FIRST RESULTS OF COMPARABILITY (VARIABILITY BETWEEN) DYLOS MONITORS IN INDOOR ENVIRONMENT AND PLAN FOR FURTHER CALIBRATION

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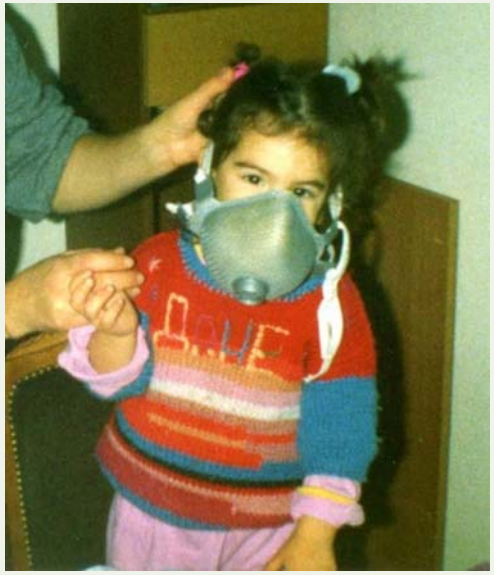
Background

A number of epidemiological studies have demonstrated that respirable particulate matter (RPM) may act as a health hazard causing respiratory mortality and morbidity [1].

In order to protect the living environment and health of citizens, it is a requirement to obtain the levels of RPM in the ambient air with high temporal and spatial resolution.



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Background

Current air quality monitoring networks aim at compliance monitoring and consist of a limited number of stations using standardized QA/QC protocols.

These references and other ambient PM and gaseous monitor units that are in use by communities and research studies are neither usable to cover large areas nor as personal monitors for widespread measuring of location-specific level of pollutants.

Small and cheap sensors represent an opportunity for building sensor networks for monitoring indicative levels of the ambient RPM.

Together with appropriate infrastructure, the sensors have a potential to offer unique opportunities for citizen-participatory sensing.

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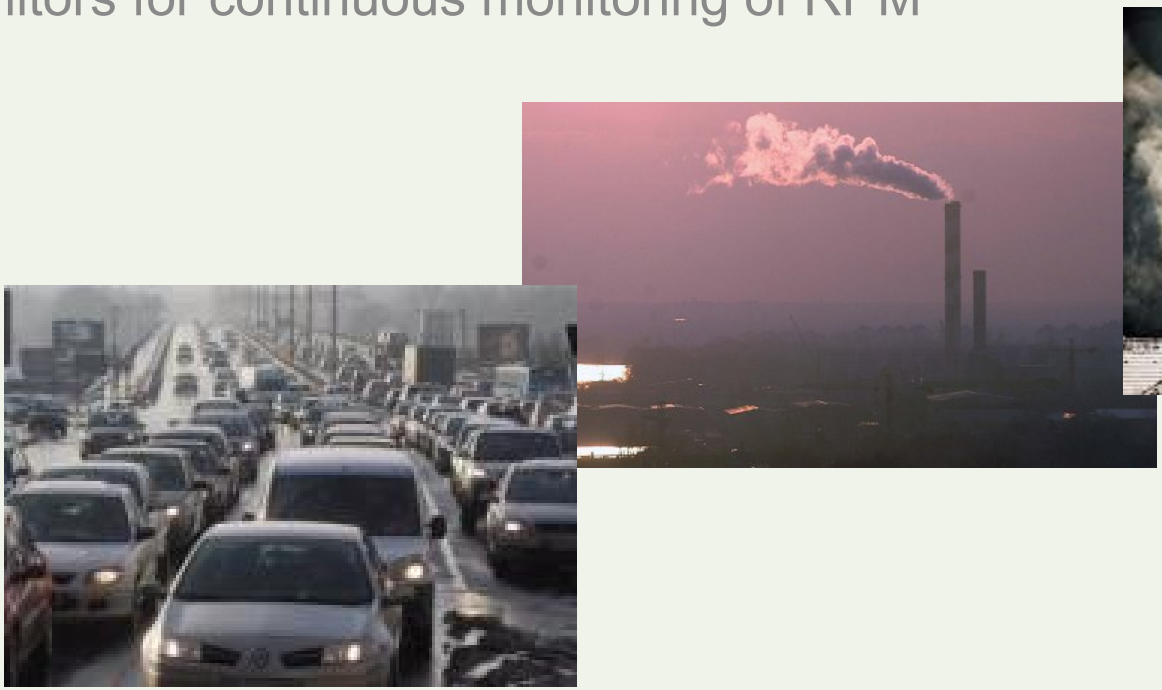
Continuous monitoring PM …

