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

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New Sensing Technologies for Indoor Air Quality Monitoring: Trends and Challenges

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ASSESSMENT OF INDOOR POLLUTION IN A SCHOOL ENVIRONMENT THROUGH DIFFERENT TECHNIQUES - EXPERIENCES FROM ONGOING AND PAST PROJECTS

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

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Background / Indoor air pollution in schools

- Children spend significant of their time at home and schools.
- IR/BW is higher for adolescents than for adults
- Children's tissues and organs developing rapidly

The susceptibility of children to air pollution is greater than in adults

Background / Indoor air pollution in schools

For many years :

The emphasis on air quality evaluation has been centred upon issues of the outdoor air pollutants :

- behaviour
- effects
- prediction

It is to expect that indoor air quality should be better than outdoor air quality due to:

- the shielding effect of buildings
- ventilation
- air cleaning devices usage.

However, a literature review about combined indoor and outdoor air quality studies show that about 2/3 of indoor air pollutant concentration were higher than.

Background / Indoor air pollution in schools

WHO reported that Indoor air pollution (IAP) is the 8th most important risk factor responsible for 2.7% of the global burden of disease.

Accordingly, indoor air quality at schools has attracted increasing public interest in the recent years.

Background / Indoor air pollution in schools

Nearly a quarter of all school children in London are exposed to illegal and harmful levels of air pollution

http://www.itv.com/news/london/2015-11-30/a-quarter-of-london-students-exposed-to-dangerous-levels-of-air-pollution-report/

The most polluted parts of London currently have levels of NO_2 about 4x then limit, 12.5% of the total area of the Capital currently exceeds the legal limit for NO_2, and that deprived parts of London are more likely to be affected.

In the report there are highlights that:

•328,000 school children and 3.8 million workers in London are exposed to unhealthy levels of NO_2

•979 out of a total of 3,161 schools in London are over the limit for NO_2

WHO INDOOR AIR PRIORITY POLLUTANTS

WHO Guidelines for Indoor Air Quality: Selected Pollutants

Group 1 -The substances considered as priority for which it is provided a scientific basis for legally enforceable standards in the Guidelines:

- benzene
- carbon monoxide
- formaldehyde
- naphthalene
- nitrogen dioxide
- polycyclic aromatic hydrocarbons (especially benzo[a]pyrene)
- radon
- trichloroethylene
- tetrachloroethylene

WHO INDOOR AIR PRIORITY POLLUTANTS

Pollutant	WHO Guidelines recommended health based guidelines/ thresholds
benzene	•No safe level of exposure can be recommended •Unit risk of leukaemia per 1 μg/m3 air concentration is 6 × 10−6 •The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17 μg/m3, respectively
carbon monoxide	•15 minutes – 100 mg/m3 •1 hour – 35 mg/m3 •8 hours – 10 mg/m3 •24 hours – 7 mg/m3
formaldehyde	0.1 mg/m3 – 30-minute average
naphthalene	0.01 mg/m3 – annual average
nitrogen dioxide	•200 μg/m3 – 1 hour average •40 μg/m3 – annual average
PAH/BaPeq	•No threshold can be determined and all indoor exposures are considered relevant to health •Unit risk for lung cancer for PAH mixtures is estimated to be 8.7 × 10−5 per ng/m3 of B[a]P •The corresponding concentrations for lifetime exposure to B[a]P producing excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are approximately 1.2, 0.12 and 0.012 ng/m3, respectively
radon	•The excess lifetime risk of death from radon-induced lung cancer (by the age of 75 years) is estimated to be 0.6 × 10−5 per Bq/m3 for lifelong non-smokers and 15 × 10−5 per Bq/m3 for current smokers (15–24 cigarettes per day); among ex-smokers, the risk is intermediate, depending on time since smoking cessation •The radon concentrations associated with an excess lifetime risk of 1/100 and 1/1000 are 67 and 6.7 Bq/m3 for current smokers and 1670 and 167 Bq/m3 for lifelong non-smokers, respectively
trichloroethylene	•Unit risk estimate of 4.3 × 10–7 per μg/m3 •The concentrations of airborne trichloroethylene associated with an excess lifetime cancer risk of 1:10 000, 1:100 000 and 1:1 000 000 are 230, 23 and 2.3 μg/m3, respectively
tetrachloroethylene	0.25 mg/m3 – annual average

WHO INDOOR AIR PRIORITY POLLUTANTS

WHO Guidelines for Indoor Air Quality: Selected Pollutants

- indoor levels of PM10 and PM2.5, in the presence of indoor sources of PM, are usually higher than the outdoor PM levels
- there is no convincing evidence of a difference in the hazardous nature of particulate matter from indoor sources as compared with those from outdoor

Pollutant	WHO Guidelines recomanded values
PM2.5	10 μg/m3 annual mean 25 μg/m3 24-hour mean
PM10	20 μg/m3 annual mean 50 μg/m3 24-hour mean

WHO INDOOR AIR PRIORITY POLLUTANTS

WHO Guidelines for Indoor Air Quality: Selected Pollutants

Group 2 are the substances where current evidence is uncertain or not sufficient for Guidelines :

- toluene
- styrene
- xylene
- acetaldehyde
- nitric oxide
- ozone
- phthalate
- biocide/pesticide
- flame retardants
- glycol ether, carbon dioxide
- limonene, pinene
- general recommendations TVOC

SINPHONIE PROJECT (2010-2012)

SINPHONIE project- School Indoor Pollution and Health: Observatory Network for Europe EC service contract (DG Sanco, Health and Consumer Protection Directorate, http://www.sinphonie.eu/

25 European countries, collected data at 141 school and 25 kindergarten

- *Passive samplers for few gases (e.g.Radello)*
- *Continual devices CO_2, CO, T, P, RH*
- *Gravimetric pumps $PM_{2.5}$, PAHs*

Campaigns in duration of one week day (5 days) in heating and nonheating season

Distribution of chemical, physical and comfort parameters in primary schools in 22 countries in Europe and comparisons with existing guidelines and comprision with schools in Serbia

Pollutant and parameter guidelines levels			N=114 schools in 22 EN countries				N=4 schools SERBIA			
	Shot -terms	Long-term	Mean	Median	Min-Max	SD	Mean	Median	Min-Max	SD
Formaldehyde[1]	100 [30] [50][120]	100 [10] [10] [10]	15	12	1-66	11	12	10	5-40	9
Benzene[1]	-	No safe [10] [20][10]	4	2	DL-38	6	15	16	1-29	9
Naphtalene[1*****]	-	10	2	DL	DL-31	8	0,043	0,037	0,015-0.108	0,029
Limonene[1]	[20]	[450]	38	9	DL-672	133	1	1	DL-4	1
NO_2[1]	200 [200]	40 [40] [135]	14	11	DL-88	9	16	13	5-30	8
$PM_{2.5}$[1]	25	10 [10] [15]	44	37	4-250	37	49	42	26-95	26
Ozone[1]	100 (outdoors)	-	8	3	Dl-142	4	2	1	DL-39	3
CO[7]	100* [100]* [30]*	-	8	3	DL-122	1	DL	DL	DL-2.4	1
T3CE[1]	-	23**	3	DL	DL-126	8	63	50	9-155	50
T4CE[1]	-	250	1	DL	Dl-81	2	1	1	0-3	1
Radon[3]	-	167***	205	101	DL-9190	2146	-	-	-	-
RH[4]	-	50****	43	42	6-98	12	44	38	26-81	18
temparature[5]	-	-	20	21	0-30	2	18	18	11-24	4
CO_2[7]	-	1000 [492]	1433	1257	269-4960	869	937	889	660-1405	220
ventilation[6]	-	-	1	0	0-4	1	2	1	0-4	1

