# Measurement of PM 2.5 Concentrations in Indoor Air Using Low-Cost Sensors and Arduino Platforms

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# Measurement of $PM_{2.5}$ Concentrations in Indoor Air Using Low-Cost Sensors and Arduino Platforms

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**Abstract**

The aim of this research was to investigate the usability of low-cost Sharp GP2Y1010AU0F sensors attached to Arduino platforms for indoor measurement of $PM_{2.5}$ mass concentrations. The OSIRIS (Turnkey Instruments, Model 2315) particulate monitor has been used for colocation. Strong positive correlation (r>0.7) was observed between the mean 15-min $PM_{2.5}$ concentration obtained with tested Sharp sensors and Osiris $PM_{2.5}$ concentrations. Arduino platform has demonstrated remarkable stability during the experiment. Further work will be focused on the influence of temperature and humidity variations on the measurement results.

**Key words:** Indoor air quality, $PM_{2.5}$ sensor, Sharp GP2Y1010AU0F, Arduino, Evaluation, Correlation

## Introduction

Particulate matter (PM) is one of the most important ambient air pollutants that adversely affect human health. Monitoring of indoor PM mass concentrations is important for human health risk assessments since most individuals in developed countries spend the majority of their time (more than 80%) indoors [1]. Prolonged exposure to $PM_{10}$ and $PM_{2.5}$ has been associated with respiratory and cardiovascular disease and is known to increase all-cause mortality [2-4].

PM in indoor air originates from outdoor infiltration and additional indoor sources such as cooking and heating devices, tobacco smoking, etc. Current EU legislation only regulates PM in ambient air, while there are not specific limits or target values for PM in indoor air at the EU level [5]. Taking in account numerous studies, the WHO has set air quality guidelines and interim targets for $PM_{10}$ and $PM_{2.5}$ [6]. These air quality guideline values for PM are set primarily for outdoor environments. However, recently published WHO guidelines for indoor air quality have adopted the same PM guideline values for indoor environments [7]. Current PM monitoring methods are usually expensive, due to limitations in sampling and analytical techniques. Monitoring of air pollutants with high spatial and temporal resolution in urban areas is still technically demanding and challenging task.

One of the possible solutions for this is application of the monitoring systems with inexpensive low-cost solid-state gas and PM sensors that are able to operate in real-time [8]. Such low-cost PM sensors require proper evaluation and calibration prior to their implementation.

The aim of this research was to investigate the usability of low-cost Sharp GP2Y1010AU0F sensors [9] attached to Arduino platforms [10] for measurement of $PM_{2.5}$ mass concentrations in indoor micro environment. OSIRIS monitor (Turnkey Instruments, Model 2315), based on light scattering technique, was used [11] for comparison of data collected with Sharp sensors.

## Materials and methods

The research was conducted in the period from 1 May to 31 August 2016 in the laboratory at the Mining and Metallurgy Institute Bor, Serbia. Two independent measurement units that were formed consisted of multiple Sharp GP2Y1010AU0F sensors and Arduino microcontroller platforms as shown in Figure 2. First consisted of the Arduino platform equipped with one Sharp sensor, and temperature and humidity sensor module DHT22 [12, and 13]. Second consisted of the Arduino platform equipped with two Sharp sensors. Sharp GP2Y1010AU0F sensor was selected because its low price and compactness. This sensor works on the light-scattering principle, which is also utilized in much more sophisticated Osiris

PM monitor. The photodiode emits a light beam in the measurement cavity, and a phototransistor captures the reflected light. When the particles enter the measurement cavity and scatter the reflected light, the voltage over the phototransistor changes because the light is blocked by the particle. The sensitivity of this sensor is 0.5V/0.1 mg/m$^3$ as shown in Fig. 1 [9].

The operation of this sensor requires input pulses for photodiode excitation and detection of phototransistor response at regular time intervals [9]. Therefore, it is necessary to connect the sensor to a microcontroller. Due to the ease of programming and connectivity Arduino platform was chosen. Arduino/Genuino Uno is a microcontroller board based on the ATmega328P microcontroller that has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button [10]. The measuring program enables sensor proper use, and data is sent via USB port on a personal computer, approximately each 5 seconds. The program is written in open source Arduino Software (IDE). Another program, written in Processing 3 software [14], reads the results from the USB port, timestamps them, and stores them on the PC. Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts. It is free to download and open source.