There are a numerous commercially available expensive regulatory, regulatory-equivalent and non-equivalent but less expensive handheld monitors for continuous monitoring of RPM



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EU Ambient Air Quality Standard

Pollutant	Concentration	Averaging period	Legal nature	Permitted exceedences each year
PM10	50 µg/m3	24 hours	Limit value entered into force 1.1.2005**	35
	40 µg/m3	1 year	Limit value entered into force 1.1.2005**	n/a
Fine particles (PM2.5)	25 µg/m3	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a

Title	Metric	Averaging period	Legal nature	Permitted exceedences each year
PM2.5 Exposure concentration obligation	20 µg/m3 (AEI)	Based on 3 year average	Legally binding in 2015 (years 2013,2014,2015)	n/a
PM2.5 Exposure reduction target	Percentage reduction* + all measures to reach 18 µg/m3 (AEI)	Based on 3 year average	Reduction to be attained where possible in 2020, determined on the basis of the value of exposure indicator in 2010	n/a

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PM small and low cost devices

The paradigm of using expensive, complex, stationary equipment, which limits who collects data, why data are collected, and how data are accessed, is changing with the availability of low cost, small and easy-to-use air pollution monitors and sensors which may be widely used giving opportunity to provide high-time resolution data in near real-time. [2]

Air pollution sensors can be separated into devices that measure the concentration of:

- gaseous air pollutants
- particulate matter

The cheapest devices for particulate matter monitoring fall in range of from 10 to 1000 EUR in price and are about one tenth in size of the largest.

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PM small and low cost devices types

Commercially available, PM devices:

- Light Scattering
- Direct measure count concentration
- Doesn't detect particle <0,5 μm and even < 0,3 μm

In development stage PM devices:

- FBAR (film bulk acoustic resonator) , QCM (impaction on piezoeletric sensors) [3]
- Direct particle mass concentration measurement
- Sensitive to changes in T and RH

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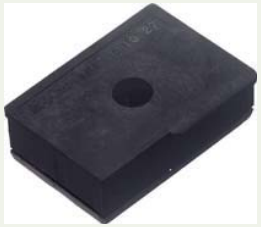
Examples of some commercial RPM sensors

The sensor technology utilized within RPM detection is based on the light scattering principle

Dylos Air Quality Monitor

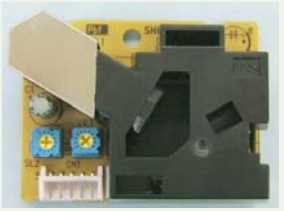
- Price 200-300 EUR
- On screen display
- Real time monitoring of two fractions: > 0,5 μm and > 2.5 μm
- Weight 2.5 lb
- Dimensions 177.9x11.3x76.2 mm
- Power 4.5 W

Sharp GP2Y1010AU0F



- Price 11 $
- Need interfacing with external microcontroller and display
- Dimensions 46.0 x30.0x16.7 mm
- Sensitivity 0.5V/0.1 mg/m3
- Power 140 mW

Shinyei Model PPD42NS



- Price 15 $
- Need interfacing with external microcontroller and display
- Detection PM > 1μm
- Weight 25 grams
- Dimensions 59 x45.0x122 mm
- Sensitivity 0.5V/0.1 mg/m3
- Power 472.5 mW

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Prior to us PM low cost devices

Similar to what was attempted in a number of previous studies, prior to using low cost RPM sensors in practice, their characteristics need to be assessed.