[EU-INDEX]
[French ANSES]
[Maximum allowable concentration Netherlands]
[Guideline value Flemish Indoor Decree]

Min: minimum; Max: maximum; SD: standard deviation; T3CE: trichloroethylene; T4CE: tetrachloroethylene; DL: detection limit

[1]$\mu g/m^3$; [3]Bq/m^3; [4]%; [5]°C; [6] /hr, [7]ppm (parts per million)

*15 minutes; **lifetime exposure with acceptable risk at 10^{-5}; ***concentration associated with an excess lifetime risk of 1 per 1,000 (non-smokers); ****by increasing the relative humidity to above 50% within 20–25°C, 80% or more of all averagely dressed individuals would feel comfortable (US-EPA). ; *****in Serbia only naphthalene particle bounded, in other gasous or both ;

III42008 PROJECT (2012-2016)

III42008 "Evaluation of Energy Performances and Indoor Environment Quality of Educational Buildings in Serbia with Impact to Health"

Campaigns of measuring air pollutants and comfort parameters in school and kindergartens with reference and :

- PM_1, $PM_{2.5}$, PM_{10}
- PAH in selected schools and kindergarten in Serbia
- CO_2
- T, p, PH

III42008 PROJECT

- **PAH in selected schools and kindergarten in Serbia**

The sampling campaigns with LVS for period of 24h perform successively in each school:

- simultaneously *indoor and outdoor*
- period *heating season*
- duration *one week*

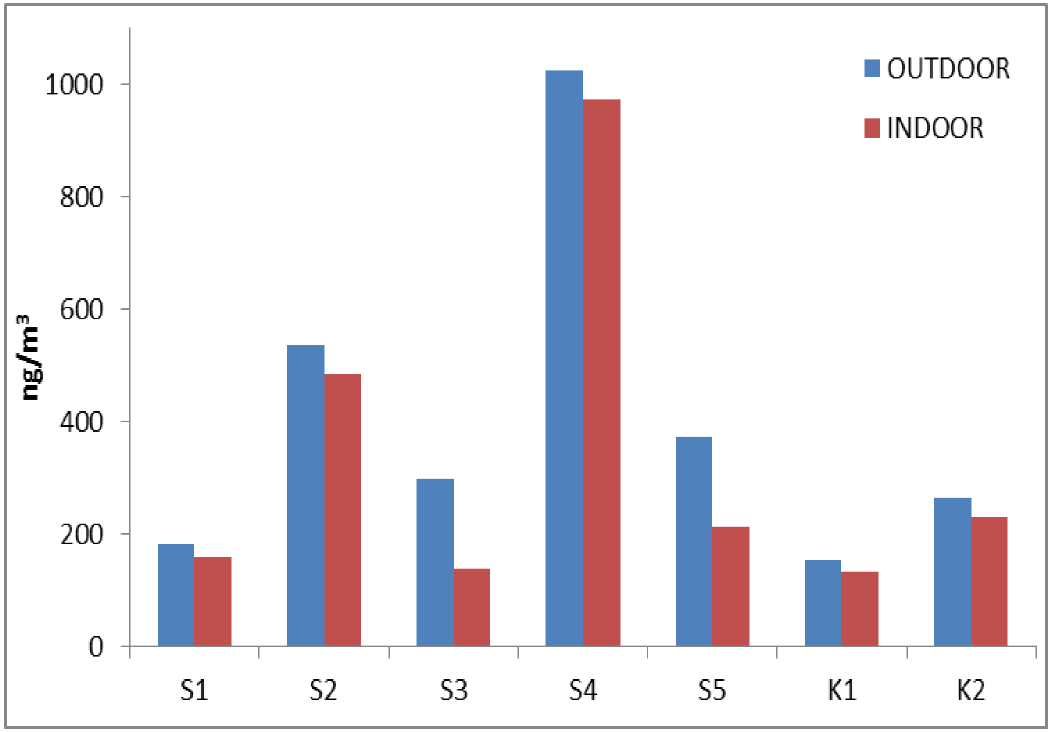
The 16 EPA priority PAH were quantified in the particulate matters collected on quartz filter (Whatman QMA, 47 mm), as well as in gas phase collected on polyurethane foam (PUF).

PAHs were analyzed using gas chromatography–mass spectrometry, CG–MS, following the TO-13A method.

Diagnostic ratios in combination with PCA indicated that traffic emission and coal combustion were the predominant source for outdoor PAHs pollution in Serbian schools during heating season.

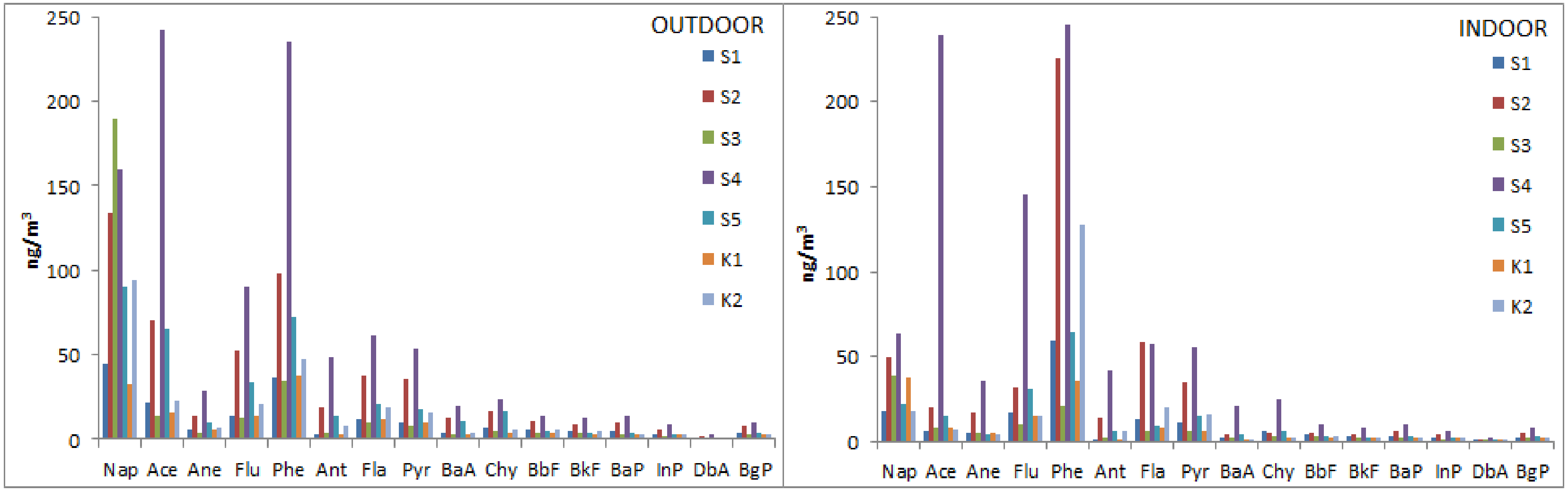
III42008 PROJECT

- **PAH in selected schools and kindergarten in Serbia**



The average total concentrations of 16 PAHs (sum of particle (TSP) and gas phases PAHs)

