System for Monitoring and Analysis of Environmental Data

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***Abstract*—Most of the employees in the office have no idea what health risks the work environment hides for them. It is important to maintain a healthy working environment in the office, as this can reduce the absence of sick staff and their good tonus can be maintained.**

An environmental data monitoring and analysis system has been developed, which includes a particulate matter sensor, a light sensor and a temperature sensor. The system includes three main units - sensor part with three different sensors, Arduino Nano sensor communication platform and web server for communication with which the Linux operating system is used. The necessary settings have been made for reading data from the sensors, converting them into digital form, storing them in a database and graphical visualization of the measured values. When visualizing the measurements, the period of visualization can be chosen - from the last hour to one year ago. The developed system has been tested for monitoring the environment of a real object.

***Index Terms*—Database, Light sensor, Linux, NOVA SD011 Sensor, Temperature sensor**

I. Introduction

The majority of office workers have no idea what health risks the work environment poses for them. However, the more office workers are aware of the risks in the workplace, the better they can protect themselves from future health problems. It is also extremely important for the employer to maintain a healthy work environment in the office, because in this way the absence of employees due to illness can be reduced and the good tonus of the employees can be maintained, which will lead to less staff turnover.

Dust is a major air pollutant. Particulate matter (PM) is a mixture of pollutants with different chemical and physical properties. Frequent violations of air quality standards are causing more and more cardiovascular and respiratory diseases, even the cause of cancer. Air pollution is becoming a major environmental cause of premature death in the EU.

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The lack of good lighting in the workplace is one of the main reasons for the deterioration of the health of employees. In order to avoid any problems with the employee's seeing, a good level of lighting in the office is absolutely necessary. But the lack of good lighting can also contribute to other complaints and problems for the worker such as headaches, rapid fatigue, etc. The most adequate solution to this problem is to install the appropriate type of lighting for the specific office and workplace. Another common problem faced by office workers is the inability to find a temperature value in the office that is suitable for everyone.

The various laws and regulations come to the rescue here, where permissible values and limits of change of relevant indicators are regulated. In the Republic of Bulgaria the Atmospheric Air Purity Act [1], Ordinance 49 [2], Ordinance № РД-07-3 [3] are in force.

The purpose of this article is to develop a system for monitoring of environment to provide real-time information on the condition of the air in the workplace. The developed system includes three different sensors for measuring the concentration of particulate matter, for measuring light and a temperature sensor.

II. Development of the Measuring System

The developed system for collecting data from the environment consists of three main blocks - used sensors, platform (Arduino Nano) and a web server for communication with which the Linux operating system is used. The communication between the sensor and the web server is via the Arduino Nano. Breadboard and a set of connecting wires are also used.

The sensor unit includes three sensors - a sensor for measuring of particulate matter NOVA SD011 Sensor; light level sensor MAX44009; ambient temperature sensor DS18B20. So many different sensors have been chosen on purpose to check whether it is possible to operate at the same time and provide up-to-date information about the parameter they are measuring.

NOVA SD011 Sensor is a laser sensor for measuring PM2.5 and PM10 particulate matter, works on the principle of laser scattering (Figure 1 and Figure 2). An important part of the sensor design is the built-in fan, which sucks air from the environment [4]. The large size of the fan allows better measurement accuracy, which is one of the advantages of SD011. The intake air passes through a chamber, which is the measuring part and where the concentration of particulate matter is measured and exits the outlet end of the sensor. The measuring part includes a laser and a photodiode. The laser emits light that is

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scattered by the particulate matter present in the sample for analysis. The scattered light is converted into an electrical signal by the photodiode, which is then amplified and processed. The SD011 sensor operates with a supply voltage of 5V DC. The sensor has a high resolution in the range of 0.3μg/m^3 to 0.0-999.9 μg/m^3, response time of 1 second, relative error of ±15% and ±10 μg/m^3. The lifetime of the laser is about 8000 hours.