For citizen-based continuous monitoring it may be necessary to perform complex procedure of calibration prior to deployment, involving various parameters such as:

- detection limit
- concentration range
- temperature range
- humidity influence
- **comparability, variability, between each other sensor devices**
- concentration differences and correlation coefficient between sensor device and reference PM monitor

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Dylos optical montor

The system's air quality sensor solution is the Dylos DC1700 Pro which collects a sample of air and determines how many particles within a specified size range are present in the air sample:

- Fine particulate, 0.5-2.5 μm
- Coarse particulate, 2.5 – 10 μm

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BAIRS RPM monitor

- Modified version of Dylos monitor -

Results of Northcross et al [4] proved that accurate calibration of cheap RPM sensors, e.g. a particle counter, may enable them to accurately estimate particle mass in a wide range of settings.

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A low-cost particle counter as a realtime fine-particle mass monitor

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BAIRS RPM monitor

- Modified version of Dylos monitor -

•Modified into a system called the Berkeley Aerosol Information Recording System (BAIRS), performances were compared against standard commercial instruments in chambers using polystyrene latex spheres, ammonium sulphate, and woodsmoke and in an urban ambient setting.

•Overall it was found that the limit of detection of the BAIRS is less than 1 $\mu g/m^3$ and the resolution is better than 1 $\mu g/m^3$ for PM2.5.

• The BAIRS sizes small (<0.5 μm) particles, and is able to accurately estimate the mass concentration of particles of varying composition including organic, inorganic, and ambient particles. It is able to measure concentrations up to 10.0 mg/m^3.

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Dylos DC1700 Pro optical monitor

For the purpose of pilot campaign, that is going to perform in framework of CITI-SENSE project in Belgrade, capital of Serbia, ambient and indoor environment in schools, together with selected gas sensors, DYLOS optical monitor is going to monitor particulate matter.

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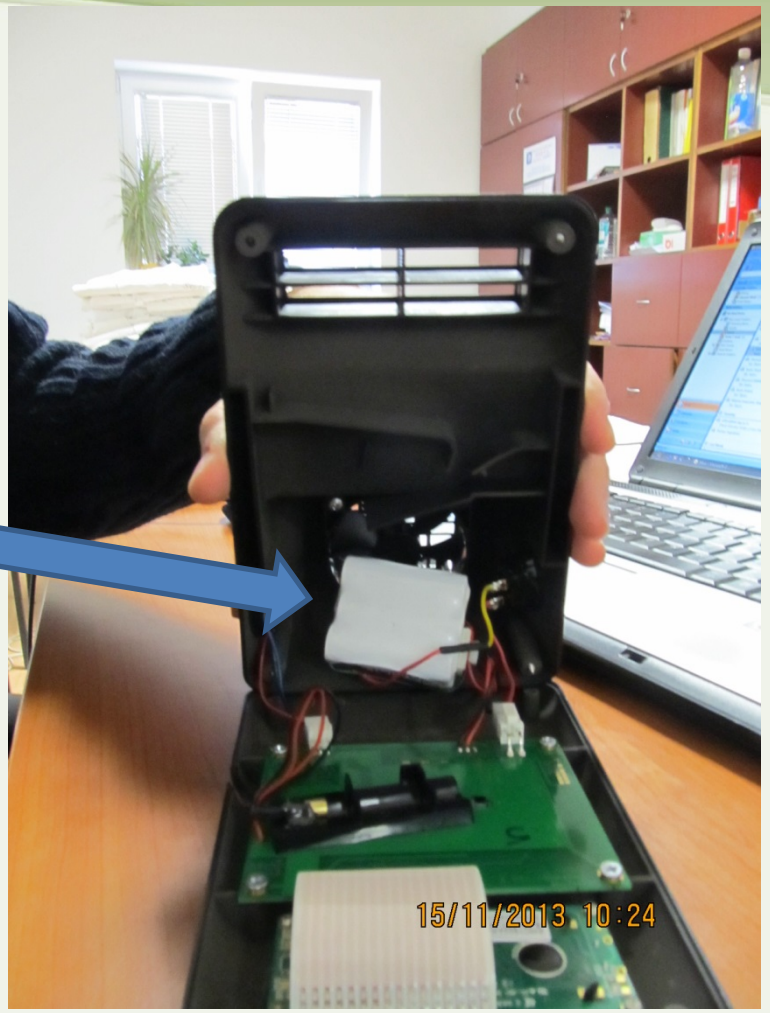
Failure detected at DYLOS monitors