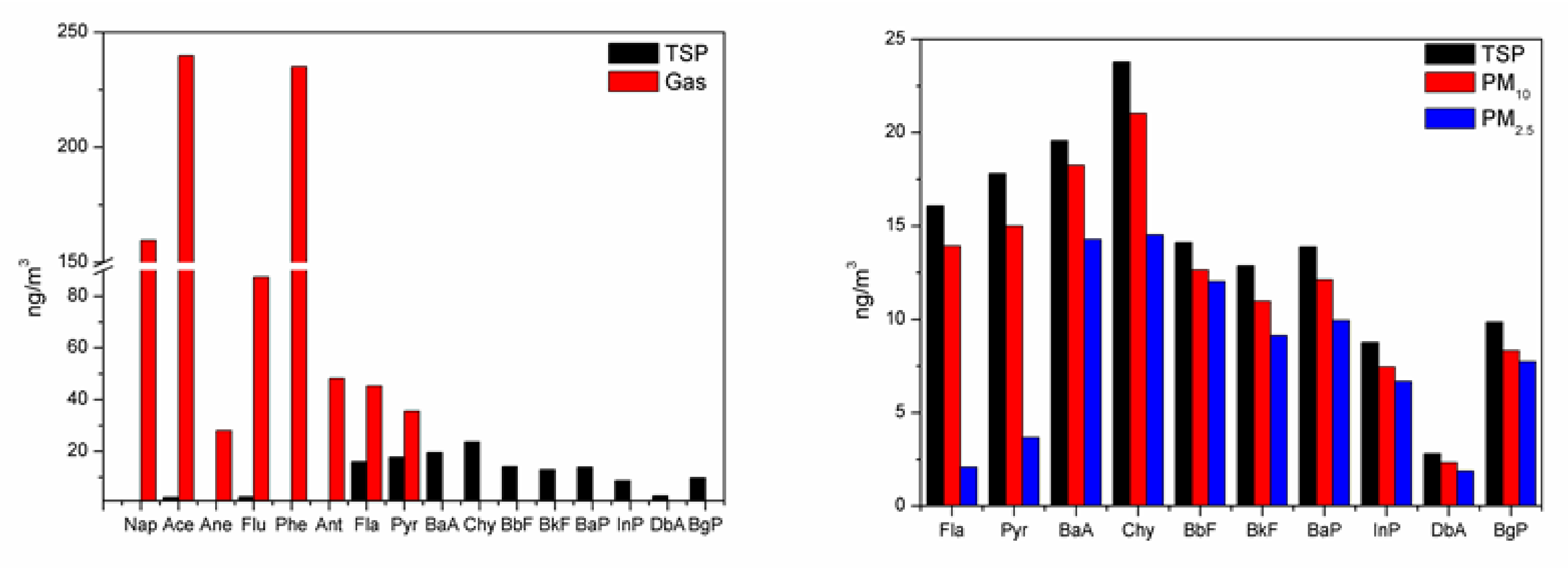
III42008 PROJECT



The total outdoor and indoor values of individual PAHs in schools and kindergartens

naphthalene (Nap)	*acenaphthylene (Ace)*	*acenaphthene (Ane),*	*phenanthrene (Phe),*
fluorene (Flu),	*anthracene (Ant)*	*fluoranthene (Fla),*	*pyrene (Pyr),*
benz[a]anthracene (BaA),	*chrysene (Chy),*	*benzo[b]fluoranthene (BbF),*	*benzo[k]fluoranthene (BkF),*
benzo[a]pyrene (BaP),	*indeno[1,2,3-cd]pyrene (InP)*	*dibenz[a,h]anthracene (DbA)*	*benzo[g,h,i]perylene (BgP)*

III42008 PROJECT



Distribution of outdoor PAHs between TSP and gas-phase (left) and particulate fractions (right) in school S4

FP7 CITI-SENSE PROJECT (2012-2016), INDOOR AIR QUALITY IN SHOOLS

PILOT STUDY

EB700 Platform

DNET (Serbia)

MAIN STUDY

ATMOSPHERIC

CITI-SENSE Platform

ATMOSHERIC SENSORS (UK)

Low-cost sensors integrated in CITI-SENSE platforms:

EB700 and ATMOSPHERIC:

- meteorological parameters (t, RH, p), Alphasense (UK)
- gases (NO, NO_2, CO, CO_2, O_3), Alphasense (UK)

