European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

SOLID NANOPOROUS SENSOR FOR THE DETECTION OF PHENOL

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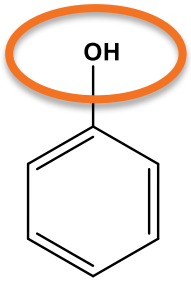
Summary

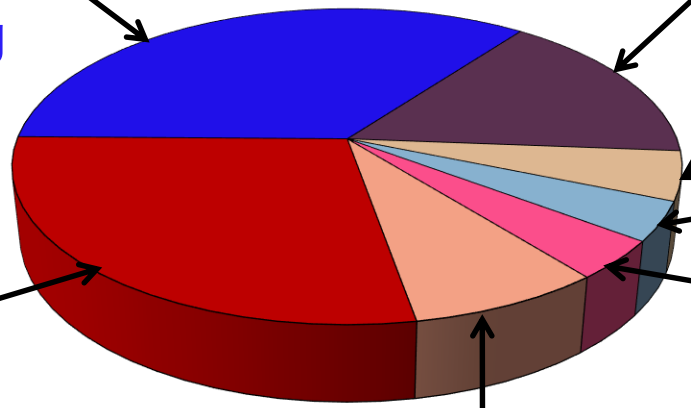
- ✓ Why is it important to detect Phenol?
- ✓ Interest of nanoporous chemical sensor
- ✓ Phenol detection in air and in water
- ✓ Conclusions and Perspectives

Phenol uses



Annual production of phenol

World	*10 million tons*
Europe	*3.3 million tons*
US	*2.4 million tons*



Phenolic resins 35%
Bakelite
Laminate flooring

Cyclohexanols 16%
Nylon

Aniline 5%

Alkylphenol 4%
Detergents

Xylenols 4%

Bisphenol A 28%
Polycarbonates

Others products 8%
Drugs (aspirin)
Cosmetics (sunscreens, hair colorings)

Phenol – Sources of emission

Air

Industries and manufactures
Automobile exhaust
Cigarette smoke
Wood burning and waste incineration

Water and soil

Surface waters, rainwater, drinking water
Industrial and urban runoff
In soil ➡ To groundwater

Workplace

Petroleum industry
Manufacture of nylon, epoxy resins and polycarbonates, wood preservatives, surfactants, additives, herbicides and coatings, and intermediates for plasticizers and other chemicals

Exposure: inhaling and skin contact

Phenol - Toxic effects - Regulations

Excessive exposure to phenol may cause health effects on:

brain, digestive system, eye, heart, kidney, liver, lung, peripheral nerve, skin and may also cause genetic damage.

In the air	**LTEL (8 h) Long-term exposure limit**		**STEL (15 min) Short-term exposure limit**	
	ppm	**mg/m³**	**ppm**	**mg/m³**
France (2009)	2	7.8	4	15.6
Europe	2	7.8		
U.S.A	5	19	15.6	60

Detection of Phenol: State of the Art

Analytical Methods for Determining Phenol

GC = Gas Chromatography
MS = Mass Spectrometry
ED = Electrochemical Detection
HPLC = High Performance Liquid Chromatography

