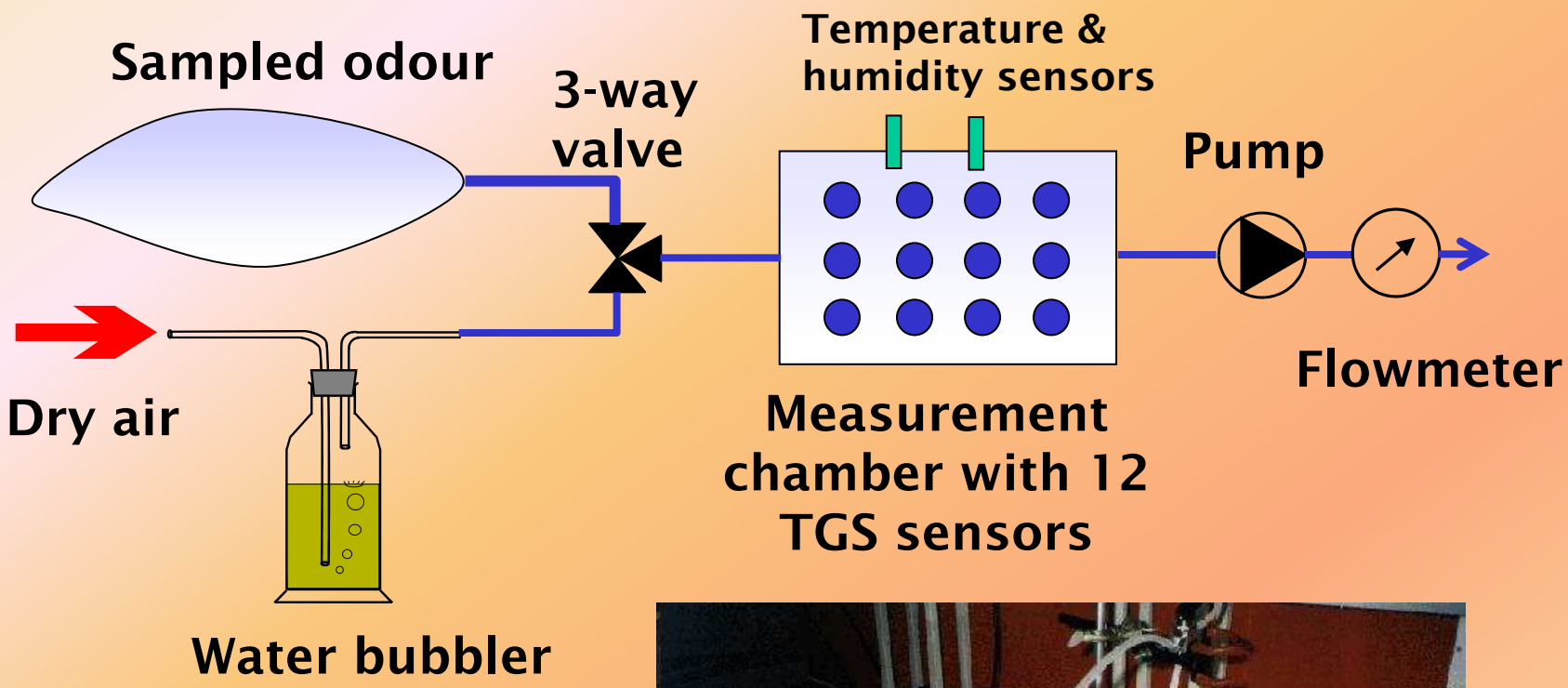
compost

# Monitoring gas ambiences

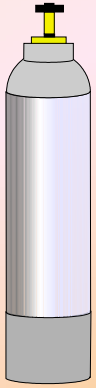



## Array of tin oxide sensors


**Drawback : heated above 300°C**
**Advantages : robust, commercially available, “non selective”**

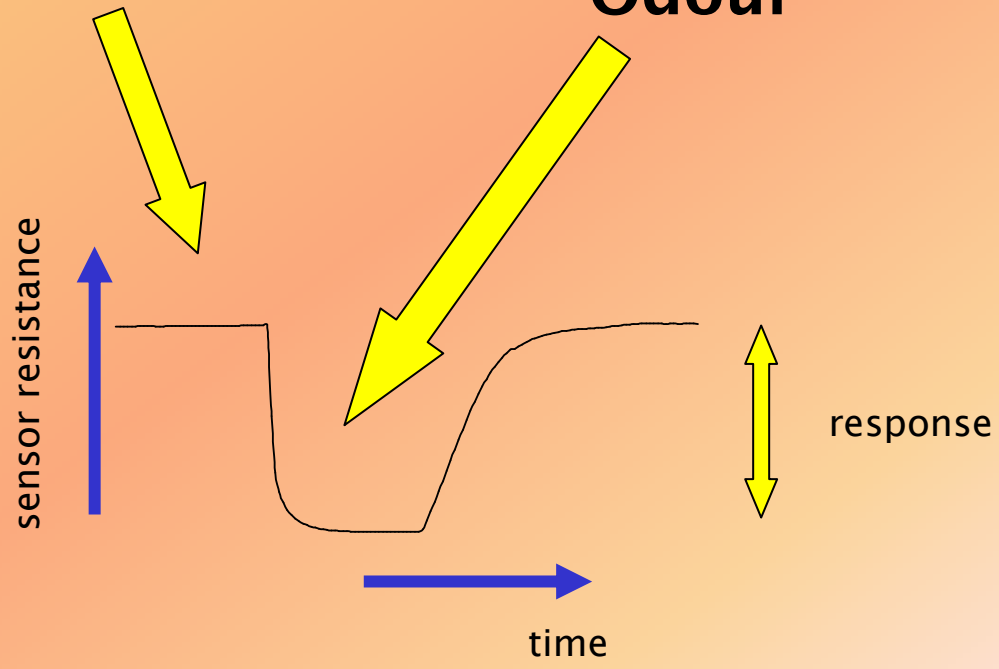

Sampled odour
3-way valve
Temperature & humidity sensors
Pump
Flowmeter
Dry air
Measurement chamber with 12 TGS sensors
Water bubbler