Fig. 1. NOVA SD011 Sensor [4]

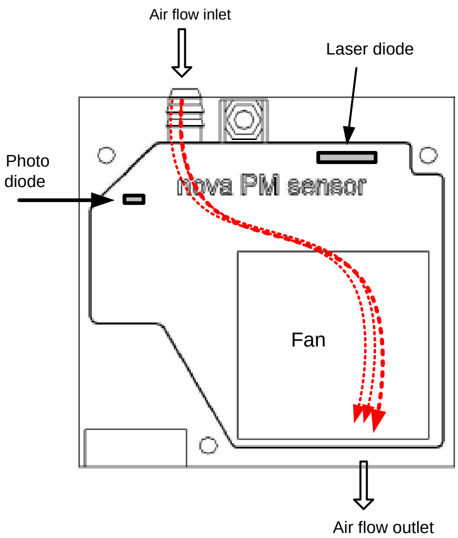

Fig. 2. Operating principle of NOVA SD011 Sensor

Due to the interface of the particulate sensor - UART, the connection is made with a UCB hub connected directly to a computer.

MAX44009 is a light sensor with built-in LED and ADC with I^{2}C digital interface, which makes it suitable for use in many mobile applications [5]. The photodiode converts light into an electric current, which is then subjected to further digital processing. The sensor has a wide dynamic range from 0.045 lux to 188.000 lux.

The I^{2}C (Inter-Integrated Circuit) interface uses two lines for serial exchange of information between devices - SDA (serial data) and SCL (serial clock). The so-called pull-up resistors must be connected to the two lines to the supply voltage. The IC is designed to operate with a supply voltage of 1.7V to 3.6 V and consumes 0.65μA. Figure 3 shows the appearance of the light sensor, and Figure 4 shows how to connect it.

The DS18B20 sensor provides information about the values of the measured temperature in degrees Celsius. It has a built-in alarm function, which is activated when the user-set limits are exceeded. The DS18B20 sensor communicates via a 1-Wire bus providing 9-bit to 12-bit ambient temperature measurements [6]. One advantage of this sensor is that it can be powered directly from the data line, the so-called "parasitic power supply", which eliminates the need of external power. Another feature of the DS18B20 is that each such sensor has a unique 64-bit code that allows multiple sensors to use the same 1-Wire bus. This allows a single microprocessor to control many DS18B20 sensors located in a relatively large area.

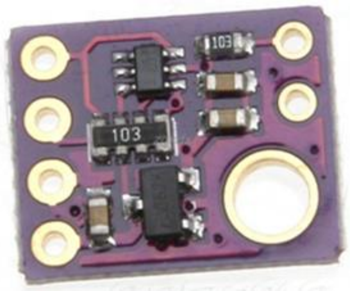

Fig. 3. Light sensor MAX44009 [5]

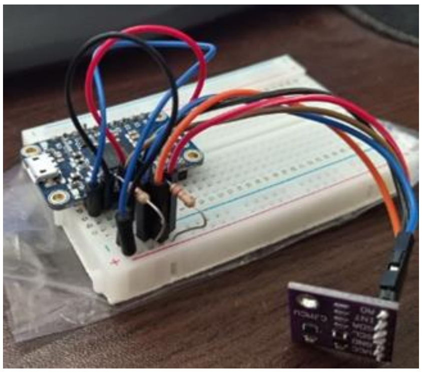

Fig. 4. Light sensor connection

The DS18B20 sensor provides information about the values of the measured temperature in degrees Celsius. It has a built-in alarm function, which is activated when the user-set limits are exceeded. The DS18B20 sensor communicates via a 1-Wire bus providing 9-bit to 12-bit ambient temperature measurements [6]. One advantage of this sensor is that it can be powered directly from the data line, the so-called "parasitic power supply", which eliminates the need of external power. Another feature of the DS18B20 is that each such sensor has a unique 64-bit code that allows multiple sensors to use the same 1-Wire bus. This allows a single microprocessor to control many DS18B20 sensors located in a relatively large area.

The measuring range of the DS18B20 sensor is from -55 °C to +125 °C (-67 °F to + 257 °F), the measurement accuracy is ± 0.5 °C, programmable resolution from 9 bits to 12 bits , no external components are required. Figure 5 shows the appearance of the DS18B20 temperature sensor.

Due to the possibility of powering the DS18B20 sensor via the data input (parasitic power supply) we can use a single wire for power supply and communication with it.

The developed system with the three sensors is shown in Figure 6. The connection between the individual components is made with connecting wires and breadboard.