high sensitivity
but
large, time-consuming, expensive

Adsorption / Extraction / Pre-concentration

Colorimetric Gas Detector Tubes

GASTEC

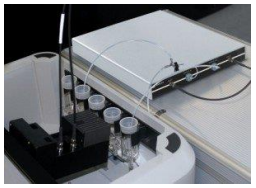
1 - 20 ppm

DRAEGER

Gas detection only

Others devices

The San++



MDL 0.119 µg/l

The zNose

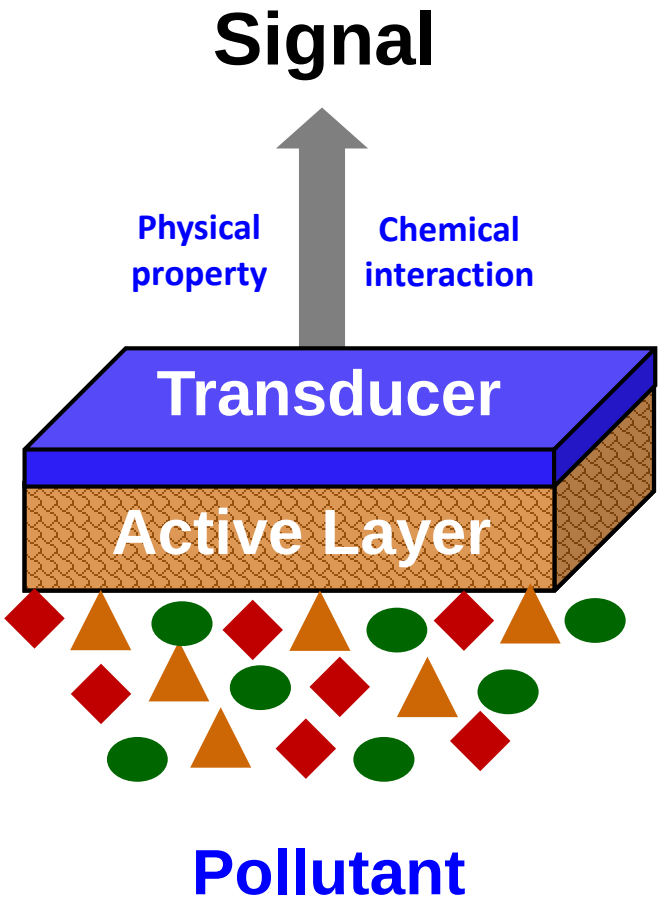
MDL 100 ppb

PID

MDL 5 ppm

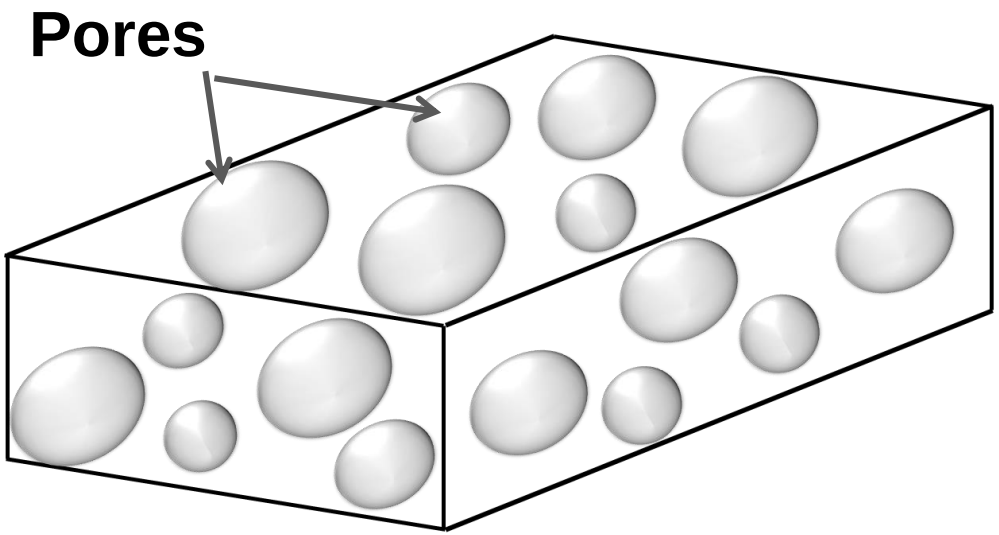
Expensive
Skilled users

Nanoporous Chemical Sensor



- Sensitivity
- Selectivity
- Low Cost
- Reduced Maintenance
- Practical

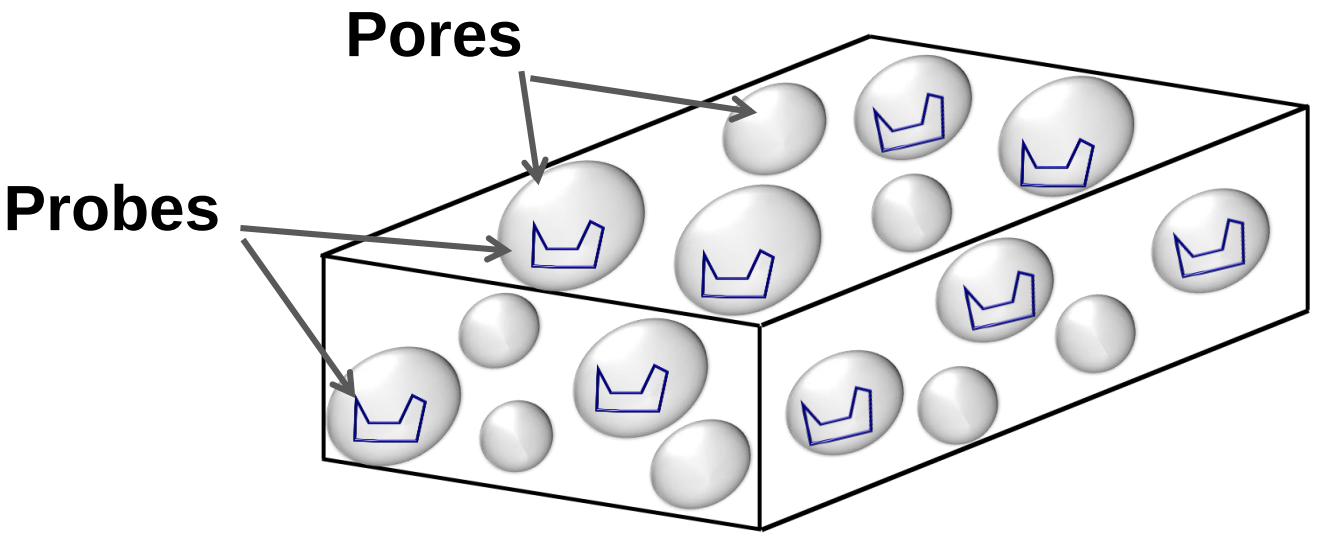
Nanoporous Chemical Sensor – Active Layer