# Classic procedure in the laboratory

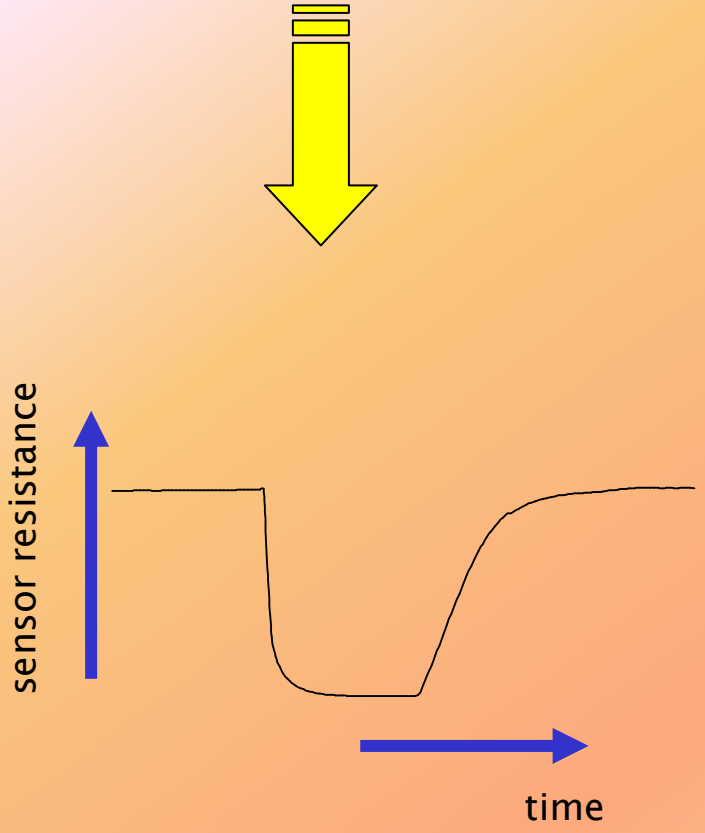


**Pure odourless air**
**(either cylinder or charcoal filter)**

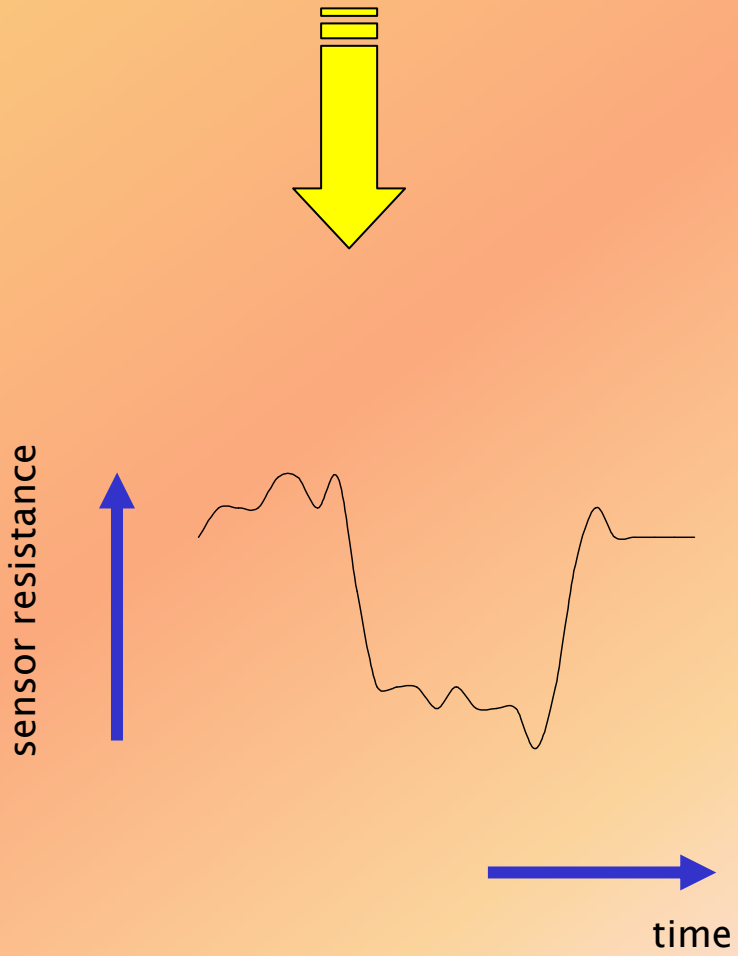
**Odour**



## In the laboratory




## Odour in the environment



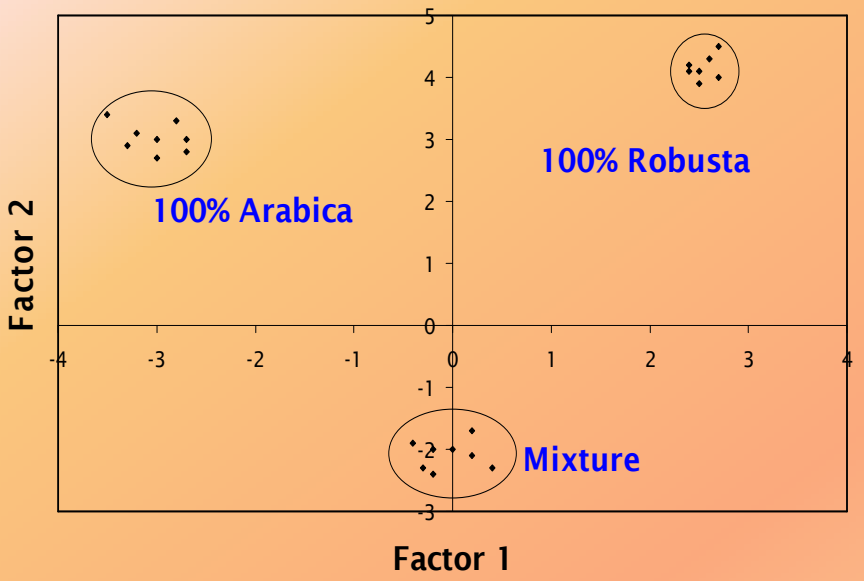
# Pattern recognition techniques (PARC)

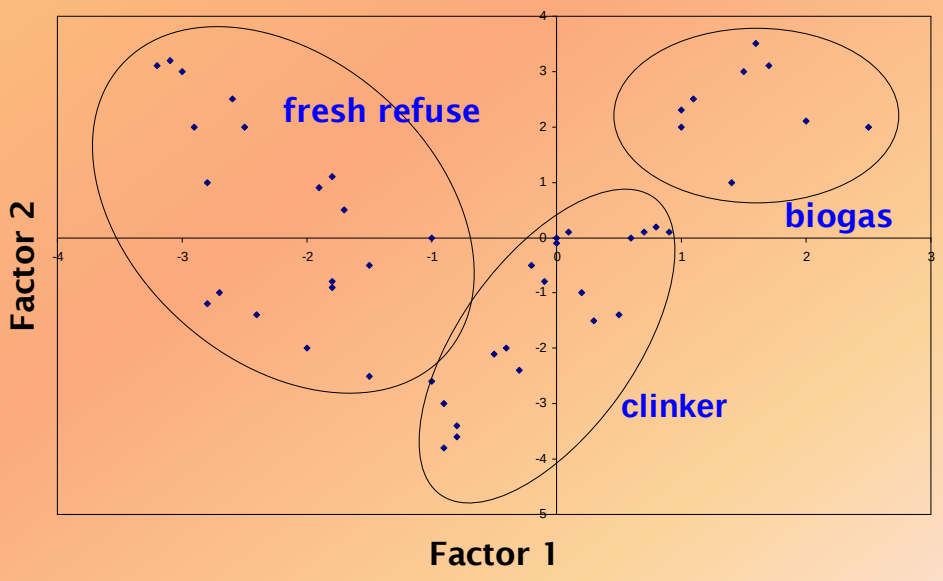
## Unsupervised procedures (CLUSTERING)

(Principal Component Analysis, Self Organising Maps Neural Networks, …)

*Free to respond to input data and to build up a "model" which is able to cluster the observations into some groups showing similar behaviour with regard to the observed variables*

***evaluation tools***




**Laboratory**

**Environment**

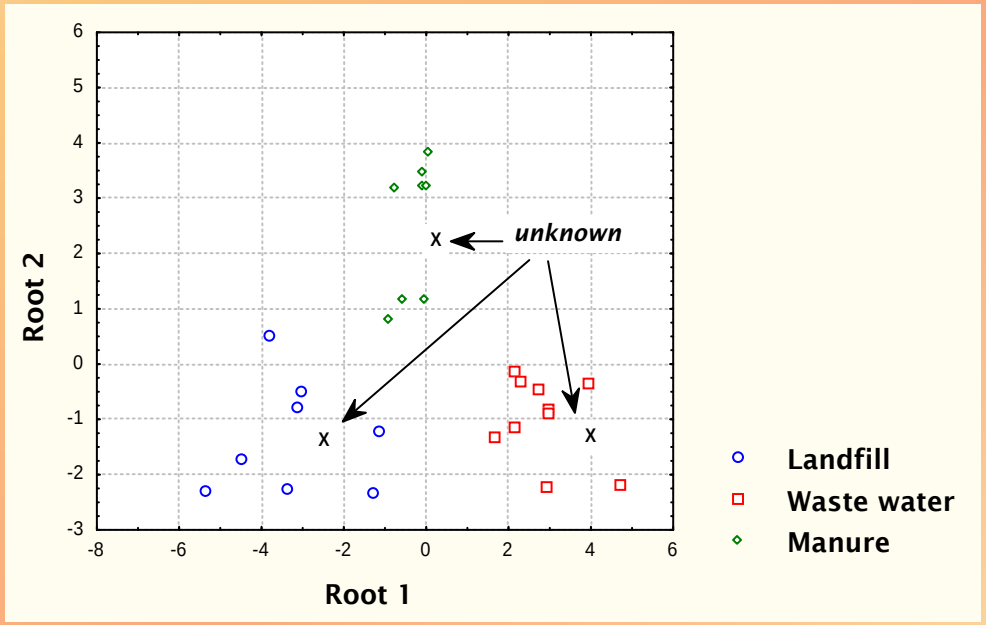
# Pattern recognition techniques (PARC)

## Supervised procedures (CLASSIFICATION)

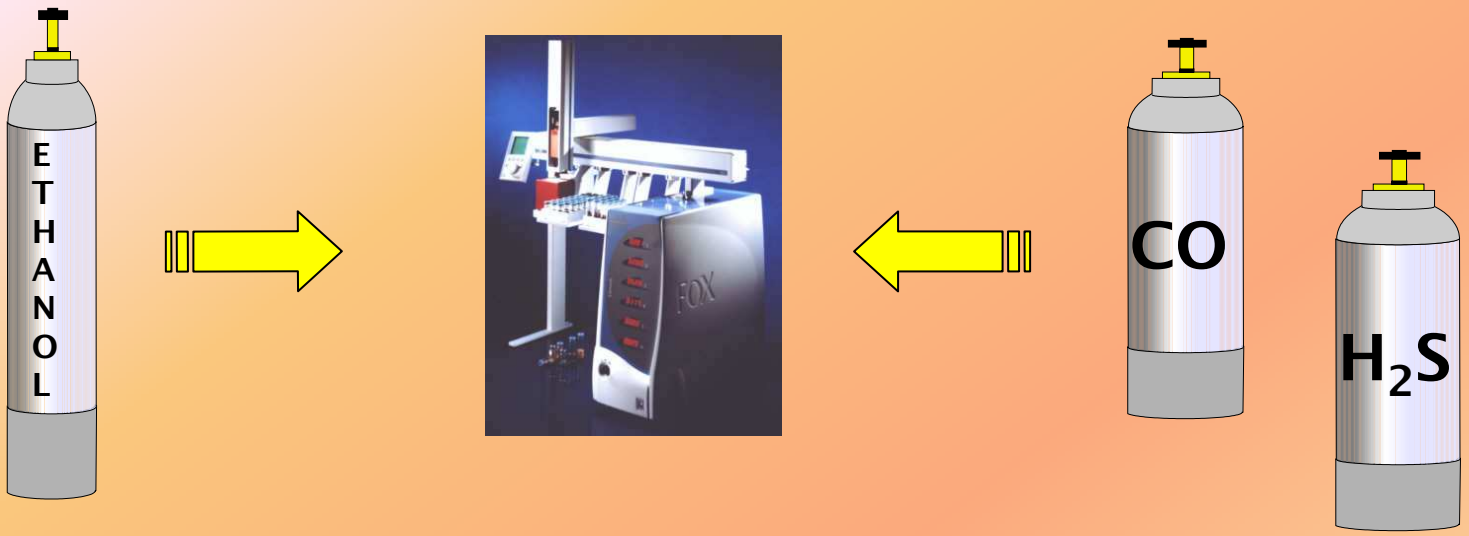
(Discriminant Function Analysis, ANN - Backpropagation, …)

*During a "learning phase", the input signals are put in relationship with the odour sources, and the membership in a specific group is known*

***model for real time recognition of unknown odours***



# First kind of applications : pure gases or simple gas mixtures

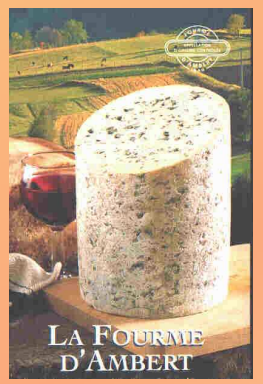



## Interest

- Testing the performance of the array
- Testing different mathematical procedures
- Testing different operational conditions
- Alternative when the sensor doesn't exist or is expensive (BTX)

## Second kind of applications :

## head space above liquids, food, …





Problem even more difficult :

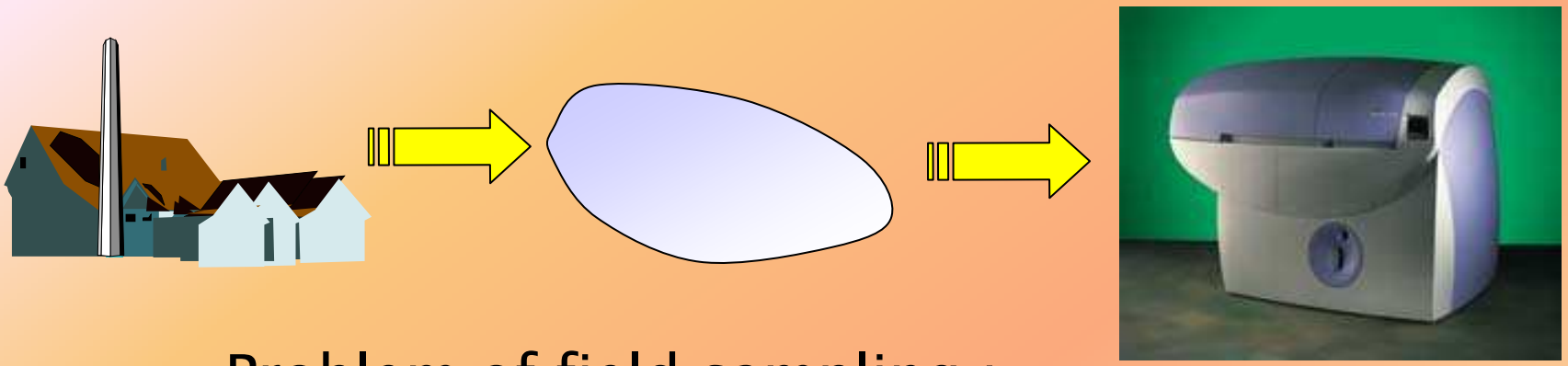
- variable gas composition

But :