EB700

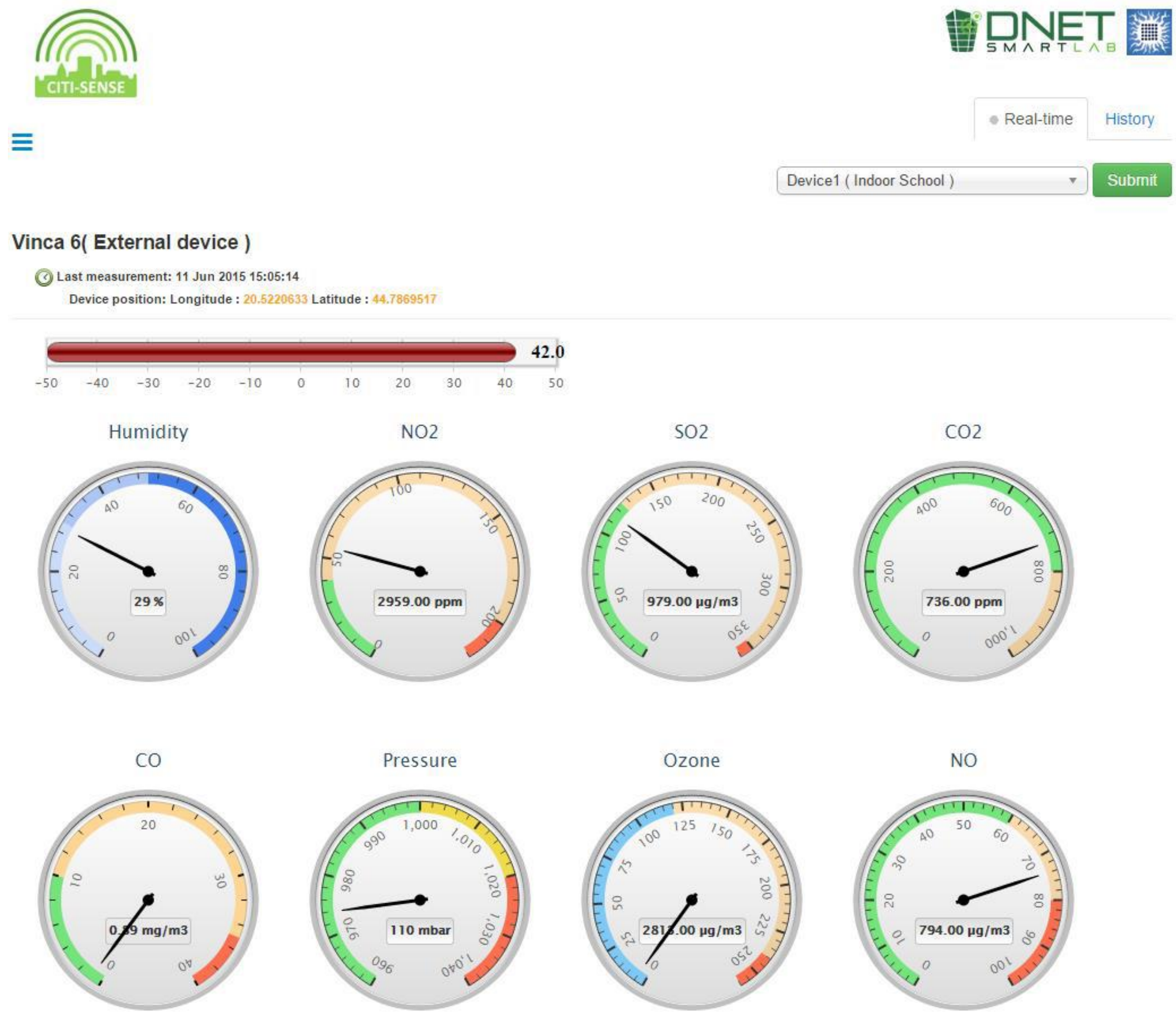
- PM monitor ($PM_{0.5\text{-}2.5}$,$PM_{2.5\text{-}10}$ μm), DYLOS (USA)

DYLOS

- PM monitor OPC-N1 ($PM_{2.5}$, PM_{10} μm), Alphasense (UK)