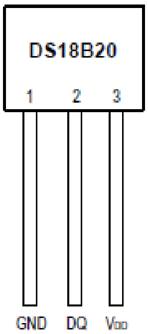

Fig. 5. Digital temperature sensor [6]

Fig. 6. Measurement system

III. Setting the System

The developed system for monitoring and analysis of environmental data works under the Linux operating system. Linux is used in web servers, computers and mobile phones. Thanks to its flexibility, adaptability and open-source nature, it is possible to set up the operating system for a specific purpose. Necessary packages and libraries must be installed for good communication between Linux and the sensors of the system. Reading data from each sensor is done using python scripts. Some of the values obtained from the sensors need to be abbreviated as significant digits due to the high accuracy of the measurement. After the successful receipt of results from all sensors, the values need to be transferred to the database, which in turn visualizes them as graphs to the web part.

Several algorithms have been developed - for reading data from the respective sensor and forwarding them to a server, an algorithm for front-end operation and an algorithm for the back-end part of the web application.

After setting up the system for reading data from the sensors and visualizing the obtained results, test measurements were performed, the results of which can be seen in Figures 7-9.

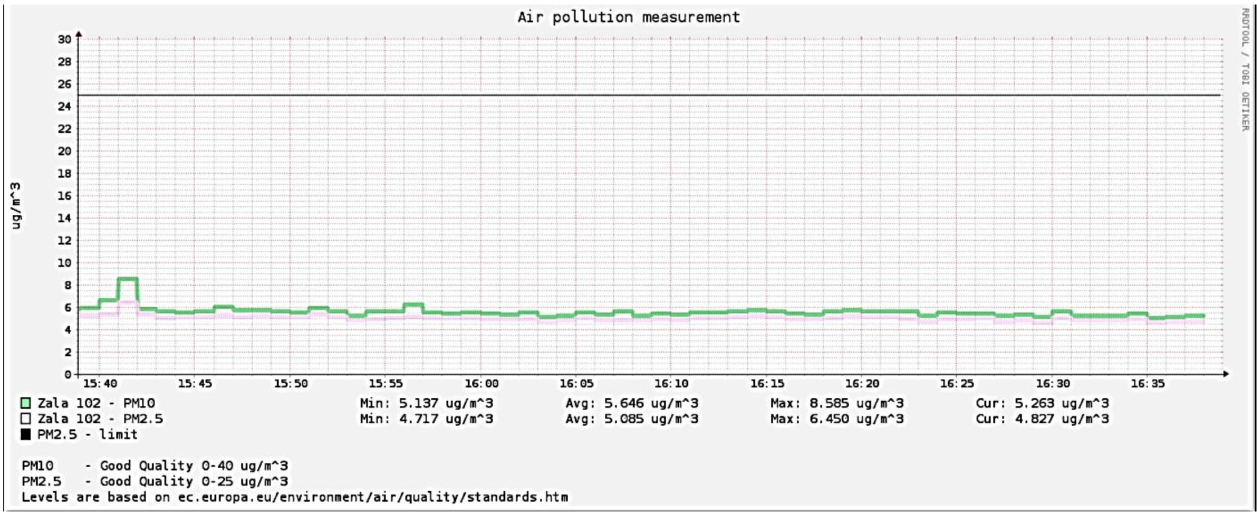

Fig. 7. Test measurement of particulate matter concentration

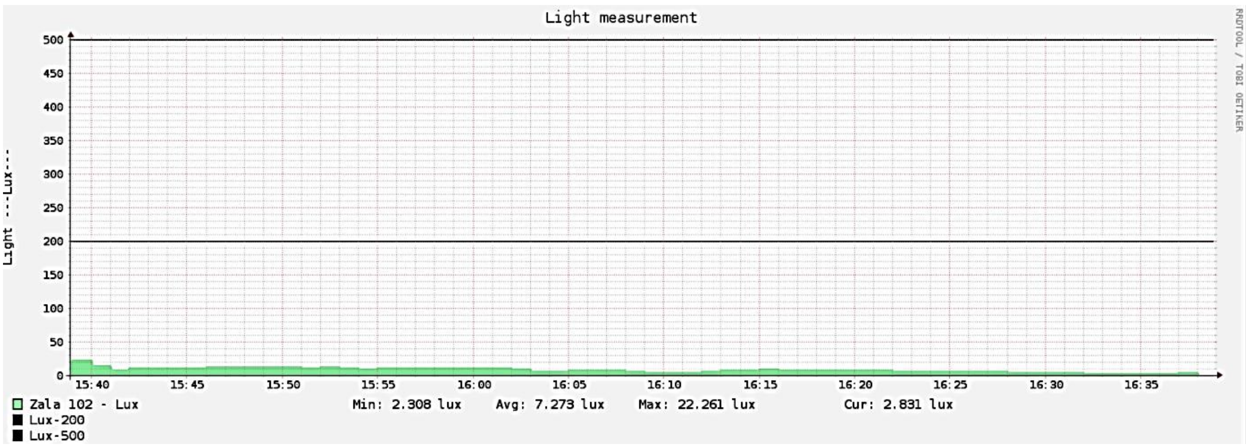

Fig. 8. Test measurement of light

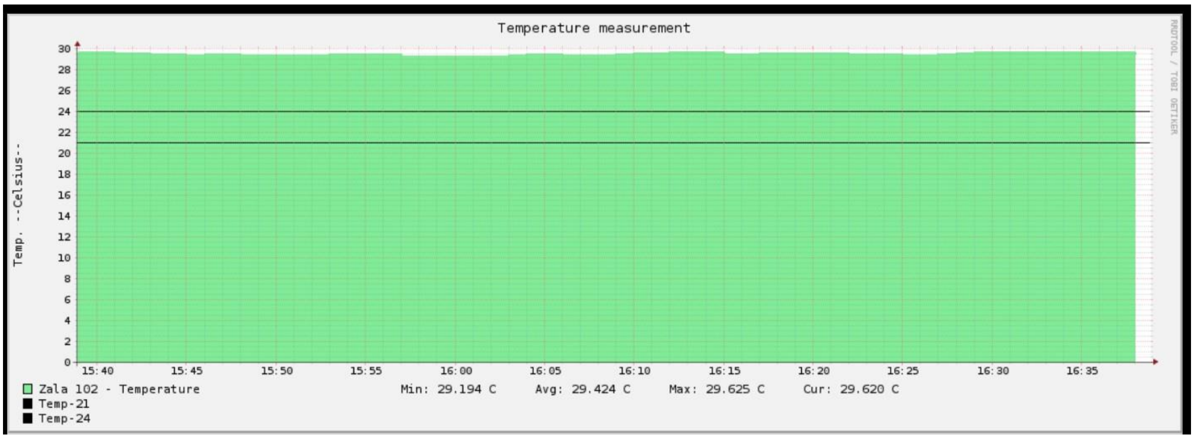

Fig. 9. Test measurement of temperature

IV. Experiments