For statistical processing of data and real-time presentation of results Microsoft Excel was used. The temperature in the laboratory was maintained in the range of 24-29 °C and relative air humidity within the limits of 50-60% in order to reduce the influences of these parameters on the measurements. OSIRIS monitor has been calibrated weekly with the reference gravimetric method using the Sven/Leckel LVS3 as a sampling device [15].

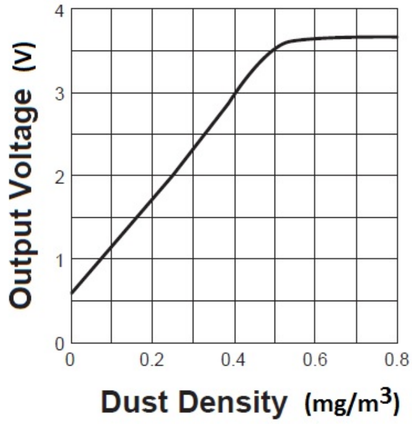


*Fig. 1. Sharp GP2Y1010AU0F sensor output characteristics (Output Voltage vs. Dust Density) [9]*

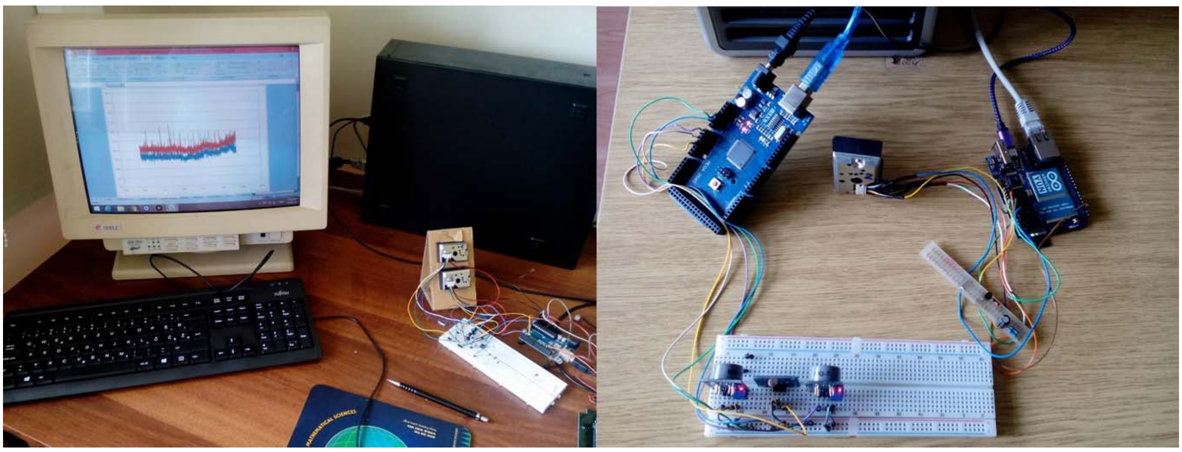

*Fig. 2. Sharp GP2Y1010AU0F sensors connected on Arduino platforms (S1 and S3 on the left, S2 on the right).*

**Results and discussion**

The results of $PM_{2.5}$ measurements obtained with the Sharp sensors (simultaneous measurement of 3 Sharp sensors connected via two Arduino platforms) were compared with $PM_{2.5}$ readings of the OSIRIS monitor over the whole measurements period (15-min averages, Osiris vs. Sharp). Correlation analysis of collected data shows that there is a strong positive correlation between the mean 15-min $PM_{2.5}$ concentrations measured with Sharp sensors and Osiris ($r_{S1}$ = 0.820, $r_{S2}$ = 0.947, $r_{S3}$ = 0.738). The results of regression analysis (shown in Figs. 3-6. and in Tab. 1) shows that measurements of Sharp sensors are in a good agreement with the Osiris measurements.