CITI-SENSE INDOOR AIR QUALITY IN SCHOOLS

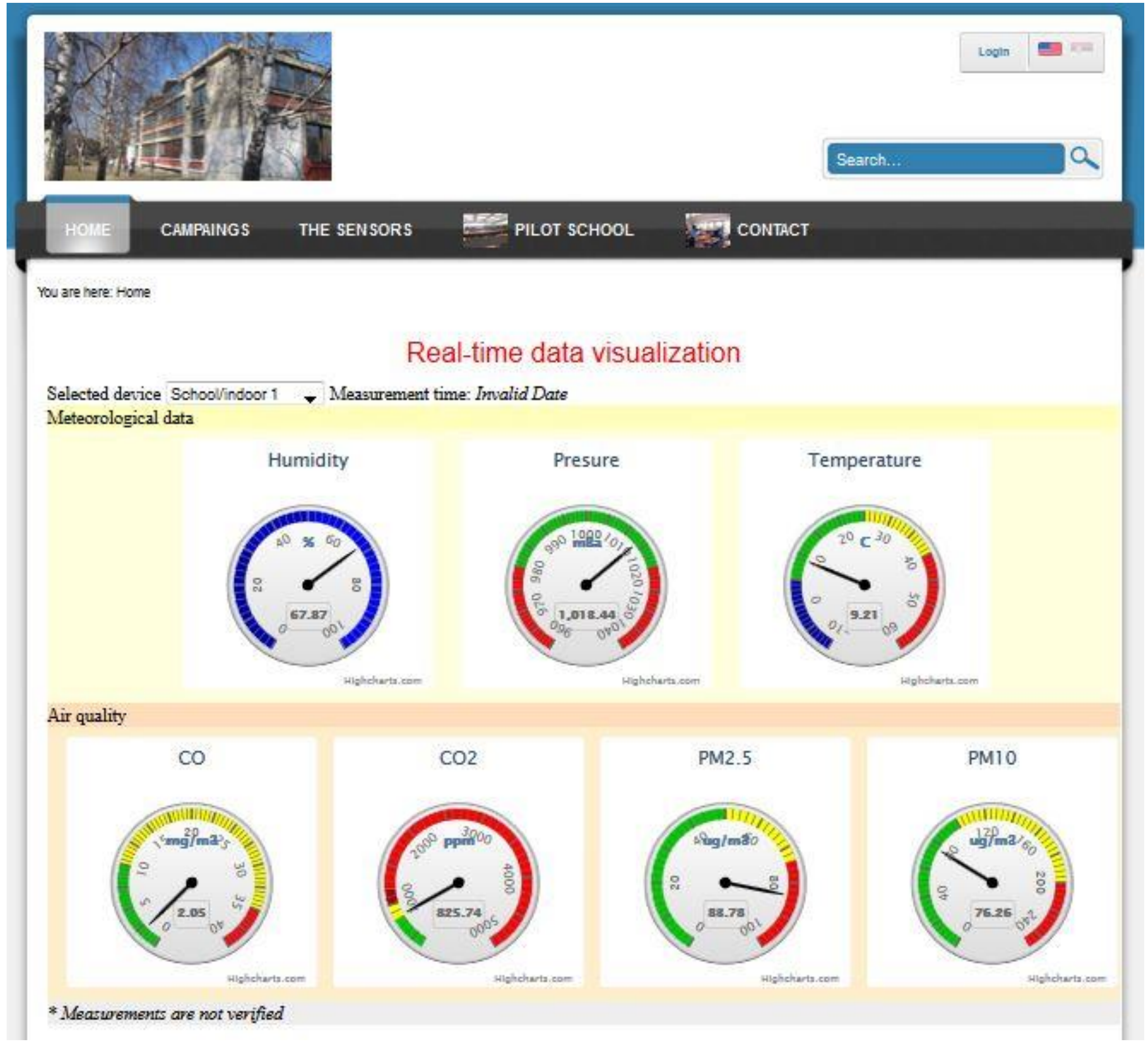
PILOT STUDY
VISUALISATION



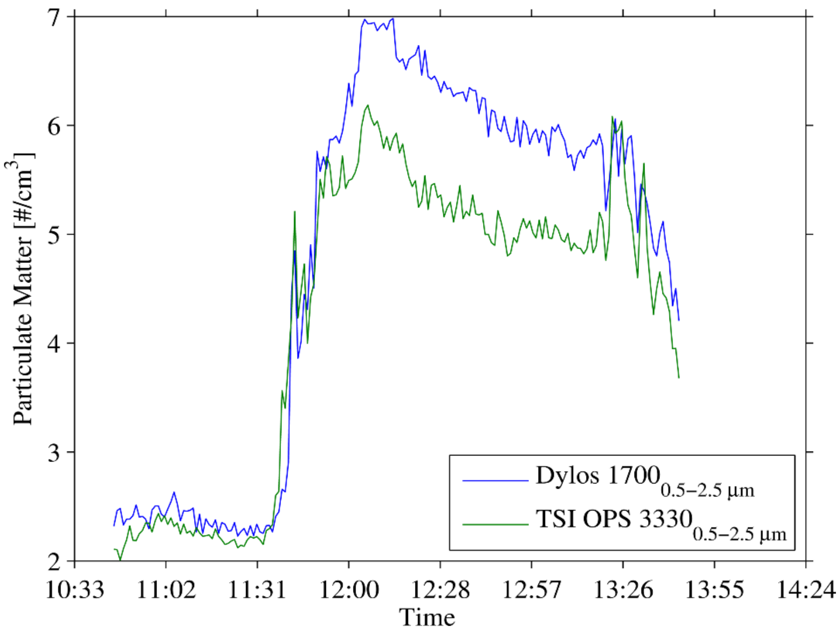
CITI-SENSE INDOOR AIR QUALITY IN SCHOOLS

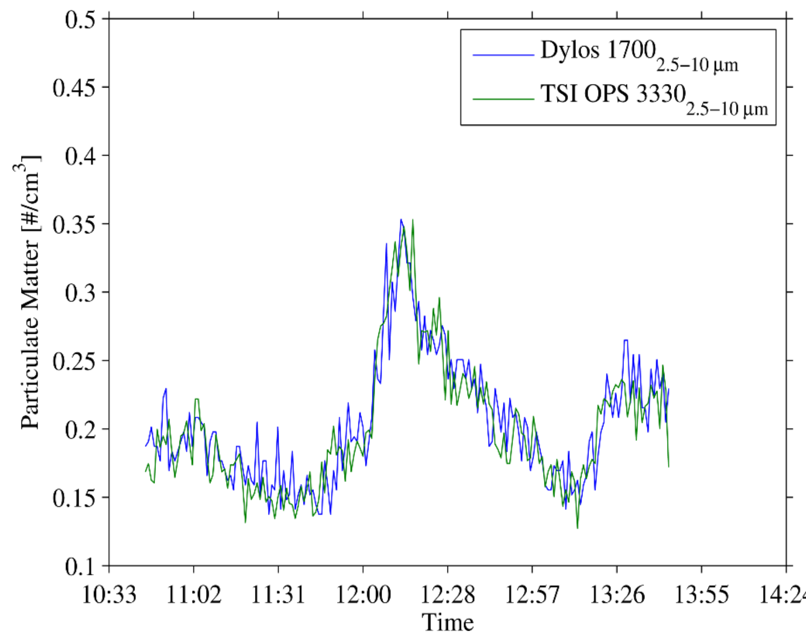
Example of real time data vizualization in a pilot school “20. oktobar” webportal in Belgrade, Serbia

CITI-SENSE studies represents an opportunity to learn about sensor-technologies and environmental risks in a practical and hands-on project while providing tools for improving the well-being at schools.



DYLOS 1700 v.s. TSI OPS 3300





Comparison of Dylos 1700 and TSI OPS 3330 in the indoor microenvironment, without any specific pollution, time series of 1-minute readings for $PM_{0.5\text{-}2.5}$ and $PM_{2.5\text{-}10}$ fraction

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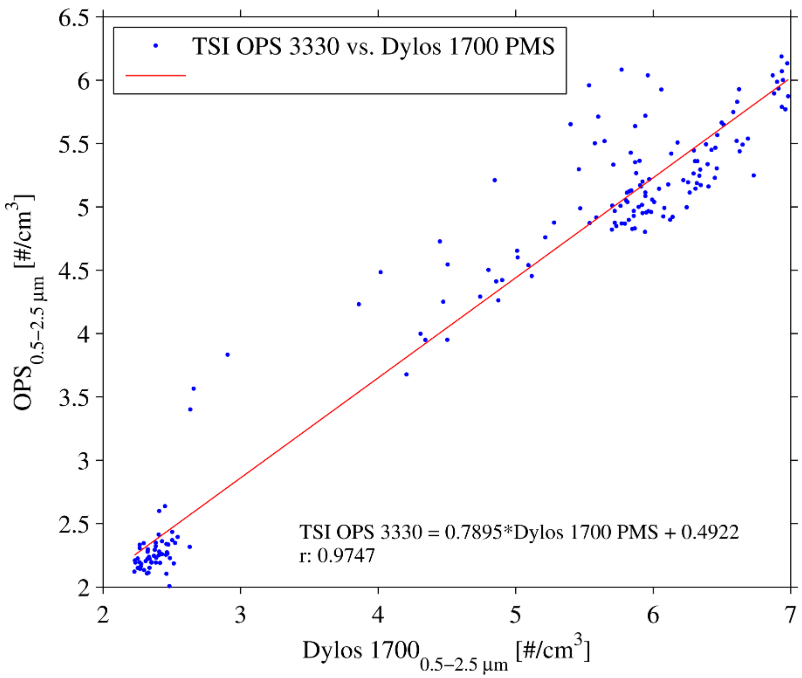
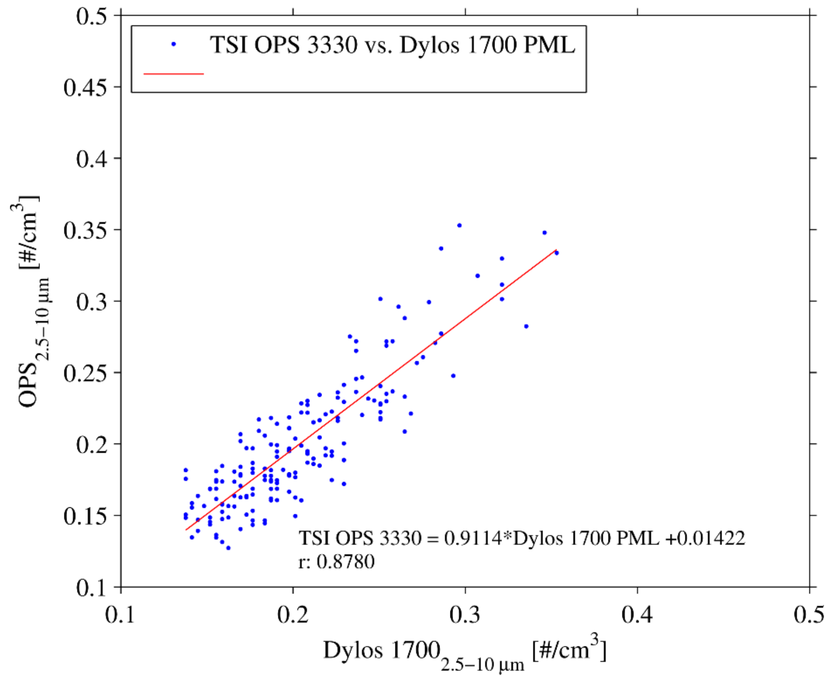
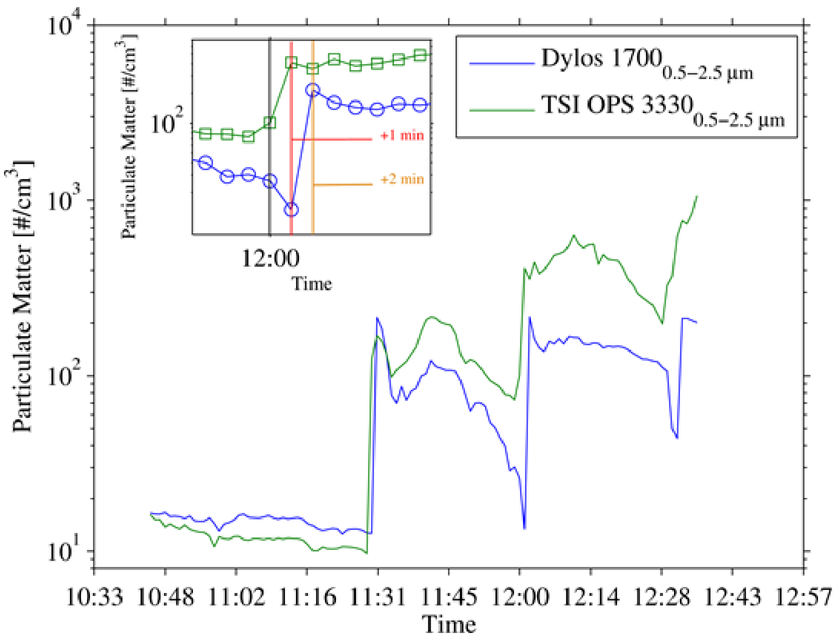
DYLOS 1700 v.s. TSI OPS 3300