- Fan may be blocked with battery



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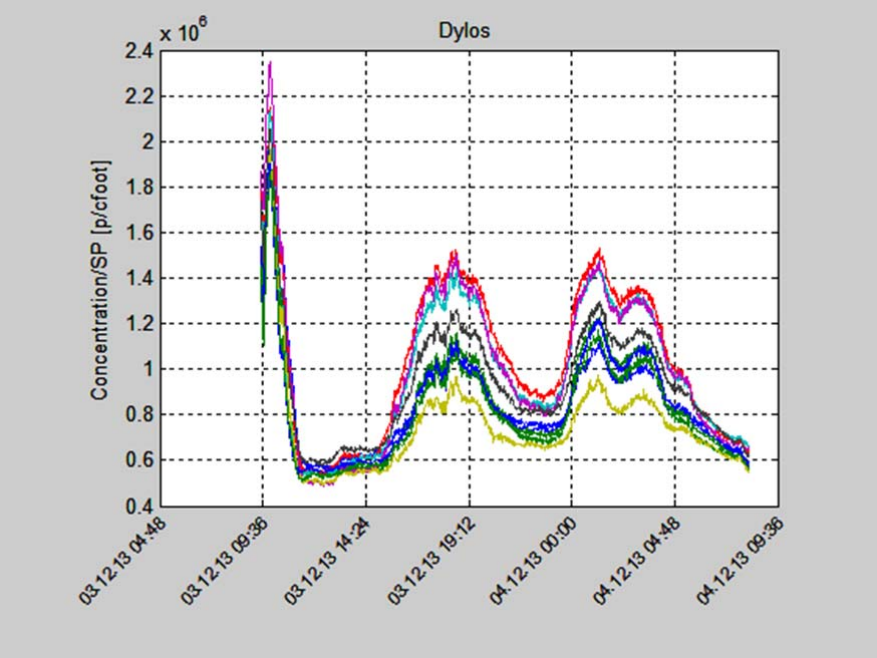
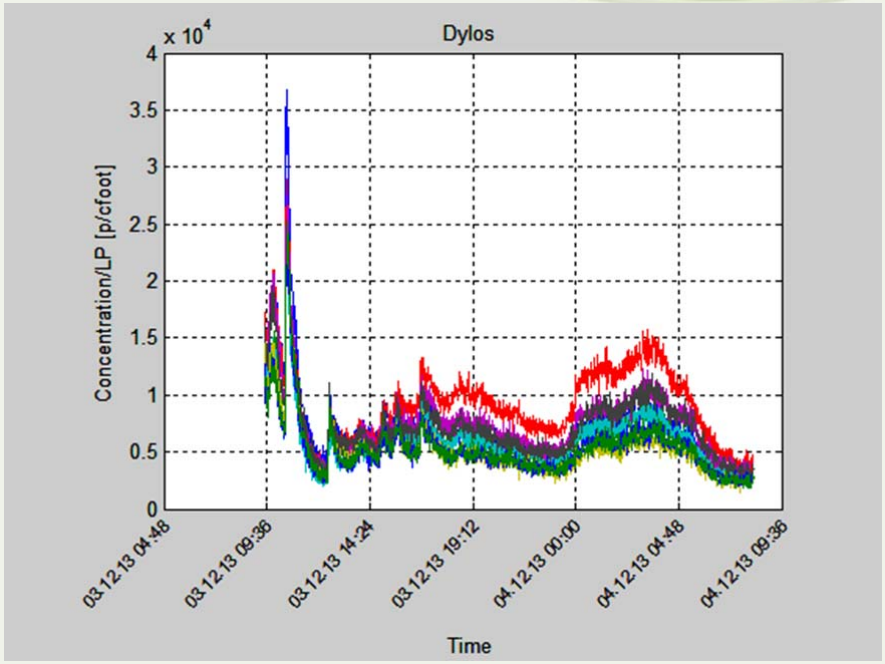
Daily variability of fraction measured with nine Dylos monitors