- same main chemicals
- head space, reproducible

## Third kind of applications :

## real atmospheres sampled in the environment or simulated by mixing several gases



Problem of field sampling :

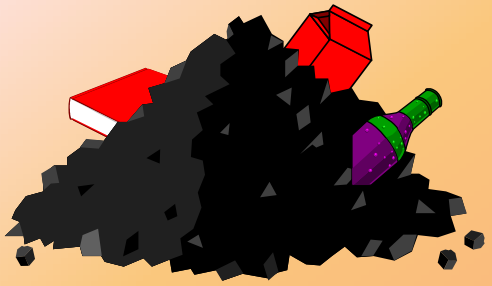
- ever-changing chemical mixture
- risk, uncertainties
- influence of ambient parameters

But :

- Reproducible laboratory conditions

## Fourth kind of applications :

## Measurement of real atmosphere directly in the field



All the difficulties are cumulated :

- ever-changing chemical mixture
- risk, uncertainties
- influence of ambient parameters
- Non-reproducible operating conditions

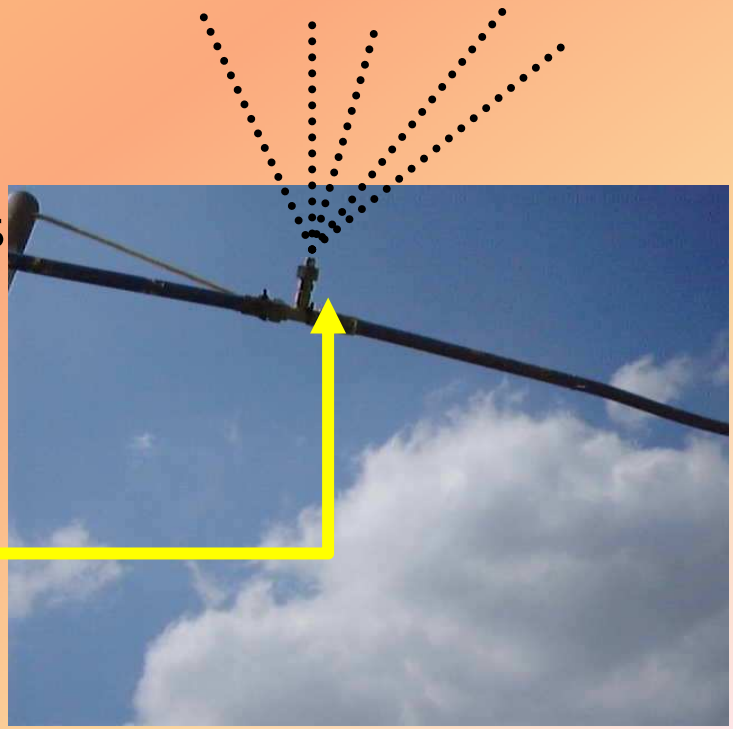
# Additional difficulty :

# Odour assessment

Department « Environmental Monitoring » at FUL : Applying the electronic nose principle (with tin oxide sensors) to recognise and to monitor real life malodours, in particular in the environement, and directly in the field.

Aims :

- Understanding the odour release
- Controlling odour abatement techniques



# Obstacles of the monitoring of real life environmental odours :

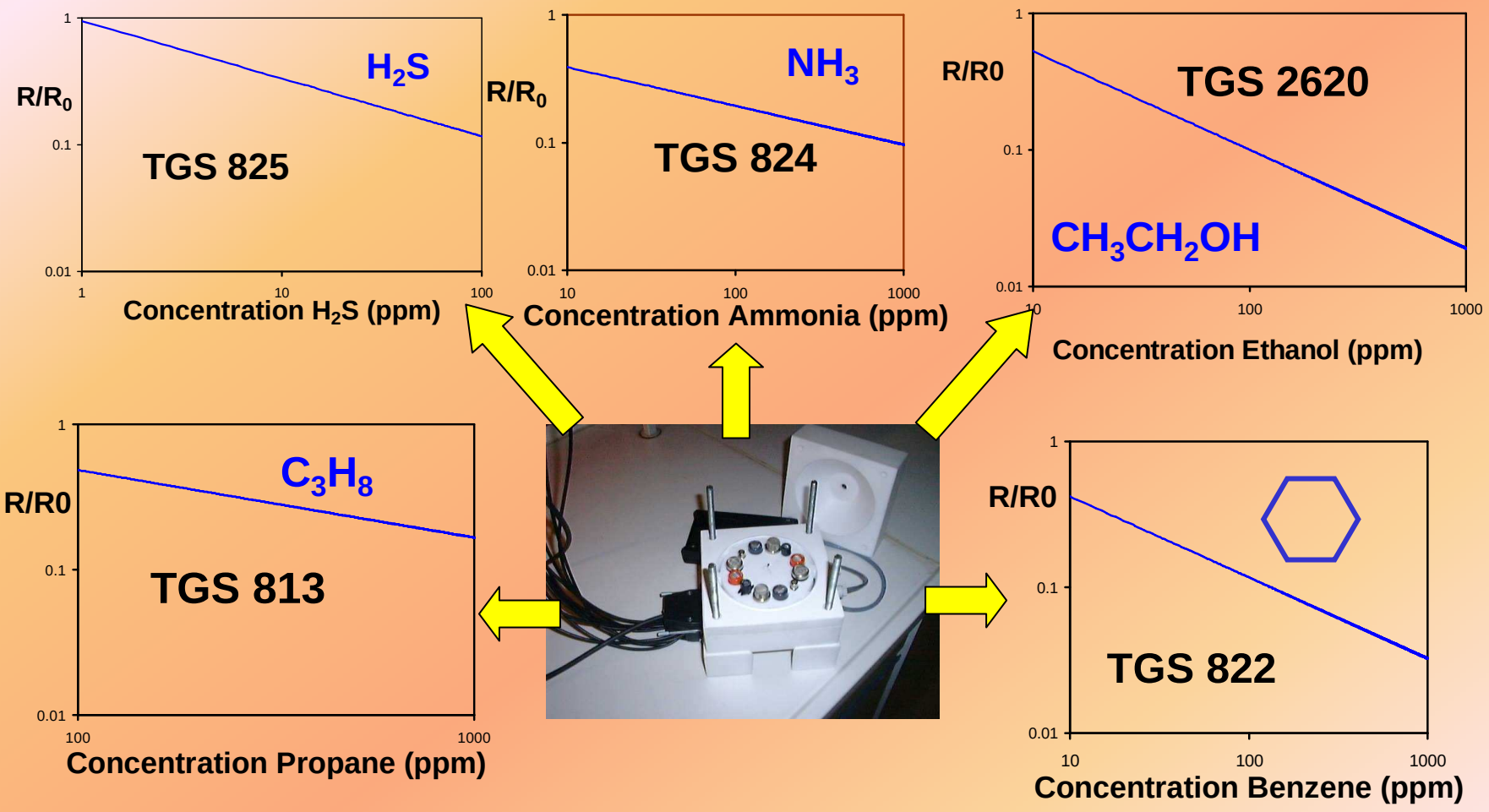
- The final goal of the study
- The analysed sample
- The operating conditions

# Obstacles of the monitoring of real life environmental odours :

- **The final goal of the study**
  - Evaluation of a global odour annoyance (not a concentration in chemicals)
- **The analysed sample**
- **The operating conditions**

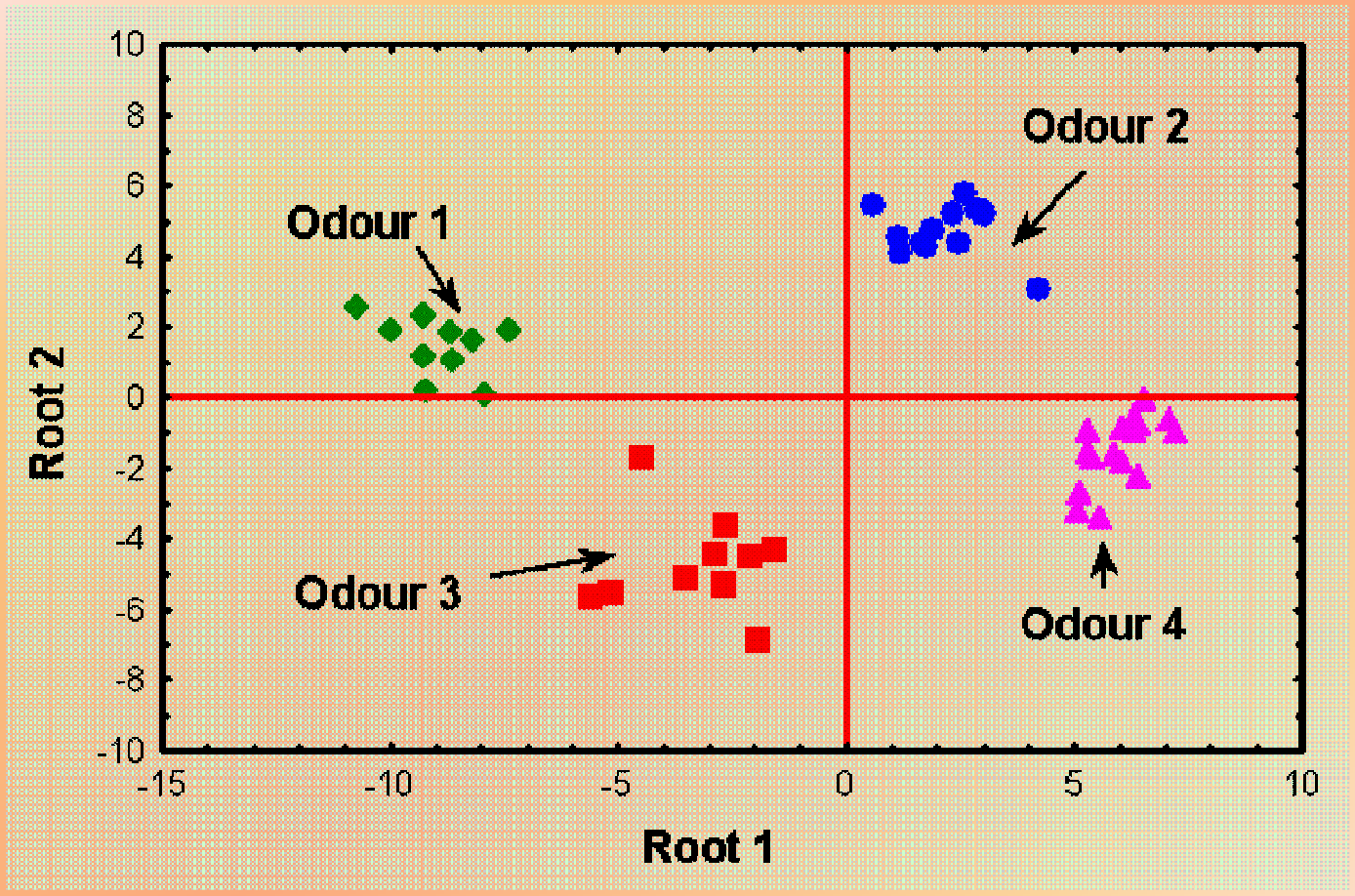
# Measuring an odour :