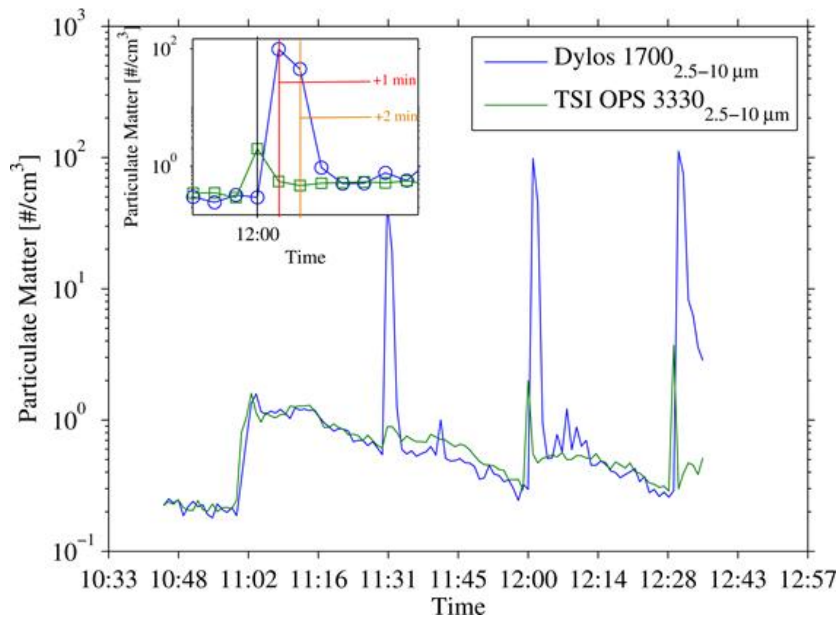




Comparison of Dylos 1700 versus TSI OPS 3330 in the indoor microenvironment without any specific pollution, linear regression and Person coefficient correlation for $PM_{0.5\text{-}2.5}$ and $PM_{2.5\text{-}10}$ fraction