RPM **fraction <2.5 μm**



RPM **fraction >2.5 μm**

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Conversion count to mass concentration

Conversion to mass concentration was perform under strong assumption:

- All particles are spherical, with a density of 1.65E12 μg/m^3 [5,6]
- The radius of a particle in the channel <2.5 μm is 0.44 μm [6,7]
- The radius of a particle in the channel > 2.5 is 2.60 μm [6,7]

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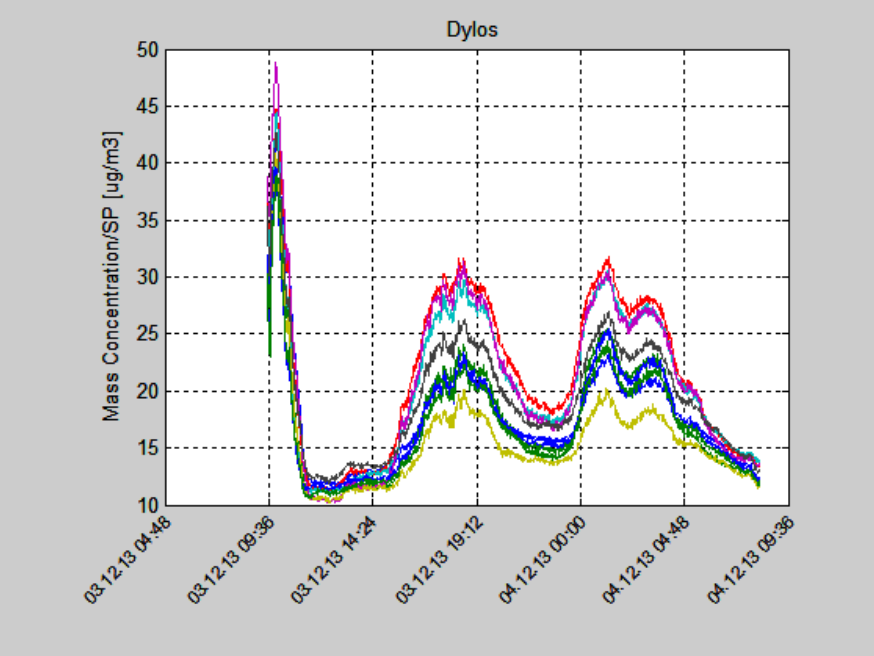
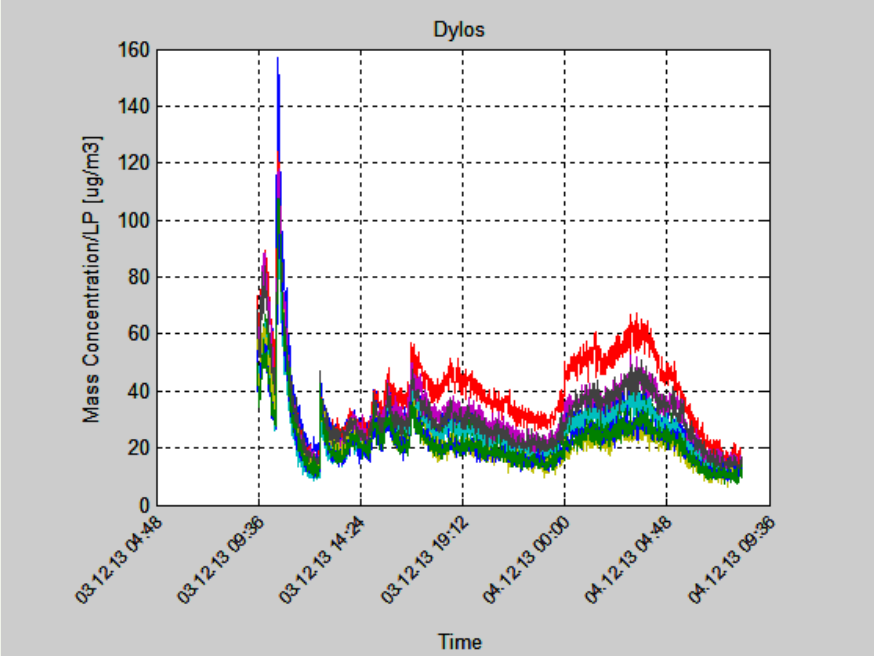
Converted count to mass concentration