A. Measurements in an office in an office building

The sensors are located on a work desk (Fig. 6), where the employee usually spends his working time. The measurements were performed for one hour, from 14:30 to 15:30. The air in the room is controlled by an air conditioning system. The obtained results for the controlled indicators are presented in graphical form.

Figure 10 shows a graph of the concentration of dust particles in the room. As the sensor distinguishes PM10 and PM2.5, the graph shows two lines - green and pink. The green line provides information on the concentration of particulate matter with a size of 10 µm, and the pink line gives information on the concentration of particulate matter with a size of 2.5 µm. According to the obtained results, the values for PM10 vary from 6.190 µg/m^3 to a maximum of 15.200 µg/m^3. Average value 8.577 µg/m^3. The values for PM2.5 vary in the range from 5.337 µg/m^3 to 12.690 µg/m^3. Average value 6.785 µg/m^3.

Figure 11 shows the results obtained for the degree of lights in the room. The higher brightness that is observed at the beginning of the graph is due to daylight, which is logical. After the artificial dimming of the room and after turning on the electric lighting, the graph shows a good degree of illumination, which is completely within the normal illumination range of 200 to 500 Lux [2].

Figure 12 shows the measured temperature data. The graph shows that the measured temperature is slightly lower than normal, which should be in the range 21^{o}C - 24 ^{o}C. The average measured values are 18,55 ^{o}C.