## 1. Suitable choice of the sensors



# Measuring an odour :

## 2. Supervised pattern recognition with « odours » as targets



Rendering plant

Paint shop in a coachbuilding

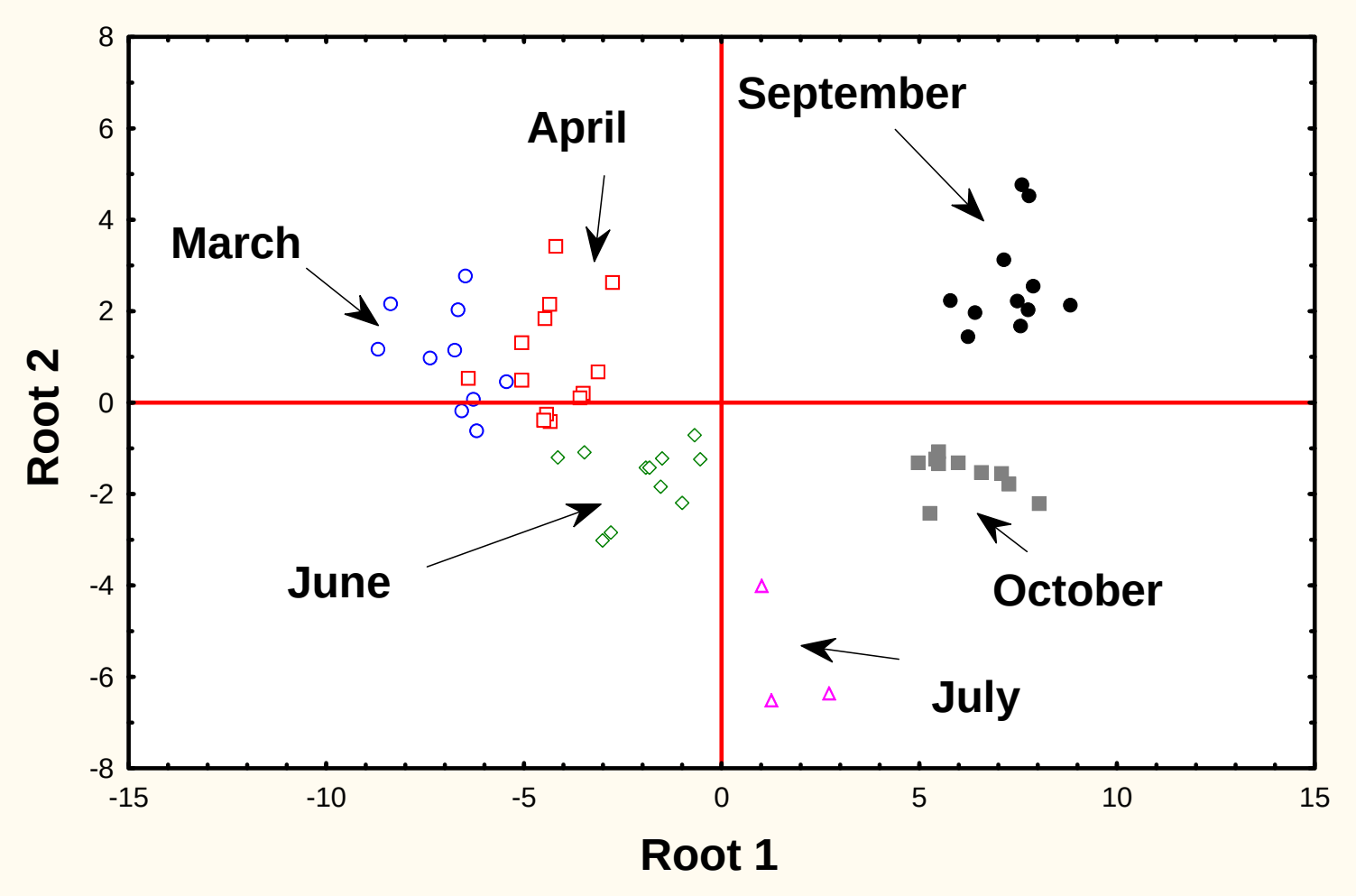
Waste water treatment plant

Urban waste composting

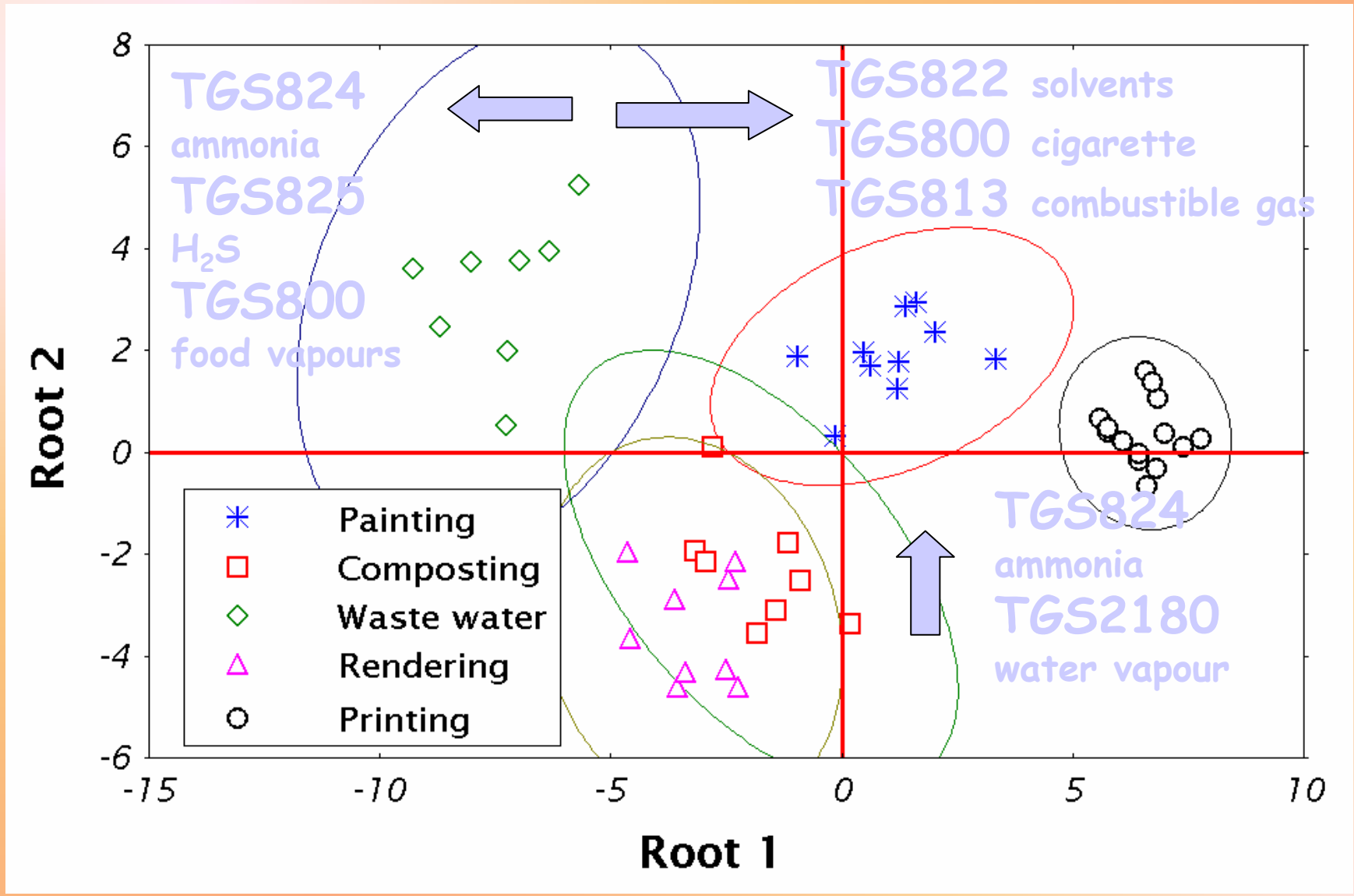
Printing house

59 samples – 7 months (March-October) – various climate conditions – various operating conditions