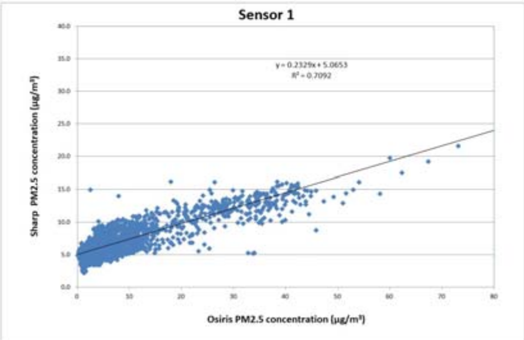


*Fig. 3. Comparison GP2Y1010AU0F S1 vs. Osiris*

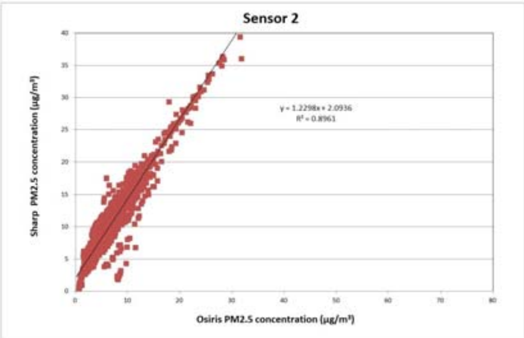


*Fig. 4. Comparison GP2Y1010AU0F S2 vs. Osiris*

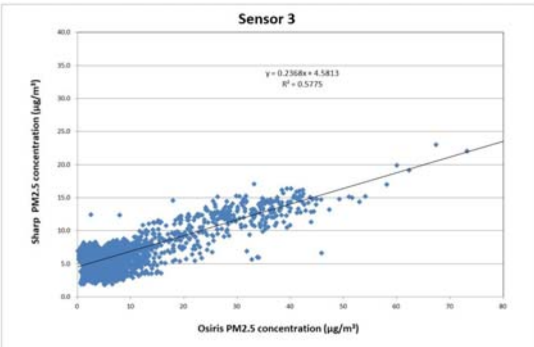


*Fig. 5. Comparison GP2Y1010AU0F S3 vs. Osiris*

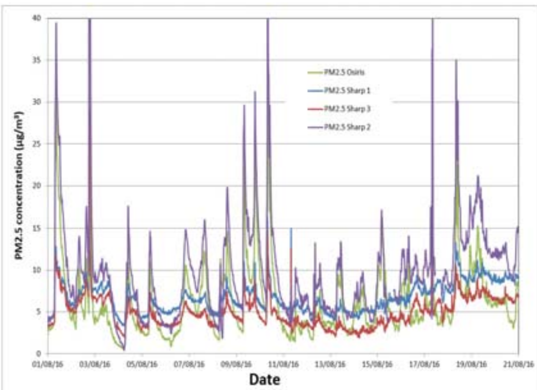


*Fig. 6. Example of the measurement results, scatter plot graph*

On the other hand, Sharp sensors S1 and S3 underestimate while sensor S2 overestimates the indoor $PM_{2.5}$ concentrations relative to the Osiris measurements. We assume that such differences are caused by the different characteristics of photo elements that were built into the sensors. Namely, sensor S2 was supplied from the different manufacturer than sensors S1 and S3.

## Conclusions

Analysis of the measurement results shows that there is a strong positive correlation between the averaged 15-min $PM_{2.5}$ concentrations obtained with Sharp sensors and with Osiris monitor. During measurements, Arduino platform has demonstrated remarkable stability. Further investigations will be focused on testing influence of the temperature and humidity variability on detected PM level. Also, the inter-sensor intra-variability will be further explored and evaluated in detail.

*Tab. 1: Regression equations and coefficients of determination (Y-Sharp, X-Osiris)*

| Sensor | Regression equation | Coefficient of determination ($R^2$) |
|---|---|---|
| S1 | Y=0.233*X+5.01 | 0.71 |
| S3 | Y=0.237*X+4.58 | 0.58 |
| S2 | Y=1.230*X+2.09 | 0.90 |

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