Nanoporous Matrix

- Tunable porosity
- Colorless
- Stable

Nanoporous Chemical Sensor – Active Layer



Nanoporous Matrix

- Tunable porosity
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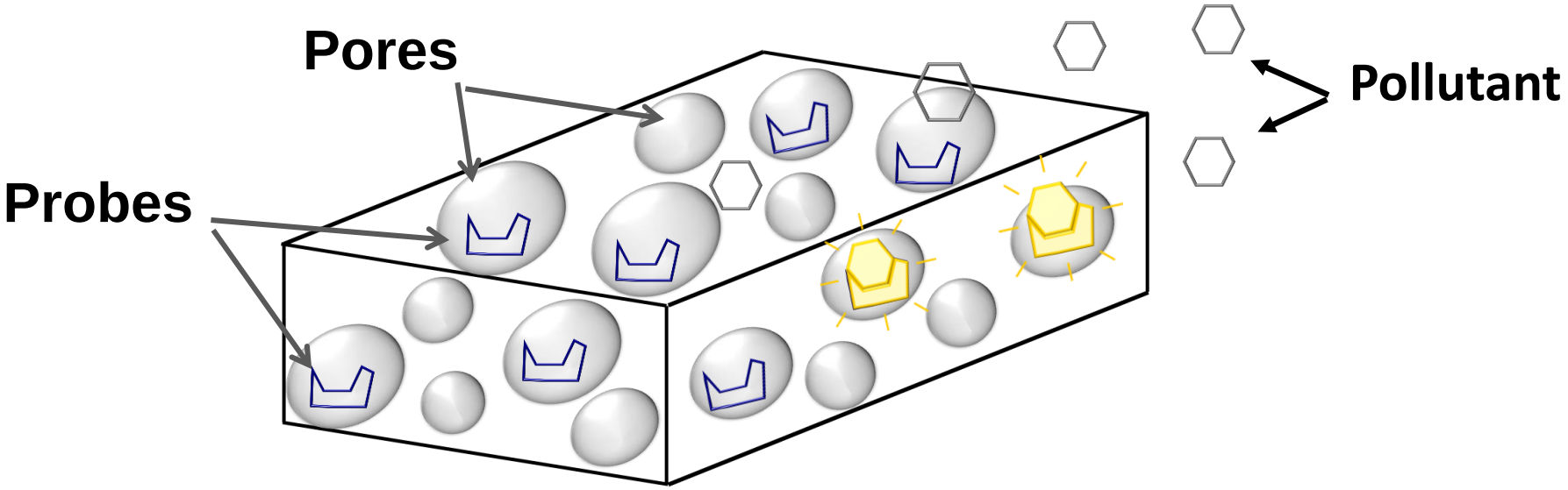
Probe-Molecules

- React with pollutant
- Selectivity
- Colored Product

Nanoporous Chemical Sensor – Active Layer



Nanoporous Matrix

- Tunable porosity
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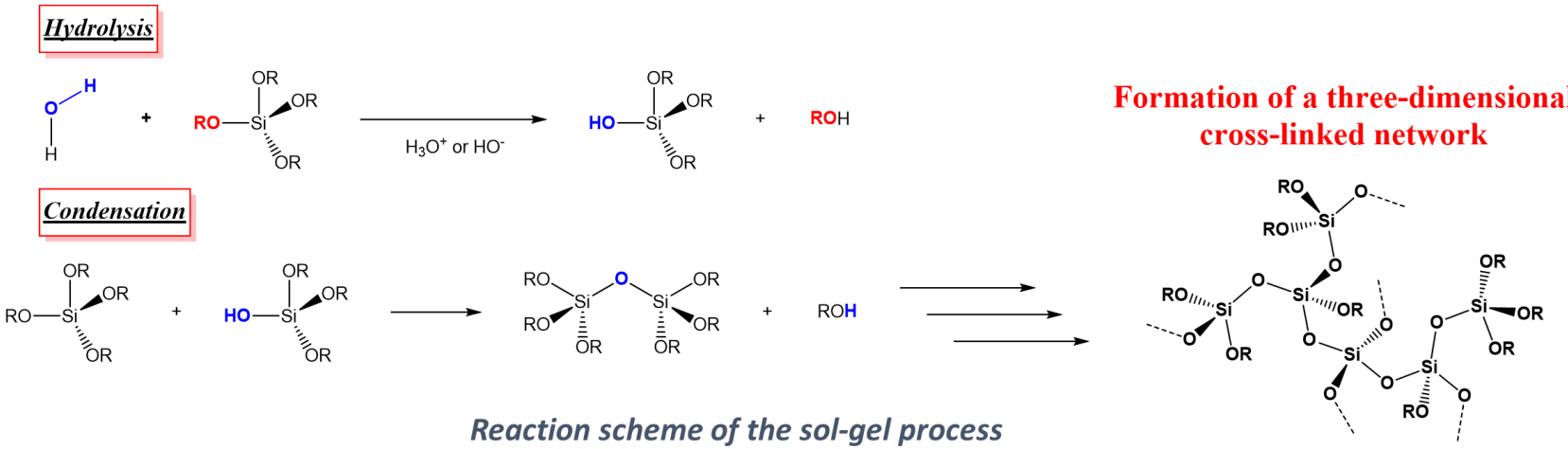
Probe-Molecules