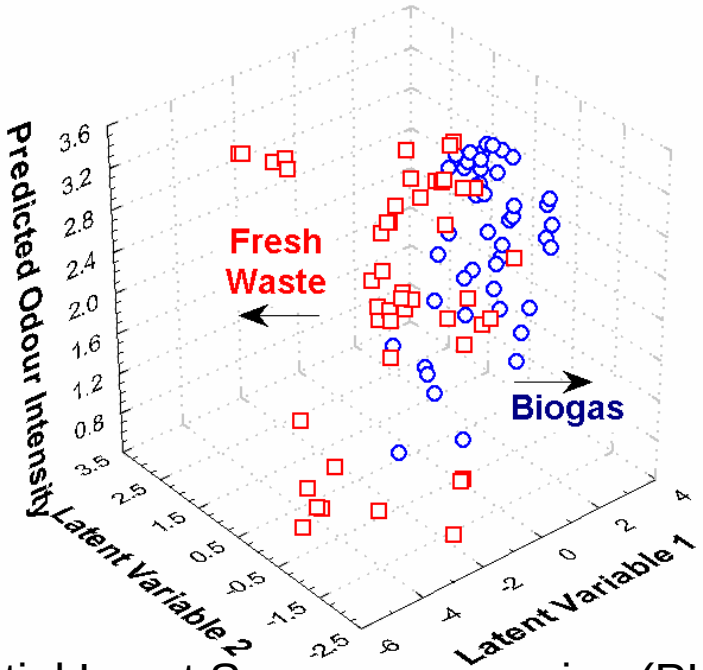
# Influence of the sampling time



# Influence of the odorous source

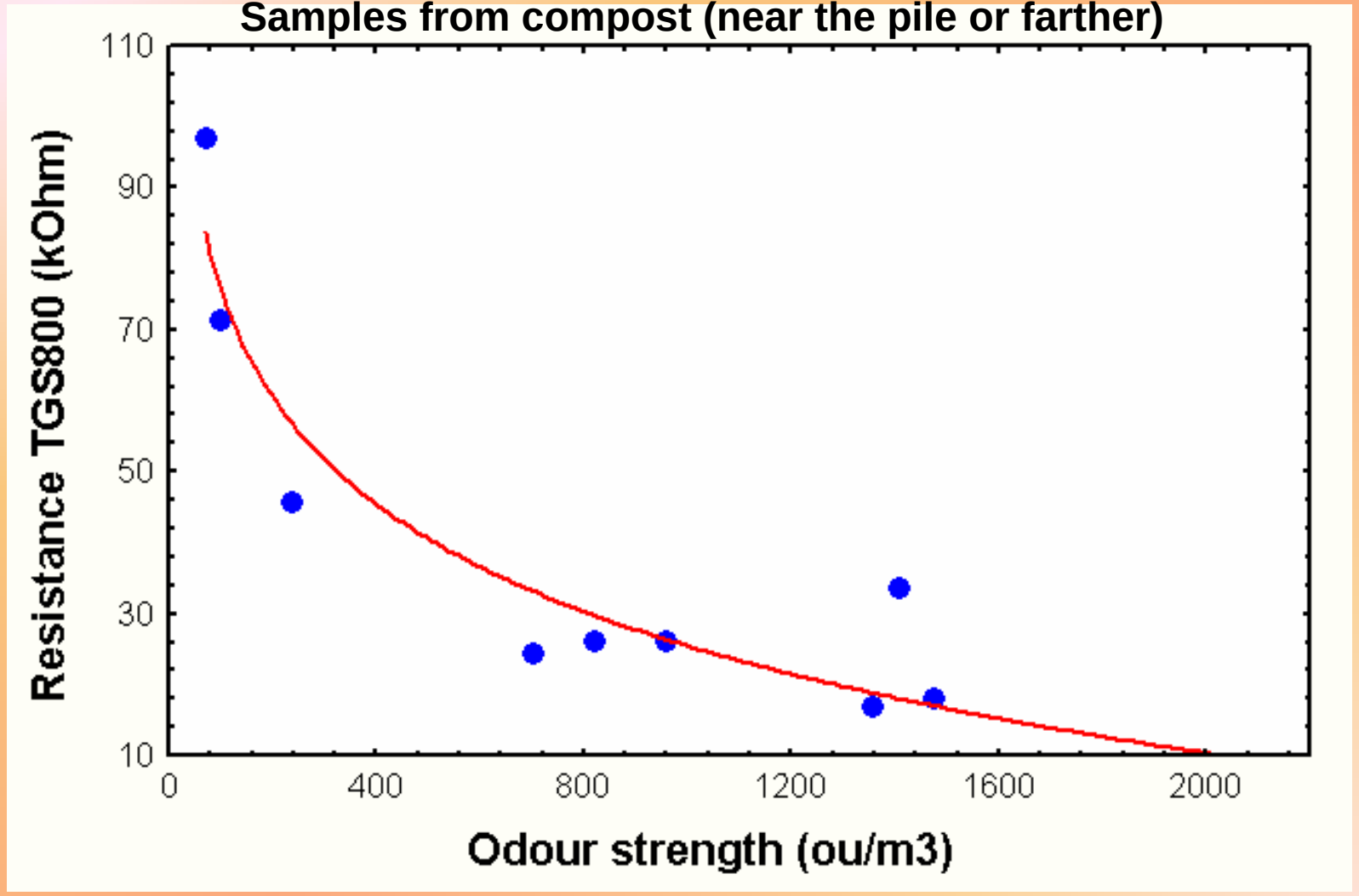


# Relying the sensor signals to the odour intensity (operator « feeling »)




Partial Least Squares regression (PLS)
71% of good predictions

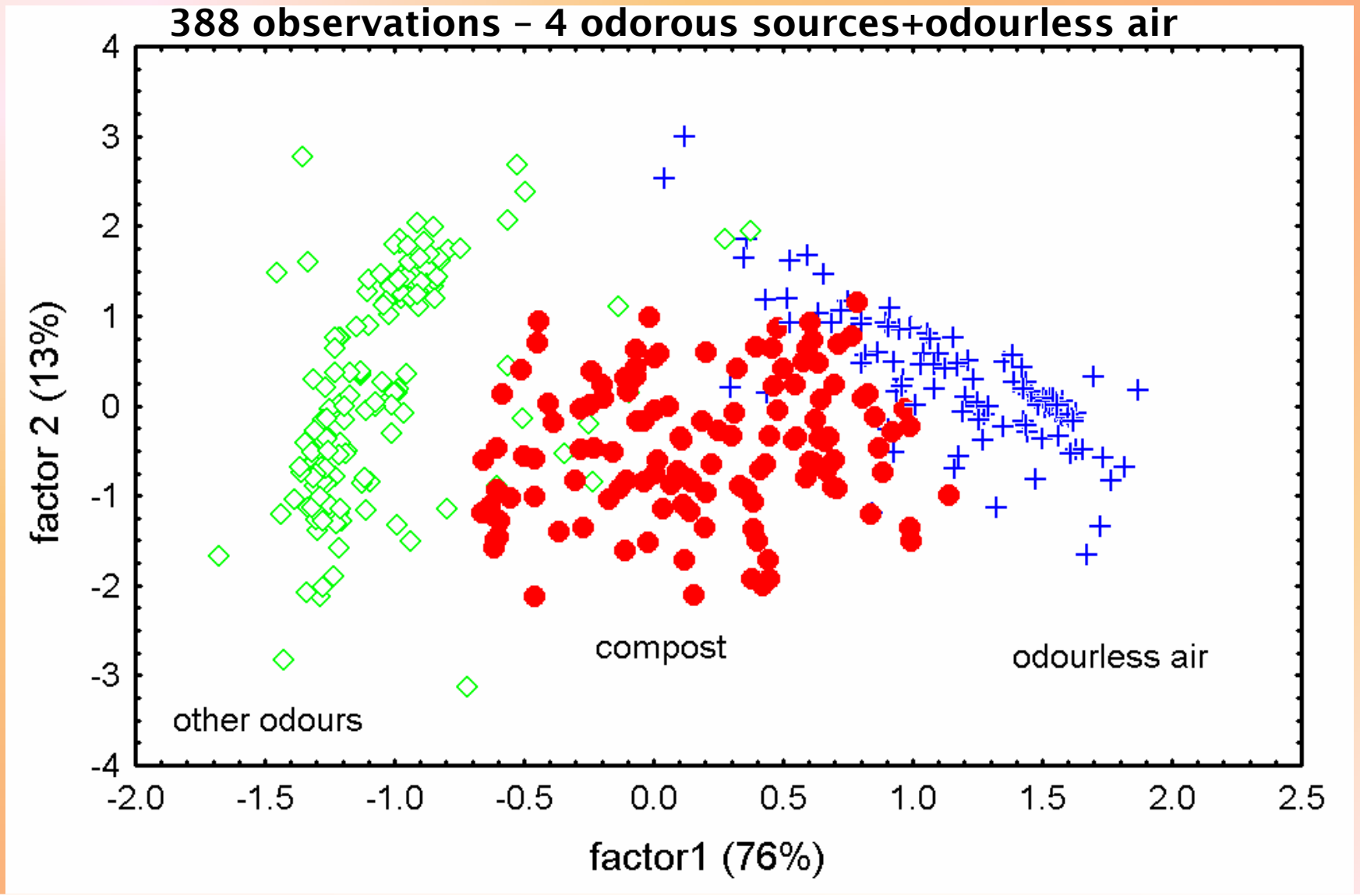
# Relying the sensor signals to the odour intensity (olfactometry)



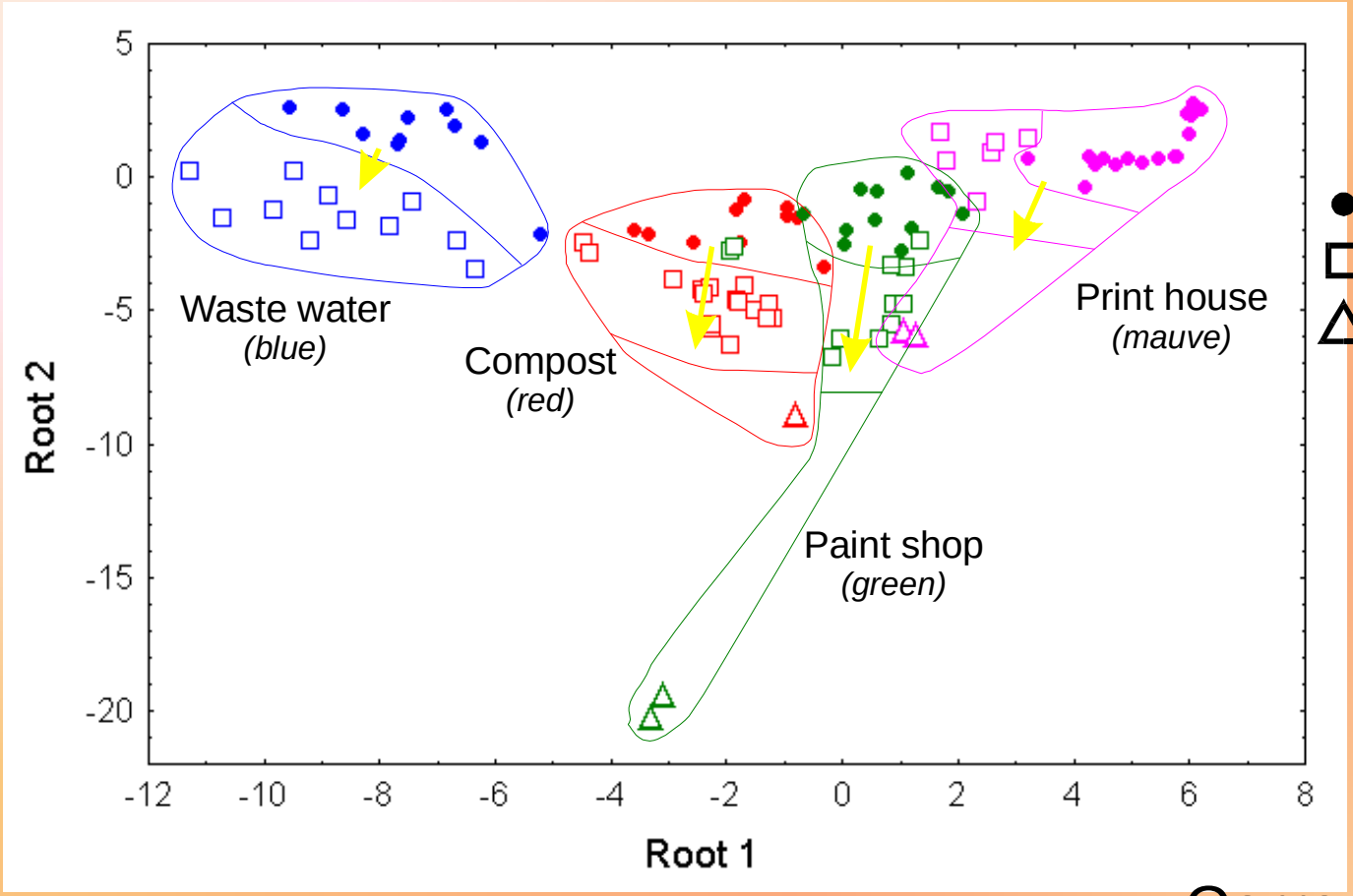
# Obstacles of the monitoring of real life environmental odours :