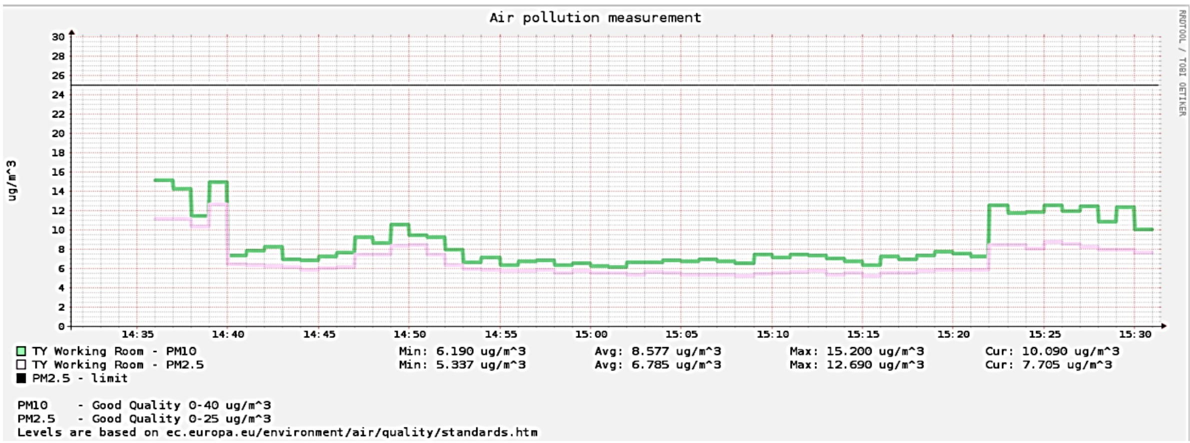

Fig. 10. Graph of the concentration of particulate matter in the office

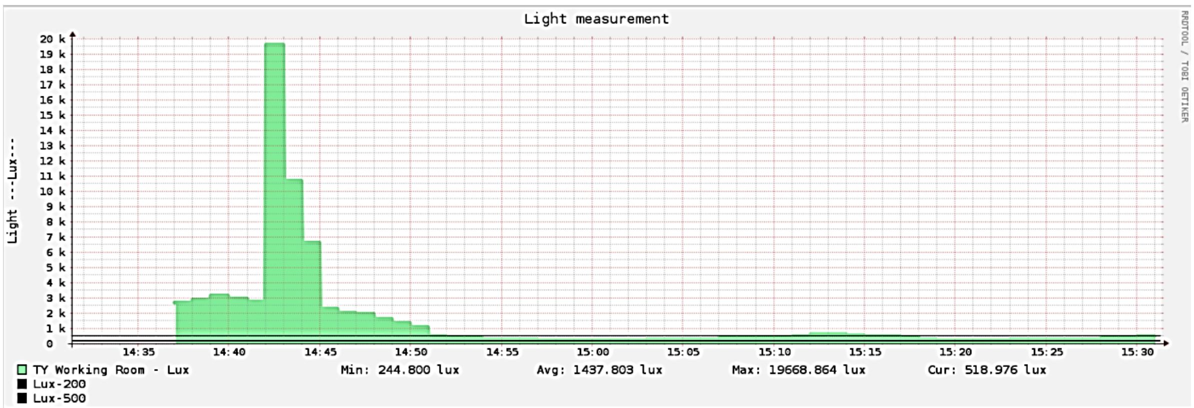

Fig. 11. Degree of lighting in the office

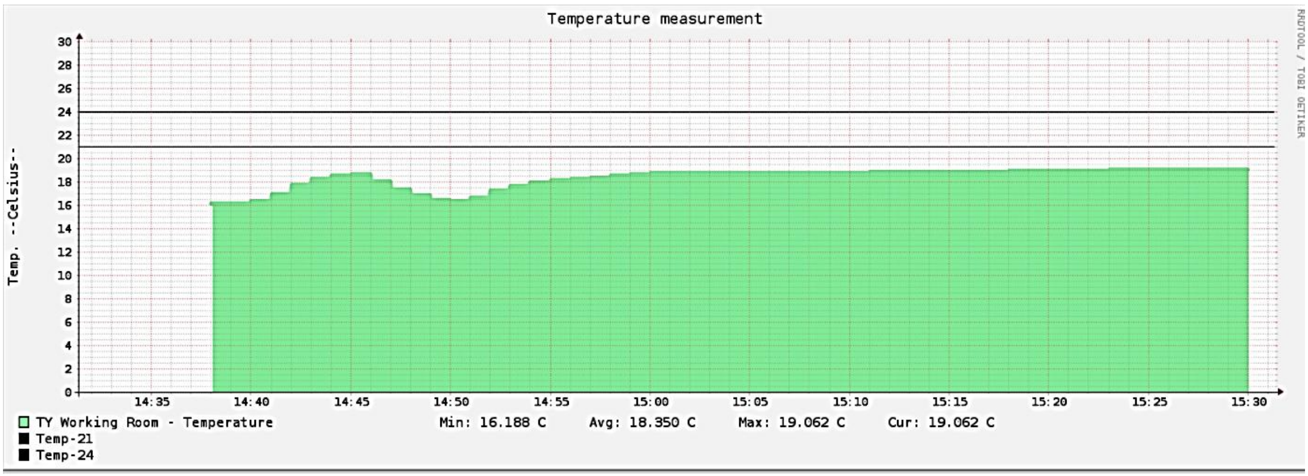

Fig. 12. Measured temperature in the office

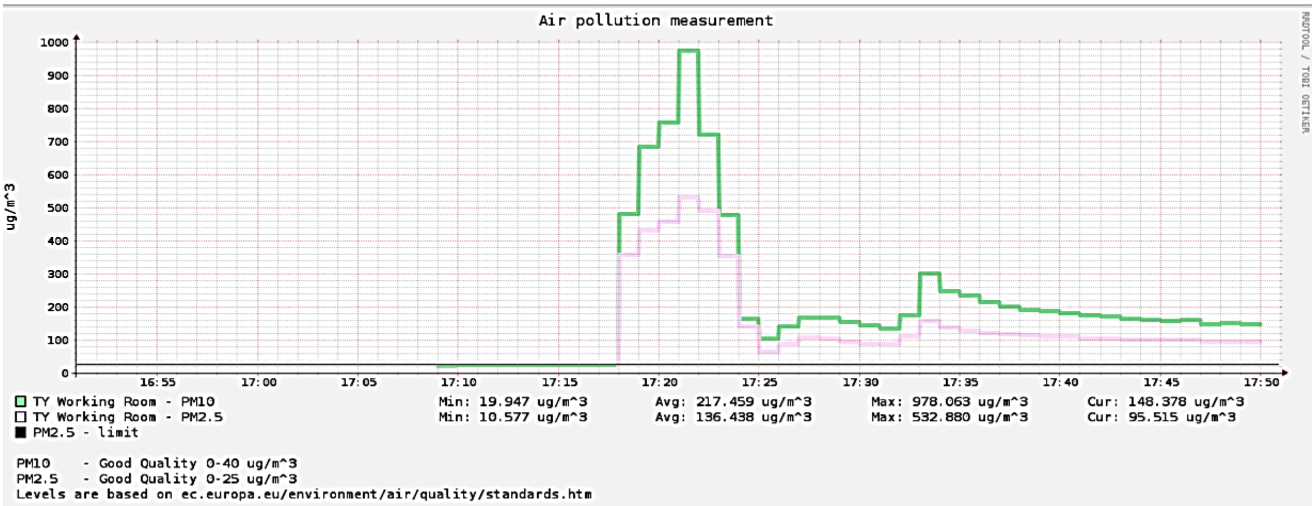

Fig. 13. Graph of the concentration of particulate matter indoor after an e-cigarette

B. PM10 and PM2.5 values after one e-cigarette

In recent years, e-cigarettes of various brands and types have become widely used. Consumers of this product often use them indoors, where smoking is prohibited. But how safe and harmless e-cigarettes are is still unclear. The experiment aims to track what happens to the purity of the air indoors after smoking an e-cigarette. Figure 13 shows the results.

Initially, the values for PM10 and PM2.5 were 19.947 $\mu g/m^3$ and 10.577 $\mu g/m^3$, respectively. A black straight line gives the limit value for pollution with PM2.5. After smoking the cigarette, the values in the graph jump dramatically, as P.M10 reaches 978.063 $\mu g/m^3$ and P.M2.5 is 532.880 $\mu g/m^3$. The measured values are many times higher than the allowable ones. 30 minutes after smoking the concentration of PM10 and PM2.5 decreases, but is still high: PM10 = 148.378 $\mu g/m^3$ and PM2.5 = 95.515 $\mu g/m^3$.

V. CONCLUSION

Maintaining the microclimate of the working environment in certain norms plays a key role in the normal work process. Monitoring the parameters of the microclimate, as well as the pollution with dust particles at the workplace should be a priority for every employer concerned about the good health of its employees and workers.

A measuring system for simultaneous measurement of the concentration of particulate matter, light ant temperature has been developed. System setup and functionality check have been performed. After conducting experiments it can be argued that тhe system is suitable for continuous monitoring of dust pollution, lighting and temperature in work and office premises.

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