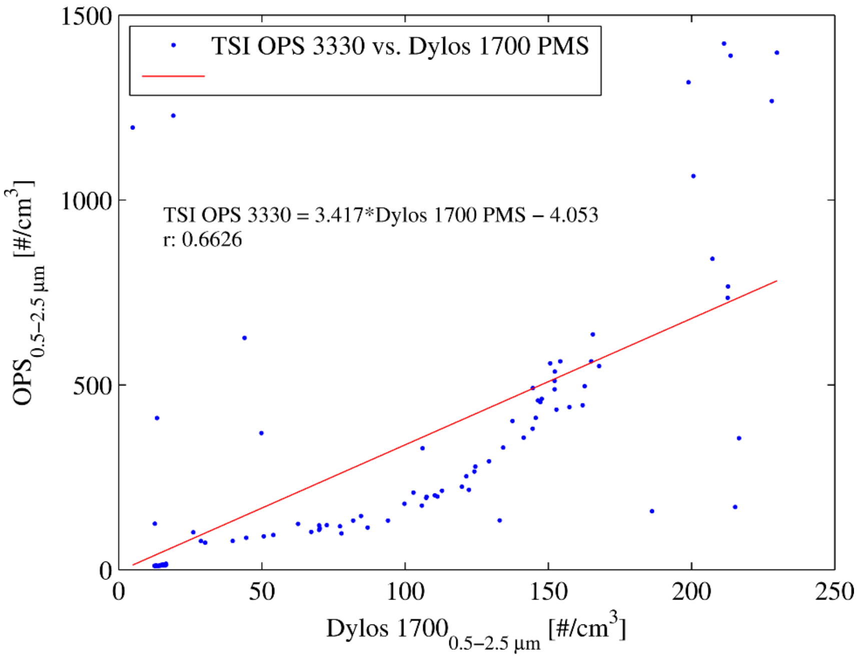
DYLOS 1700 v.s. TSI OPS 3300

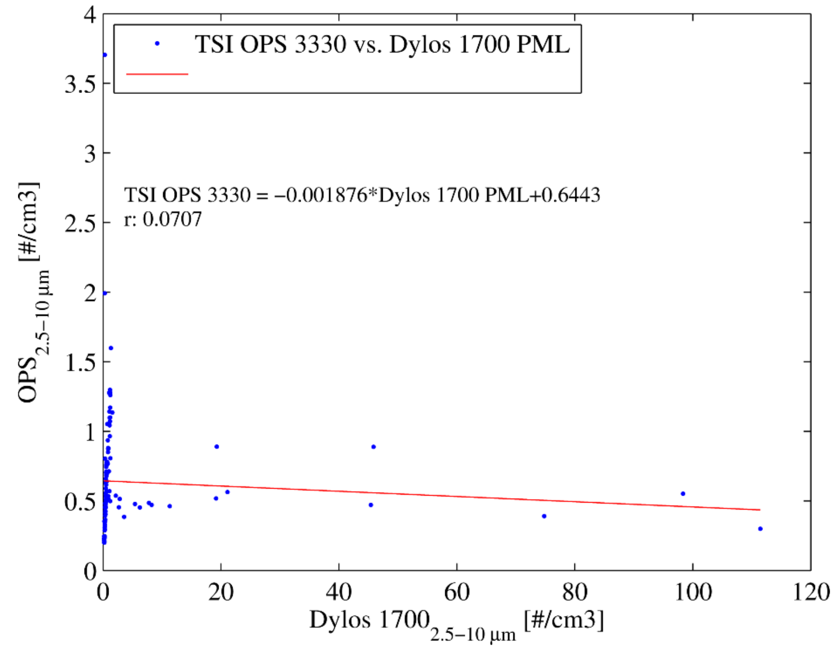




Comparison of Dylos 1700 versus TSI OPS 3330 in the indoor microenvironment when cigarette smoking was used as a source air pollution, time series of 1-minute readings for $PM_{0.5\text{-}2.5}$ and $PM_{2.5\text{-}10}$ fraction

DYLOS 1700 v.s. TSI OPS 3300



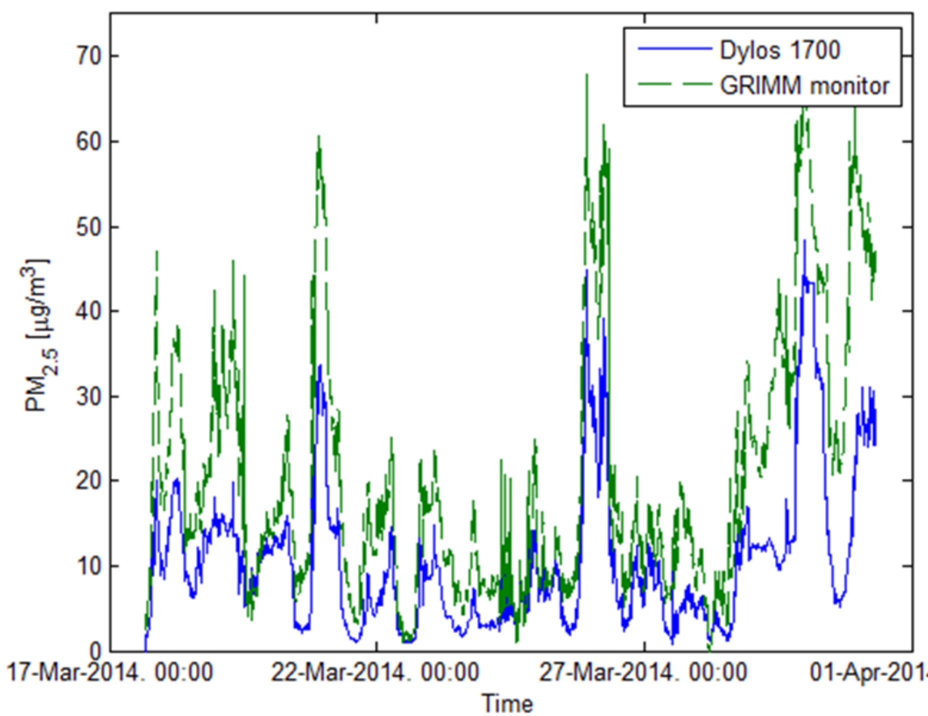


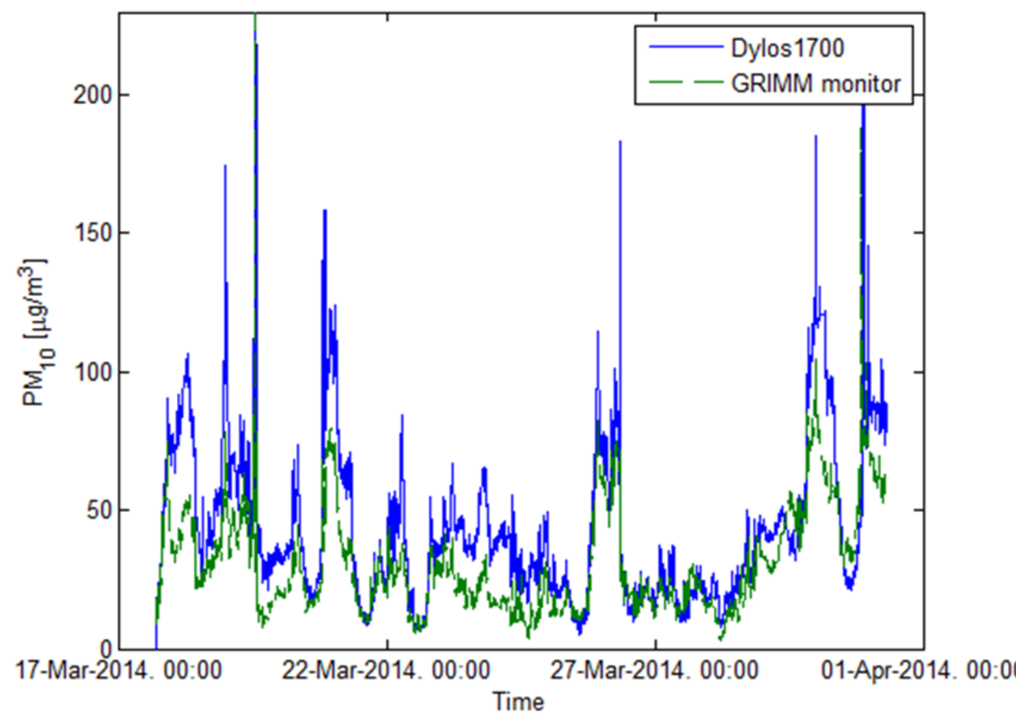
Comparison of Dylos 1700 versus TSI OPS 3330 in the indoor microenvironment when cigarette smoking was used as a source air pollution, linear regression and Person coefficient correlation for $PM_{0.5\text{-}2.5}$ and $PM_{2.5\text{-}10}$ fraction

DYLOS 1700 v.s. GRIMM device at ATM

We have first performed a filtering of the signals from the DYLOS 1700 platforms by using a smooth function described by Gracia that provided examples of simplified Matlab codes [Gracia, 2010]. This allows fast, automatic and robust smoothing of signals with arbitrary dimensions followed by conversion of the count to mass concentration on the basis of approximations from the literature data [Tittarelli, 2008; Lee, 2008]. Smoothing function provides an option to set the input parameter of smoothness with which it is possible to control the filtering process. By increasing the smoothness, the correlation coefficient between the signals from the DYLOS and the GRIM PM monitors has improved.