- The final goal of the study
- The analysed sample
  - Highly variable (process, influence of environmental parameters)
- The operating conditions

# Group overlapping : various « purity » levels



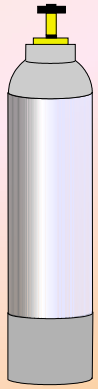
# Group overlapping : sensor drift



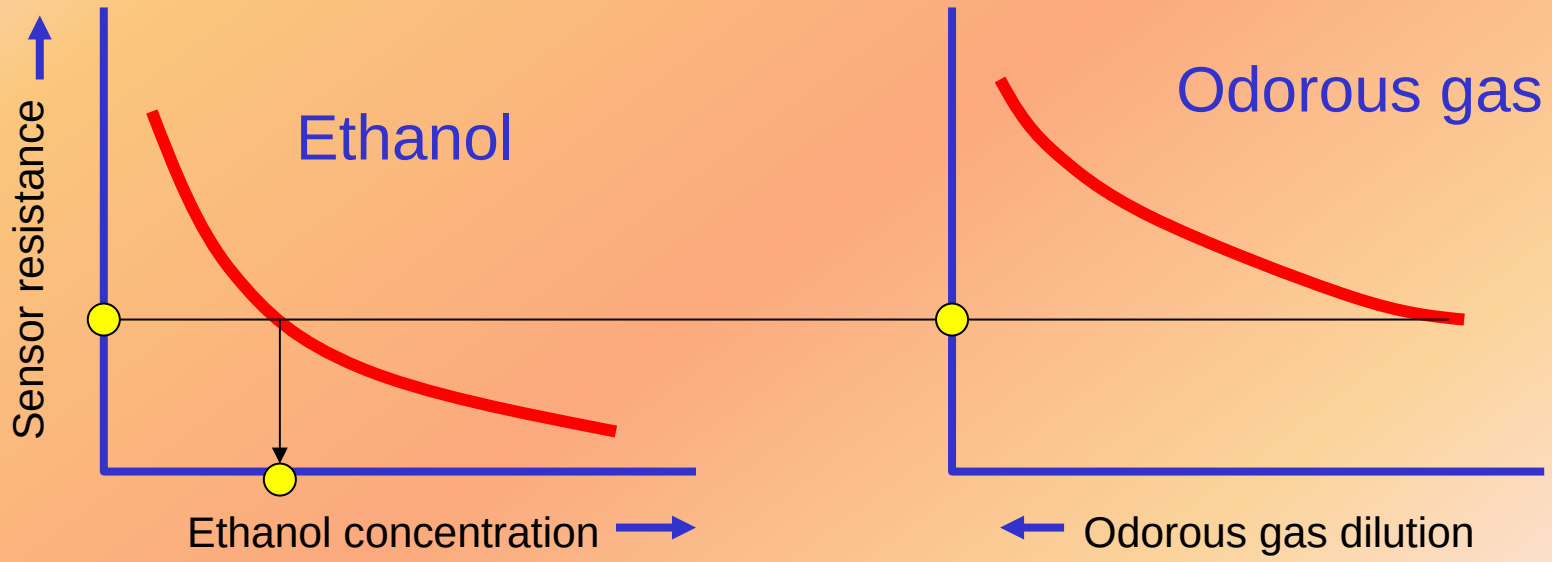

Correct classification :

- 1998 : 97.9 %
- 1999 : 81.8 %
- 2001 : 20.0 %

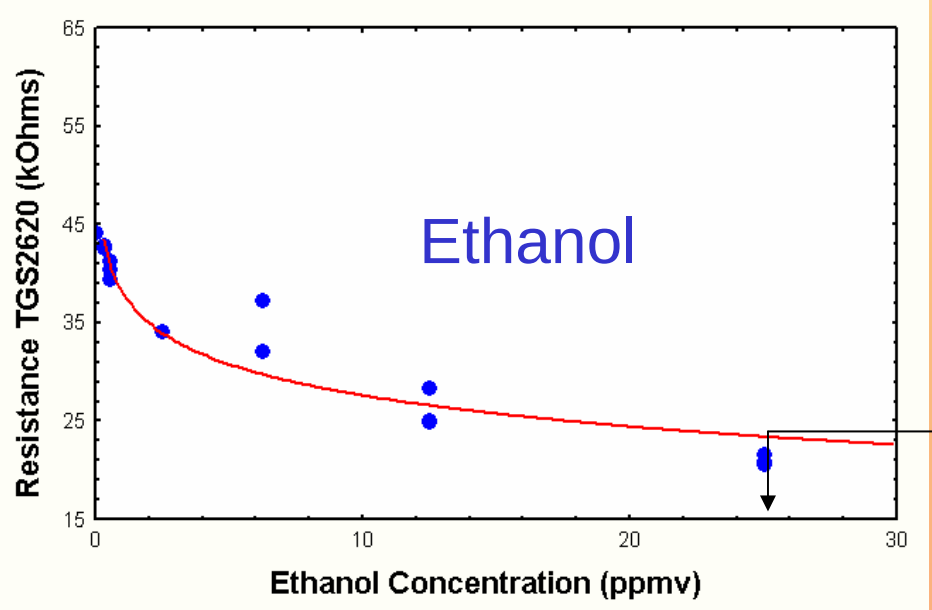
# Sensor calibration ?

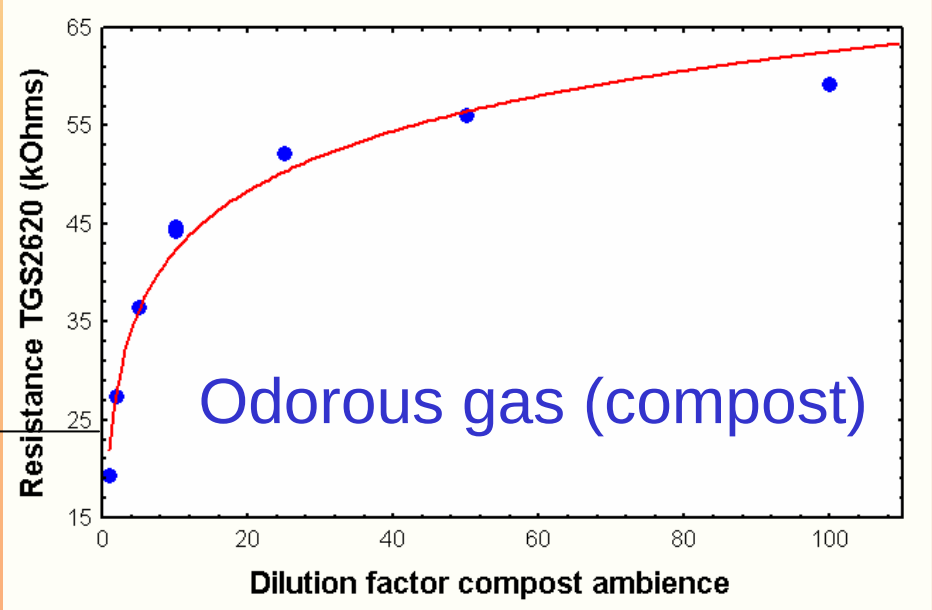


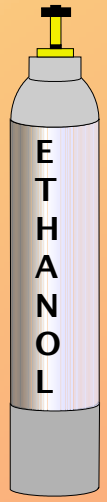
- Which standard gas ?
- Ethanol = single gas
- What is the « concentration » of the odorous gas mixture ?
- Our solution : equivalence between the « concentration » of the odorous gas mixture and the concentration of ethanol



# « Sensor calibration »

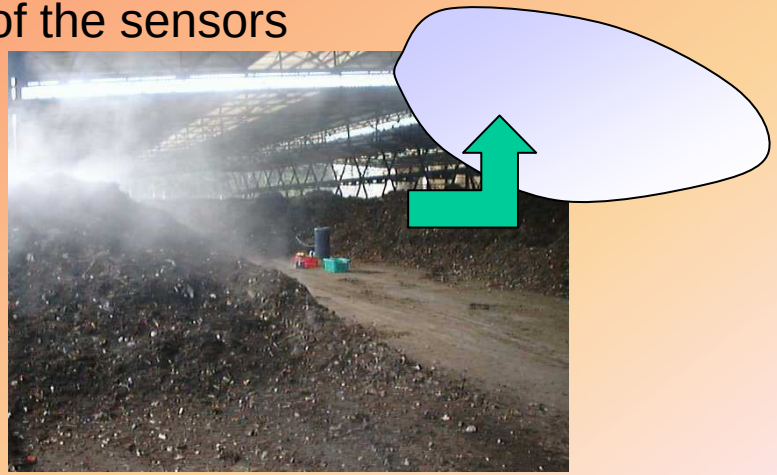



Assessing the « concentration » of odorous gas and the detection threshold of the sensors