- React with pollutant
- Selectivity
- Colored Product

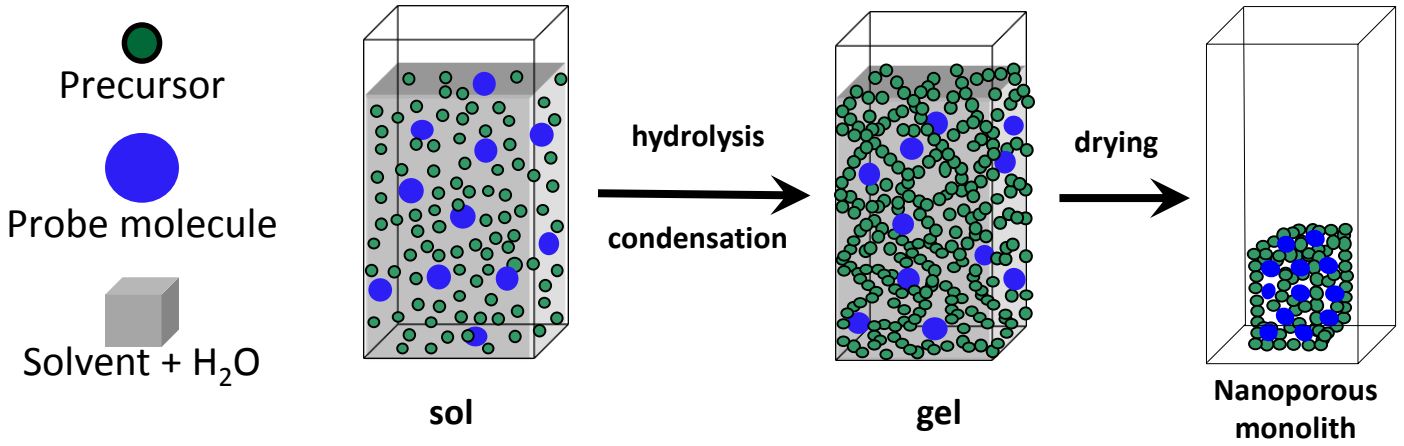
→ Visual Detection

→ Optical Measurement

Sol-Gel process



Reaction scheme of the sol-gel process

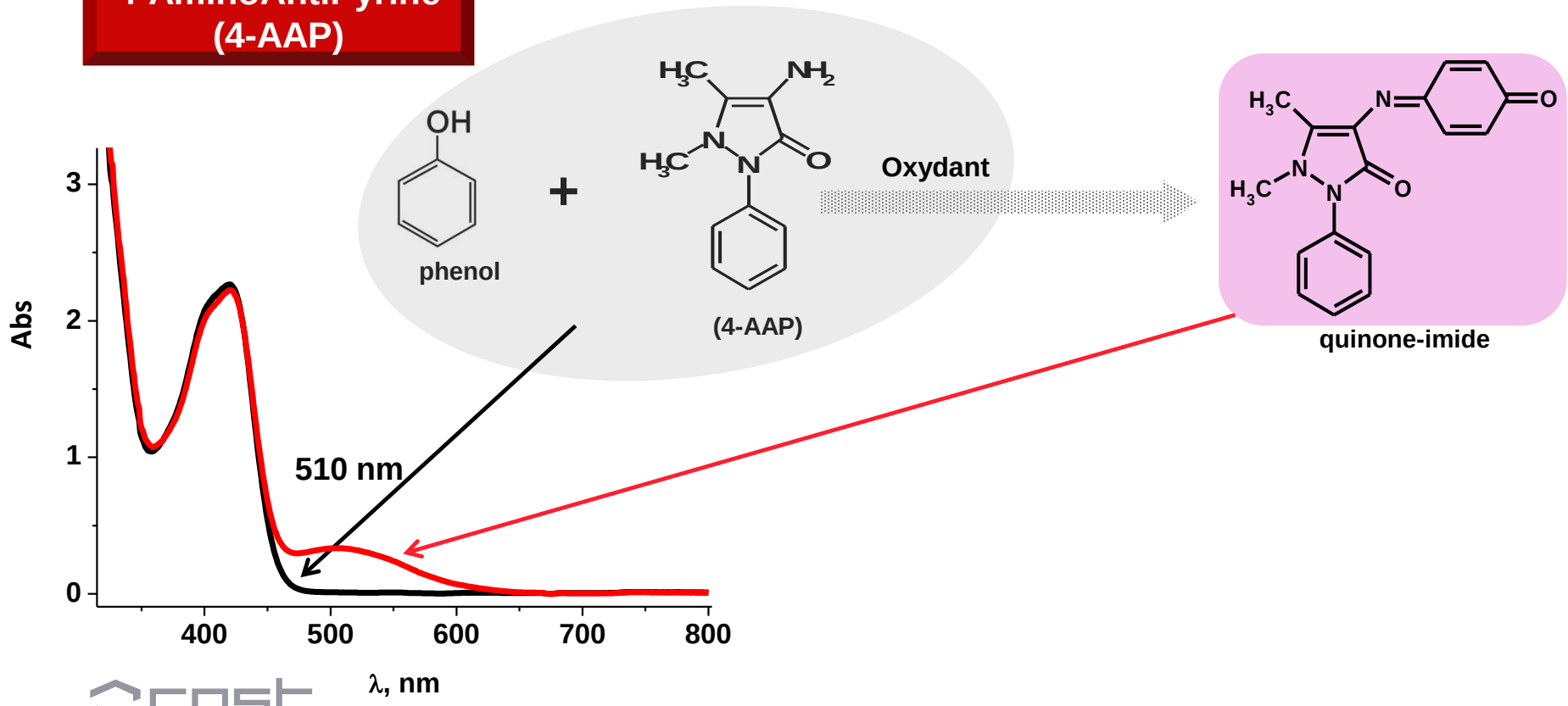


Principle of detection of phenol

Choice of Probe Molecule

One probe molecule ⟷ **One targeted pollutant**

4-AminoAntiPyrine (4-AAP)