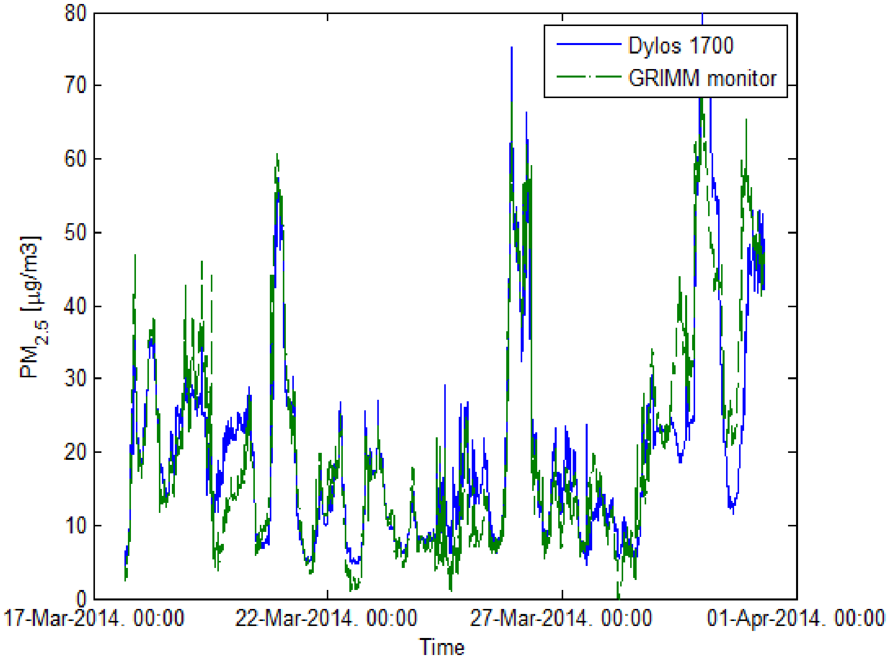
DYLOS 1700 v.s. GRIMM device at ATM

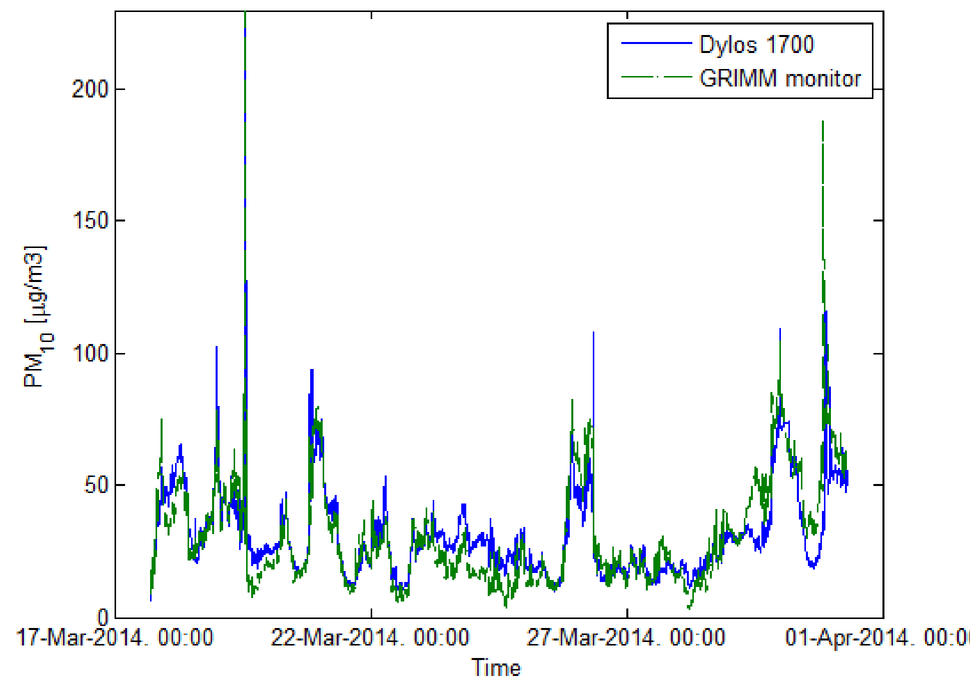




Comparison of PM fraction measured with the DYLOS 1700 monitor filtered and converted to mass concentration data and the reference Grimm device for $PM_{2.5}$ (left) and PM_{10} (right)

DYLOS 1700 v.s. GRIMM device at ATM





$PM_{2.5}$ cal=0.550 + 6.926 $PM_{2.5}$ Dylos ;r=0.917

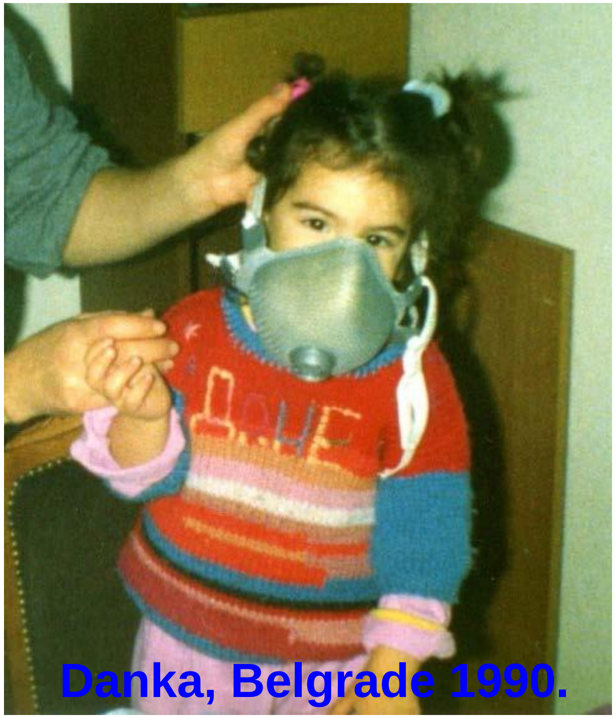
$PM_{10\ cal}$=1.603 + 3.357 $PM_{10\ Dylos}$; r=0.858

Comparison of PM fraction measured with the DYLOS 1700 monitor filtered, converted to mass concentration data and calibrated to the reference Grimm device for $PM_{2.5}$ (left plot) and PM_{10} (right plot)

ADVENTAGES AND DISADVETAGES OF APPLIES METHOD FOR INDOOR AIR QUALITY

- High temporal and spatial resolution is an imperative to obtain reliable data that could be used to setup measures and polices that would protect the health of the citizens and children
- Reference and equivalent ambient PM and gaseous monitoring units and devices are not to provide individualized personal information, e.g. to monitor data permanently in schools
- For monitoring indicative levels of the ambient air pollution, at a much higher spatial resolution, a network of small and cheap sensors could represent an alternative opportunity. If appropriate infrastructure is in place these sensor networks have the potential to offer unique opportunity for citizen-participatory sensing.
- The true potential of data collected with low-cost sensors gathering is still under intensive investigation
- Not all, but some but for some ambient pollutants and comfort data are ready to be measure with low-cost sesoar and present to public such there are t, p, RH, PM, CO_2, CO,…

Thank you for your attention



Danka, Belgrade 1990.