RPM **fraction <2.5 μm**



RPM **fraction >2.5 μm**

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Coefficient correlation between DYLOS monitors

	A1	B2	C3	D4	E5	F6	G7	H8	I9
A1	1	0,964843	0,927165	0,920577	0,947524	0,989953	0,973987	0,947986	0,96056
B2	0,964843	1	0,97047	0,974812	0,977075	0,962491	0,99038	0,988238	0,988857
C3	0,927165	0,97047	1	0,993322	0,994599	0,916038	0,980466	0,966645	0,965765
D4	0,920577	0,974812	0,993322	1	0,989402	0,921256	0,980489	0,980353	0,977648
E5	0,947524	0,977075	0,994599	0,989402	1	0,93901	0,987667	0,969952	0,971347
F6	0,989953	0,962491	0,916038	0,921256	0,93901	1	0,970727	0,956893	0,968446
G7	0,973987	0,99038	0,980466	0,980489	0,987667	0,970727	1	0,986909	0,989426
H8	0,947986	0,988238	0,966645	0,980353	0,969952	0,956893	0,986909	1	0,996525
I9	0,96056	0,988857	0,965765	0,977648	0,971347	0,968446	0,989426	0,996525	1

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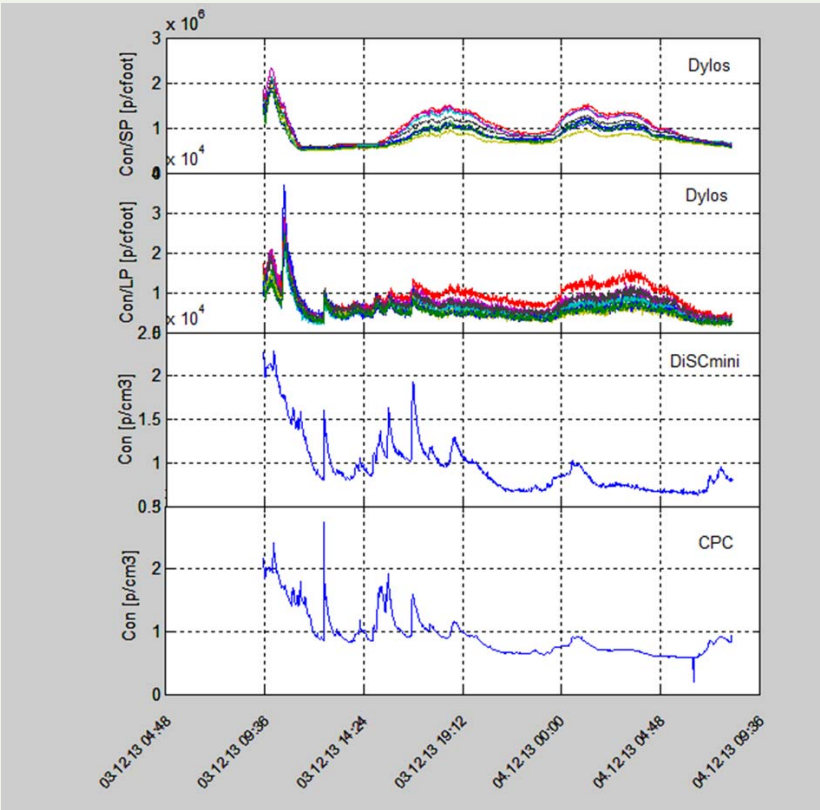
Paralell monitoring of PM with Dylos Monitor, TSI-CPC and DiscMini



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Conclusion and plan for further calibration

- For a 24h period correlation coefficient between each of DYLOS DC1700 Pro monitors fall between 0,899 and 0,996
- Daily variability were between 0,5x 10^6 and 2,4x 10^6 p/ft^3 and 0,3 x 10^4 and 3,7 x 10^4 p/ ft^3
- Using previously published data the particles/ft^3 were converted to µg/m^3. Converted daily values fall in range of 10-50 µg/m^3 for fine friction and 10-160 µg/m^3 for coarse PM fraction
- Difference between sensor devices that show the highest and the lowest values was 30% for both fractions.
- Upon parallel measurement with a reference monitor a calibration factor will need to be calculated for each DYLOS device taking in account different meteorological condition and main source of pollution in the field