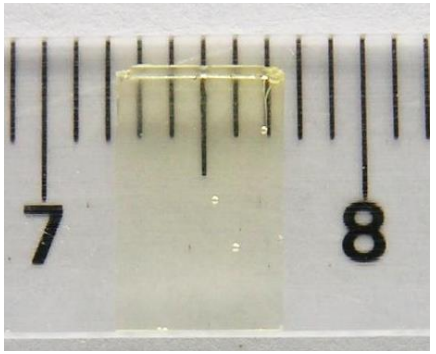


Principle of detection of phenol

Nanoporous matrix:

TMOS / APTES / MeOH / H_2O

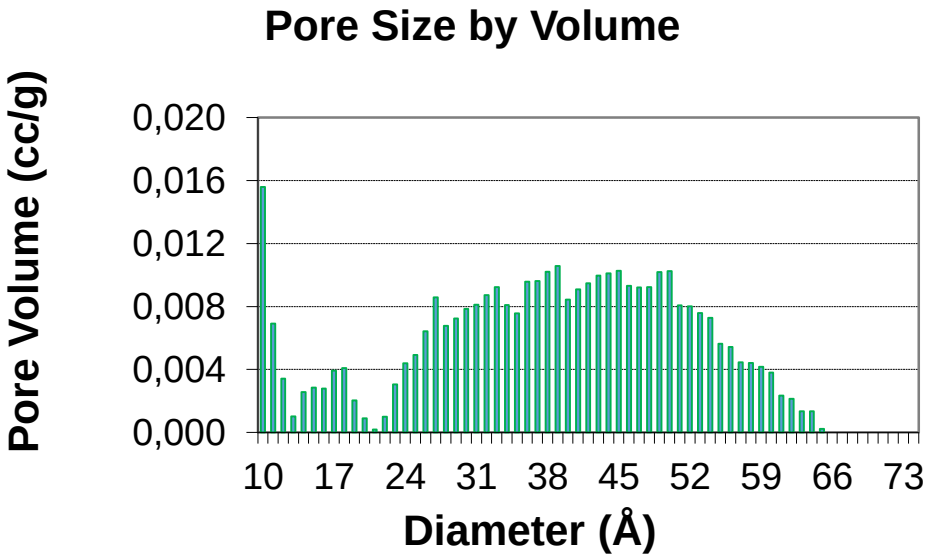
Doped with AAP:



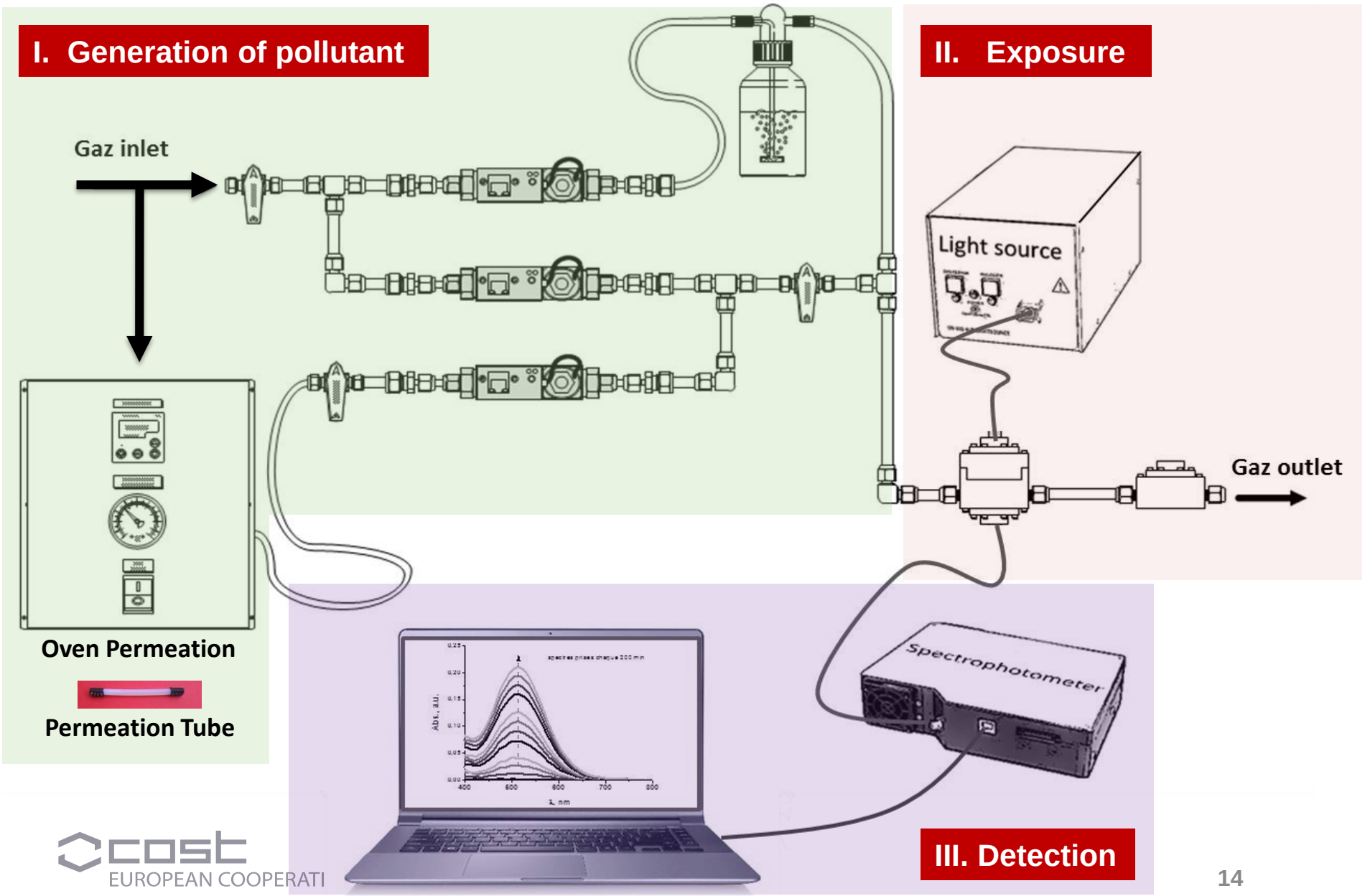
8 x 5 x 1 mm

TMOS = tetramethoxysilane;
APTES = (3-aminopropyl)triethoxysilane

Specific Area: 516 m^2/g
Pore Volume : 0.35 mL/g
Pores Size: 10-60 Å



Experimental detection set-up



Air detection

Monolith doped with AAP exposed to a flux

Exposure:

Flux 500 mL/min

Air + PhOH 12 to 200 ppb

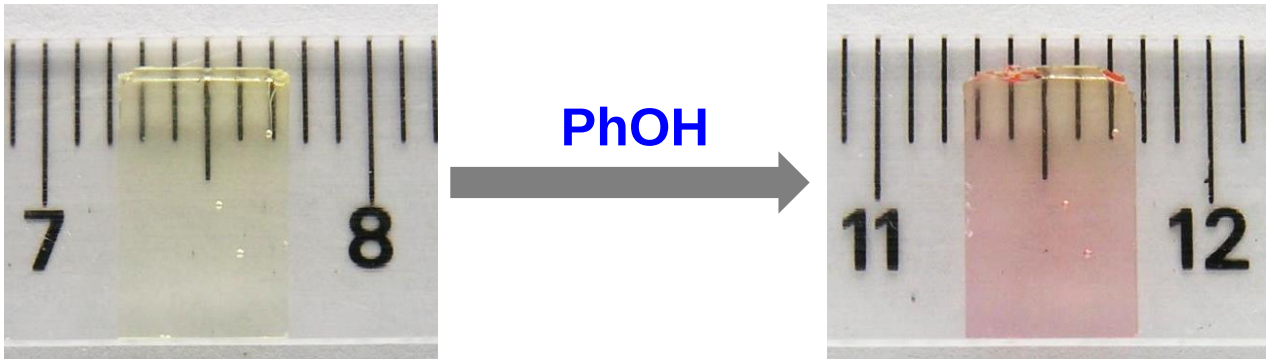
Relative Humidity 50% / 22°C

Nanoporous matrix :

TMOS / APTES

MeOH / H_2O

Doped with AAP:



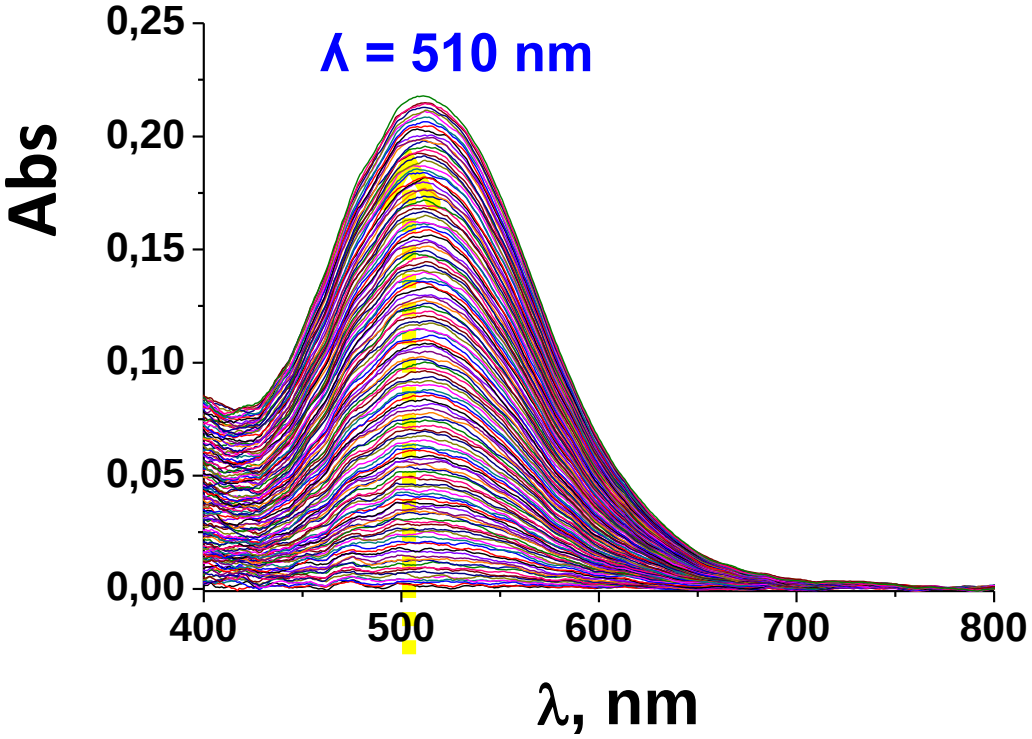
Before exposure

After exposure

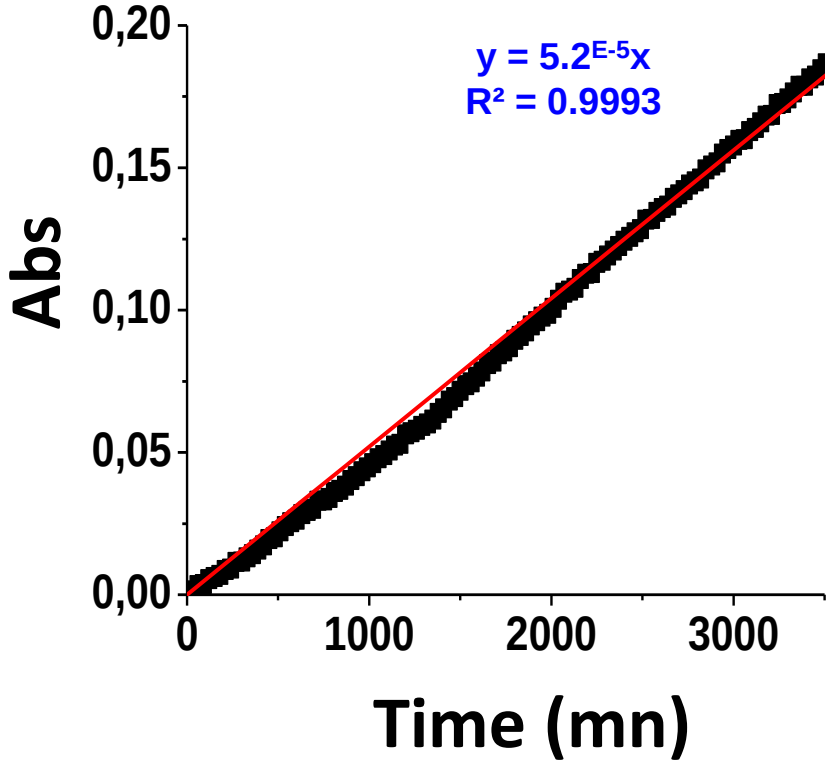
Air detection

Continuous exposure

100 ppb PhOH



Rate of formation of quinone imide dye

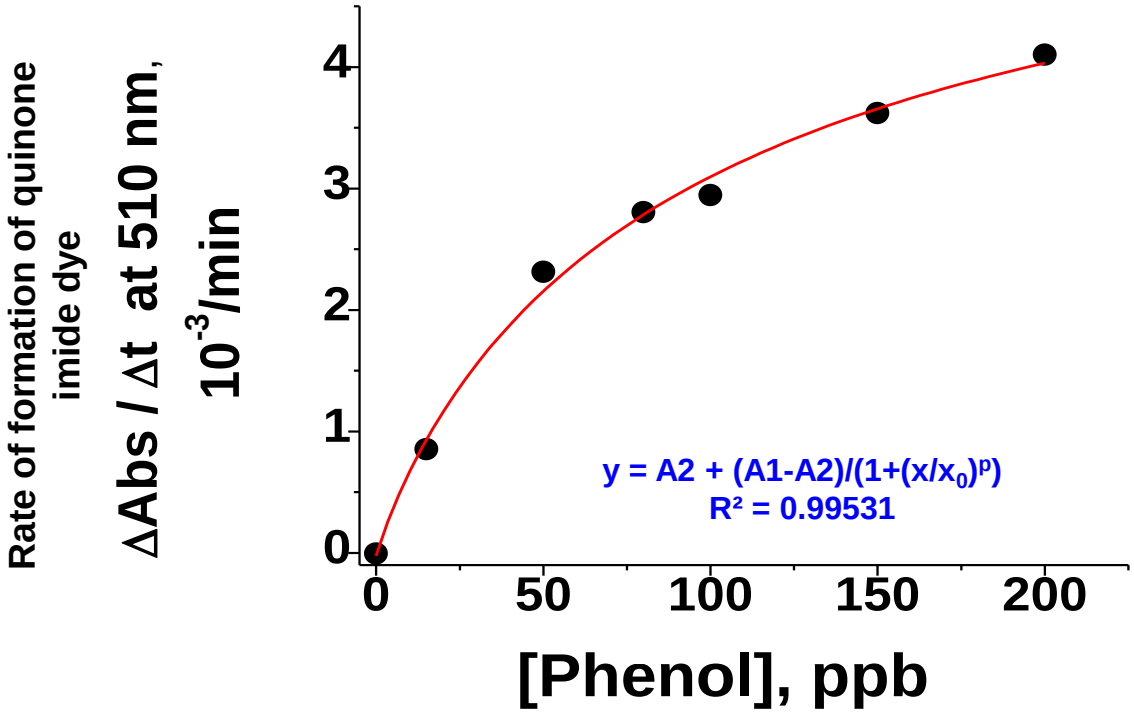


Air detection

Continuous exposure

Calibration curve for PhOH detection in air

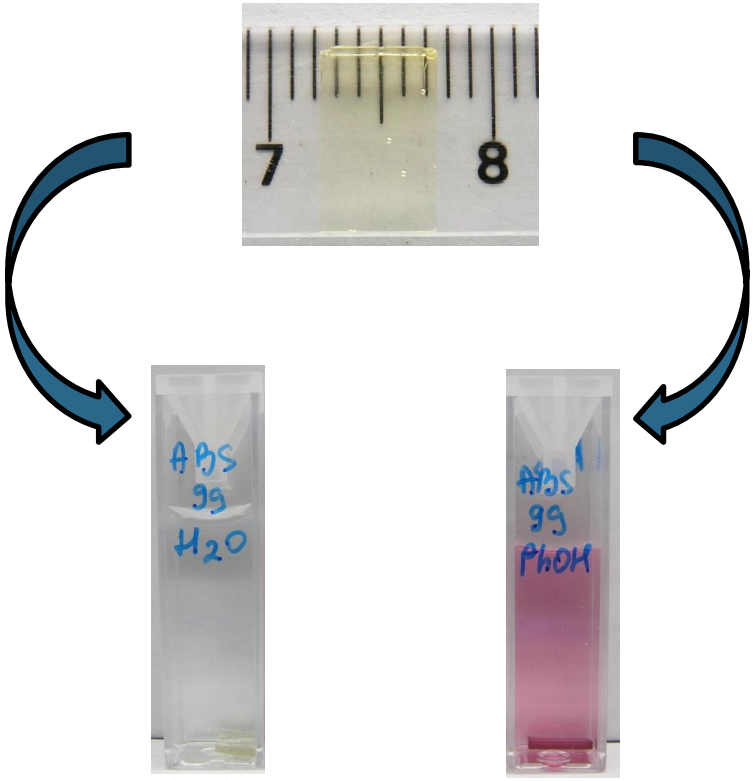
Conditions: 500 mL/min, 22 °C, 50% relative humidity