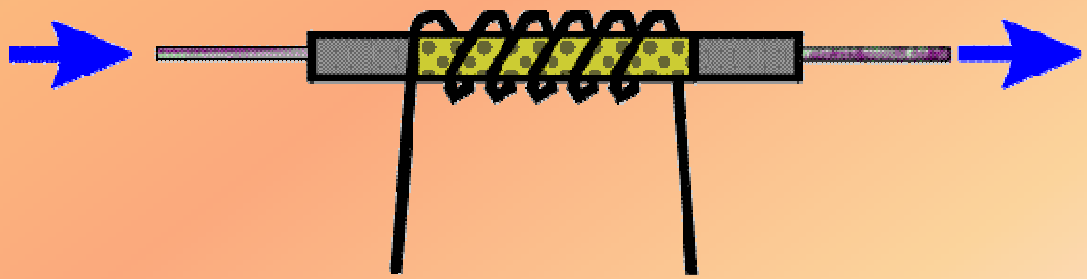
1 … 25 ppmv
ethanol-equivalent



# Low concentration level

10 ppm … 1 ppm … 100 ppb … 10 ppb

Improving the sample uptake : e.g. pre-concentrating the analytes prior to investigation with the e-nose by a « field pre-concentrator »



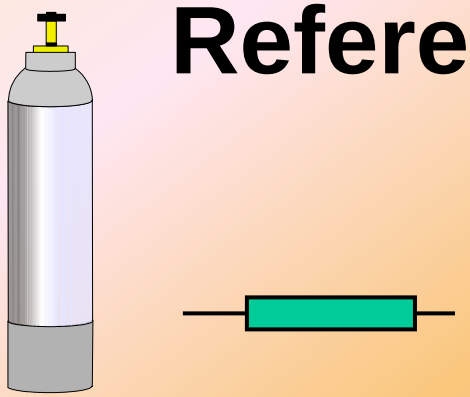
# Obstacles of the monitoring of real life environmental odours :

- The final goal of the study
- The analysed sample
- The operating conditions
  - far from any buidling, not easy to reach

Instrument :

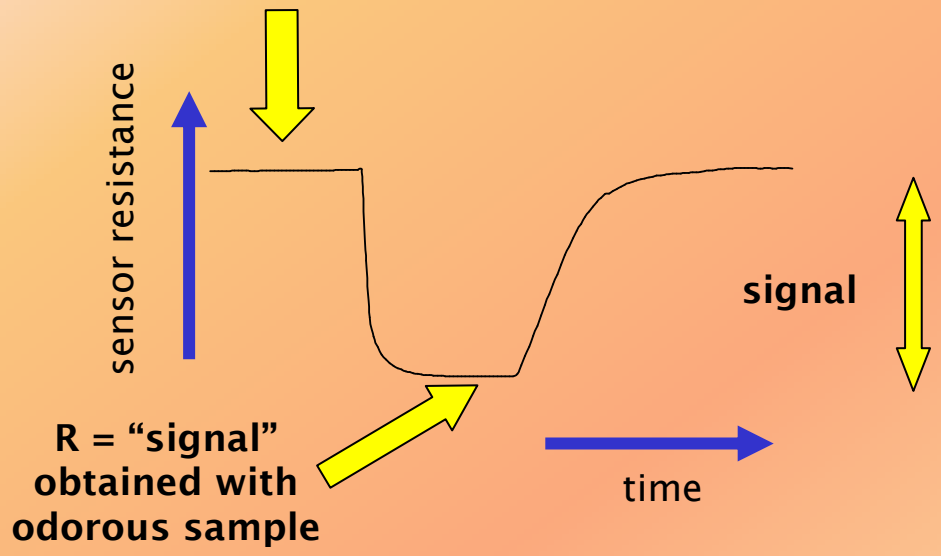
- Simple
- Transportable
- Reduced maintenance

# Reference to the base line

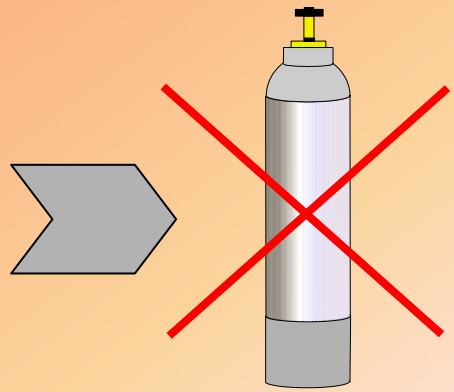


$R_0$ = “base line” obtained with “pure” air

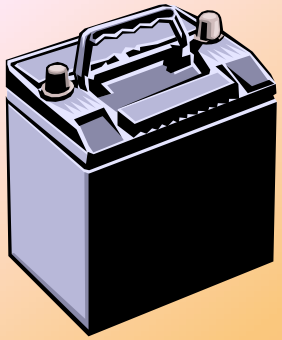
Best classification in our case




**not ($R_0$-R) but R**

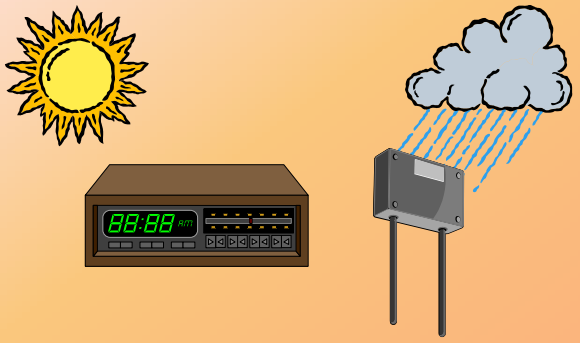


# Non-availability of the electrical supply network




- 2 amperes with « TGS800 » series
- About 600 mA with « TGS2000 » series
- Thin film ?

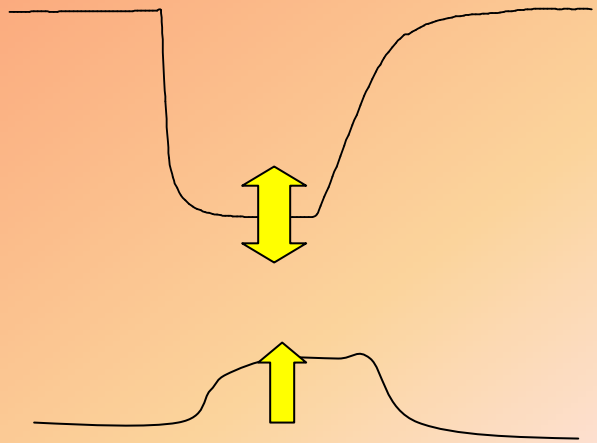
# Influence of ambient parameters



- Air humidity
- Temperature
- Wind speed

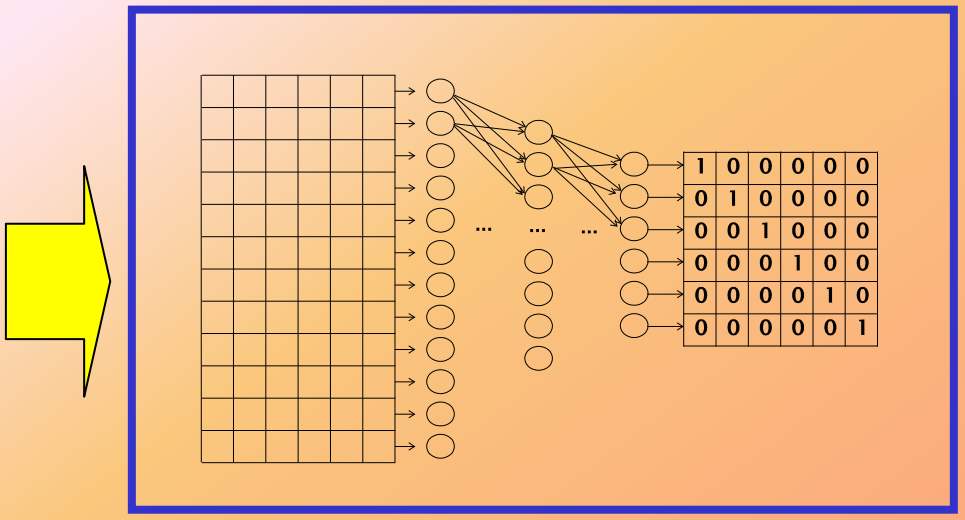
The air humidity takes part of the global odour :
not possible to dry or to saturate the sampled gas

Water vapour



**Synthetic odours** (alcohols, esters, amines, aldehydes, ketones, sulfides)
prepared in Tedlar bags under uncontrolled external conditions (various humidity level)

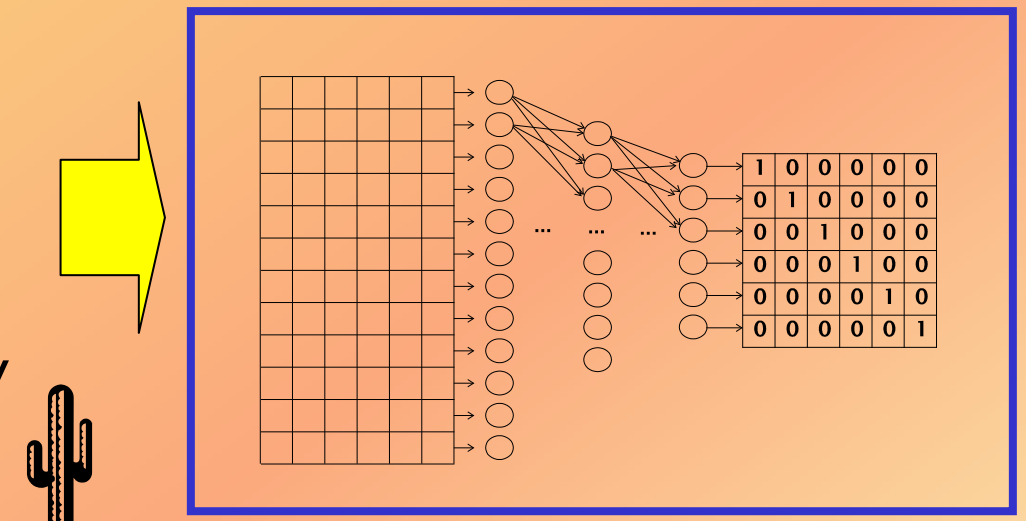
Training set of signals generated by odour at **any humidity level**