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References

1. C.A. Pope, D.W. Dockery, “Health effects of fine particulate air pollution: Lines that connect”, *Journal of the Air & Waste Management Association*, **56** (2006) 709-742
2. E. G. Snyder,T.H. Watkins,P.A. Solomon, E.D. Thoma, R.W. Williams, G.S. W. Hagler, D. Shelow, D. A. Hindin, V. J. Kilaru, P.W. Preuss, “The Changing Paradigm of Air Pollution Monitoring”, *Environ. Sci. Technol*., **47** (2013) 11369−11377
3. I. Paprotnya., F. Doeringa., P.A. Solomonc , R.M. Whitea, L.A. Gundelb L.A., “Microfabricated air-microfluidic sensor for personal monitoring of airborne particulate matter: Design, fabrication, and experimental results” *Sensors and Actuators A: Physical*, (2013)
4. A.L. Northcross, R.J. Edwards, M.A. Johnson, Z.M. Wang, K. Zhu.,T. Allene, K.R. Smith, “A low-cost particle counter as a realtime fine-particle mass monitor*”, Environ. Sci.: Processes Impact* ,**15** (2013) 433-439
5. A. Tittarelli, A. Borgini, M. Bertoldi, E. De Saeger, A. Ruprecht, R. Stefanoni, G. Tagliabue, P. Contiero, P. Crosignani “Estimation of particle mass concentration in ambient air using a particle counter,” *Atmospheric Environment*, **42** (2008) 8543-8548
6. M. Uva, R. Falcone, A. McClellan, E. Ostapowicz, Preliminary Screening System for Ambient Air Quality in Southeast Philadelphia -Data Validation, , Electrical and Computer Engineering Department of Drexel University May 13, 2009 May 13, 2009 (accessed October 2013)
7. Lee, J. et al., “Seasonal variations of particle size distributions of PAHs at Seoul, South Korea”, *Air Quality Atmospheric Health*, **1** (2008) 57-68

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