Monoliths efficient to detect phenol in gas phase

Water detection

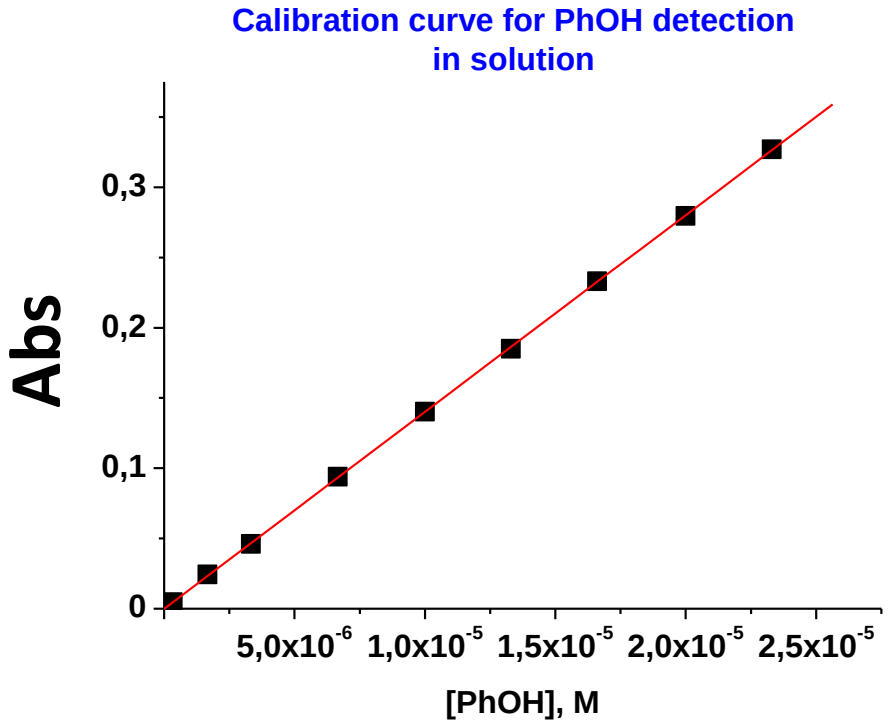
Analyzing of aqueous solutions of phenol



Water

Aqueous solution of PhOH

For each [C] at a specific Time



Conclusions

- Direct detection of Phenol
- Color change

Perspectives

- Increase of [phenol]
- Influence of humidity
- Phenol derivatives
- Measurement campaign