**Good recognition of 6 new samples**

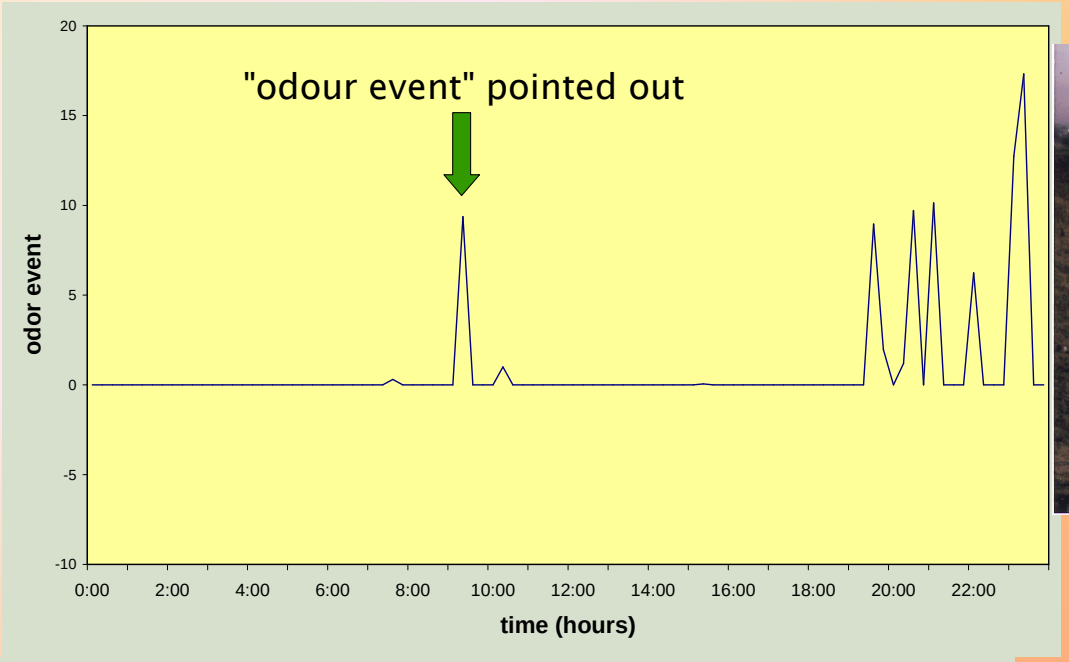
**Neural network** (18 log-sigmoïd neurons, backpropagation)

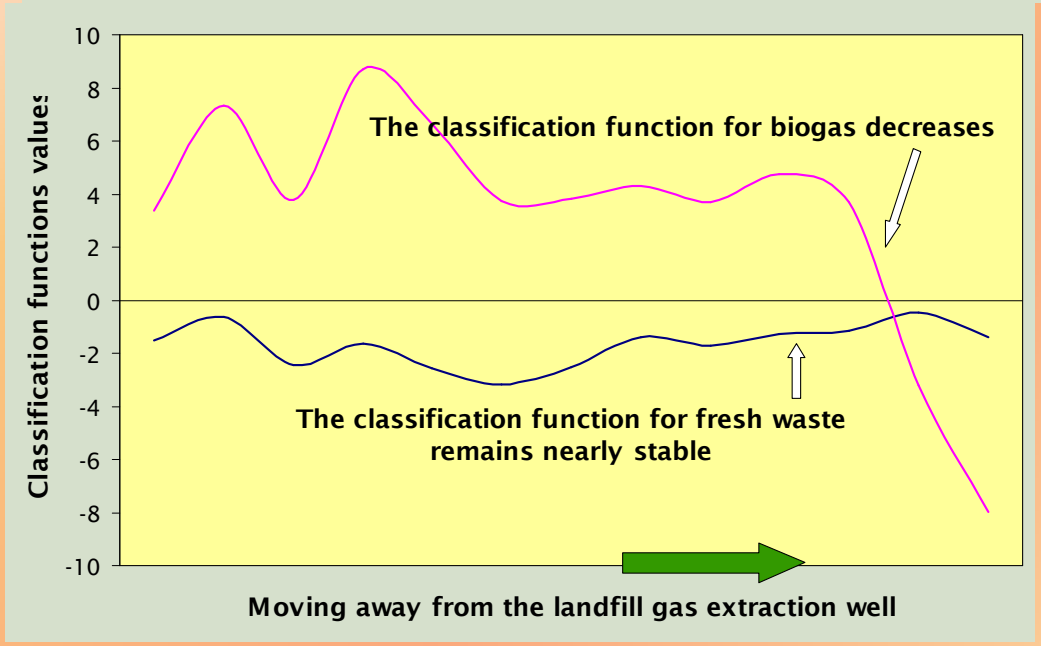
Training set of signals generated by odour at **low humidity level**






**Unable to recognise 6 new samples at higher humidity**


"odour event" pointed out
odor event
time (hours)
20
15
10
5
0
-5
-10
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00

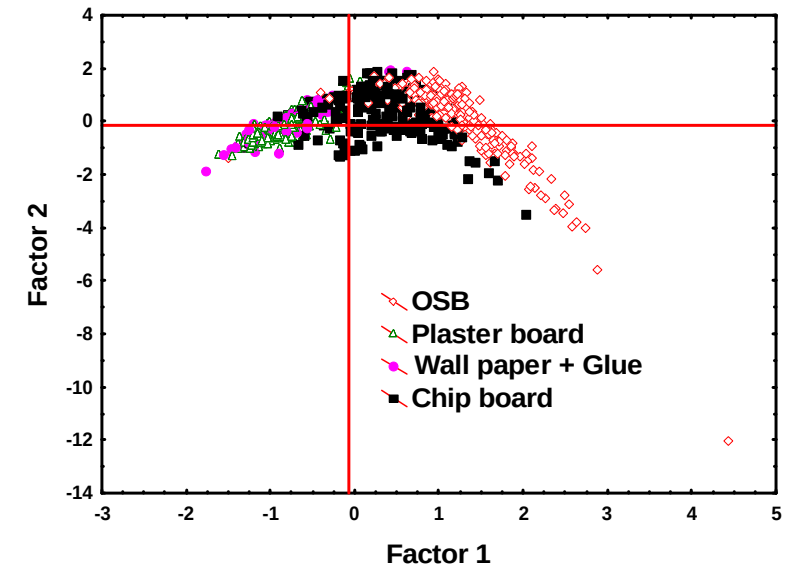

Classification functions values
The classification function for biogas decreases
The classification function for fresh waste
remains nearly stable
Moving away from the landfill gas extraction well
10
8
6
4
2
0
-2
-4
-6
-8
-10

# Detection of Moulds Growing on Building Materials by Gas Sensor Arrays and Pattern Recognition

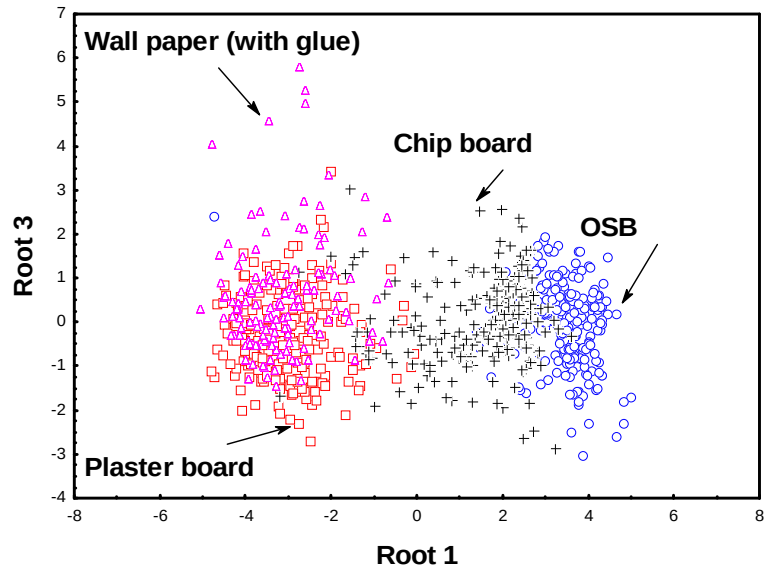



- **5 different materials typical of Belgian houses used as substrates for mould growing: plasterboard, particleboard, oriented strain board, wallpaper and glue.**
- **4 different types of moulds : *Aspergillus Versicolor*, *Penicillium Aurantiogriseum, Penicillium Chrysogeum and Cladosporium Sphaerospermu.***

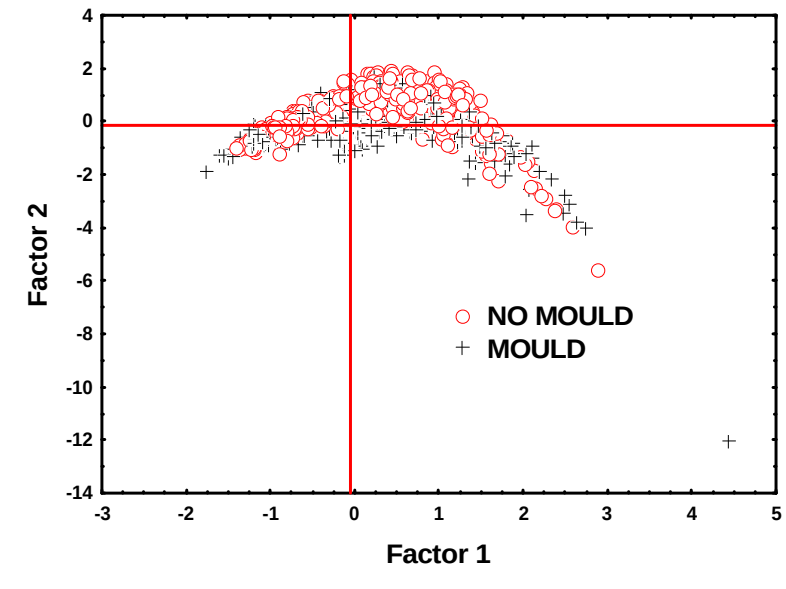
PCA shows that the main cause of the variance is the material type




79% of correct classification for the materials with Discriminant Analysis.
Only « paper wall » is less well classified (confusion with plaster board).



PCA projection seems to indicate that the classes “Mould / No Mould” are non-separable, non-gaussian and multi-modal




**But**

**89% recognition on calibration data set with linear discriminant analysis**

**87% recognition with cross validation with fuzzy KNN**

# Conclusion

- electronic nose with very simple configuration leads to promising results
- hope of designing a portable instrument to predict an unknown odour, “on line” in the environment
- monitoring of environment = challenge, but a rough estimation is sufficient
  => no need for restricting operating conditions
- further work is still needed
- => for the sensors : improvement of the sensibility, the reproducibility, the electrical consumption, the drift