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NEW EXPERIMENTAL APPROACH OF ATMOSPHERIC POLLUTANT COMPOUNDS DETECTION

BY

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Abstract. Improving the monitoring techniques of environmental and meteorological parameters in real time is a continuum challenge in our days. Based on the Arduino modern platform the atmospheric pollutant compounds detection can be configured in order to improve the environment management systems. In this paper, we have developed a compliant air quality monitoring system in the laboratory, and we have focused mainly on the assessment of dustiness present both indoors and outdoors. The measurements demonstrate the use of the system, and the recorded data has led to the elaboration of some analyses that can explain some of the effects of the atmospheric pollutants.

Keywords: air quality; dust; atmospheric pollutants.

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1. Introduction

Air occupies about 96% of the volume of the Earth atmosphere, the remaining 4% being occupied by water vapour. Atmospheric air, along with other environmental components, has a vital significance for nature in general. Air is a mixture of nitrogen (78%) and oxygen (21%) necessary for the activity of aerobic organisms, including humans. This mixture also contains an insignificant amount of other gases: neon, argon, helium, krypton, xenon, radon, carbon dioxide, hydrogen, water vapour and other particles that practically have no influence on living organisms. The development of human society leads to the creation of an anthropogenic negative impact on the air quality (Unga *et al*., 2013).

The problems of environmental quality control and, implicitly, air quality, have arisen with the numerical increase of the population that has occupied, in one form or another, the entire surface of the planet, altering it profoundly through pollution. These human interventions have triggered a series of processes that endanger the future of mankind and of our planet (Minea, 2002). The quality of human life is not just about the quality of air, it also refers to the quality of indoor air; that is, in our dwelling, at office or in the classrooms. Our health depends directly on the quality of inhaled air. Consequently, the construction materials, and the cleaning solutions used for a building are very important for air quality. Also, the scope of the space or the way in which the room is ventilated has an important contribution regarding the air quality (Cazacu *et al.*, 2017).

The new studies show that certain atmospheric pollutants may appear in bigger quantities inside closed spaces rather than outside (Amarandi *et al.*, 2018). In the past, less significant attention is paid to interior air pollution, compared to external air pollution, especially emissions from industrial activities and traffic. In the last few years, however, there have been many cases where indoor air pollution has become a real threat. Poor indoor air quality can be particularly damaging to the sensitive groups such as babies, senior citizens, and the sufferers of chronic, cardiac and pulmonary diseases. Radon, a radioactive gas which usually forms in the soil, is one of the main indoor air pollutants. Cigarette smoke, gases or particles from combustion, chemicals and allergens are also responsible for the indoor pollution. Carbon monoxide, nitrogen dioxide, volatile organic compounds and particles can be found both externally and internally.

For an easy understanding of all the negative effects of air pollution and in order to determine the capacity to establish ecological recovery and reconstruction measures, it was necessary to organize and carry out a wide-ranging environmental quality control, a so-called ecological monitoring or integrated monitoring (Godeanu, 1997). In parallel with scientific development, environmental surveillance becomes a systematic and methodical concern, carried out through various measurement systems, with which various environmental parameters such as temperature, humidity, and solar radiation have been recorded over a long period of time.

Over time, the tendency to unify the units of measurement for all these parameters was manifested and materialized, moving from the empirical pursuit and recording to the systematic, scientific study of all these indicators or factors.

The parameters are monitored for the purpose of describing the climatic conditions and the changes over time of these factors; the differentiation of natural phenomena from anthropogenic disturbances, as well as the identification of ecosystem response to changes in climatic factors, air quality and precipitation.

Parameters that characterize climatic factors, air quality and precipitation are physical and chemical. Physical parameters include temperature, wind speed, wind direction, air humidity, atmospheric pressure, rainfall, while SO_2, NO_2, NH_3, suspended particulate matter and sediment dusts are among the chemical parameters that characterize air quality. For air samples to be representative, a number of factors must be taken into account: the source and the area of pollution, the type of pollutant, spreading area, pollution level and short-term concentrations.

Because meteorological factors (temperature, humidity, atmospheric pressure, air currents, precipitation, etc.) cause substantial changes to the air pollution level, they must be observed and noted along with the pollution level during measurements.

The air quality monitoring involves a series of actions to observe and measure the quantity and quality of some air condition indicators, such as the concentrations of air components. The monitoring system allows us to obtain useful data for the rapid identification of polluted areas and for strategic and tactical decisions to combat pollution and to prevent it (Mihăiescu, 2014).

Our air quality monitoring system has been created with financial accessibility in mind. In addition, another advantage of the system is that it is possible to modify the parameters according to the research that the students perform. With our monitoring system, we can measure four main parameters: air humidity, temperature, CO_2 and dust.

For the air humidity and the temperature, we use a single common sensor, but for the last two parameters, we use two different sensors: one for CO_2 and another for the dust measurement. Sensors control is given by the Arduino plate using a specific coding language, the code provided by the manufacturer of each sensor individually and calibrated in the laboratory according to the needs and functions required in the work.

2. Experimental Setup

The interpretation and use of the sensors are provided by Arduino Nano, being the smallest data acquisition board that has successfully met all the requirements of the air quality monitoring device.

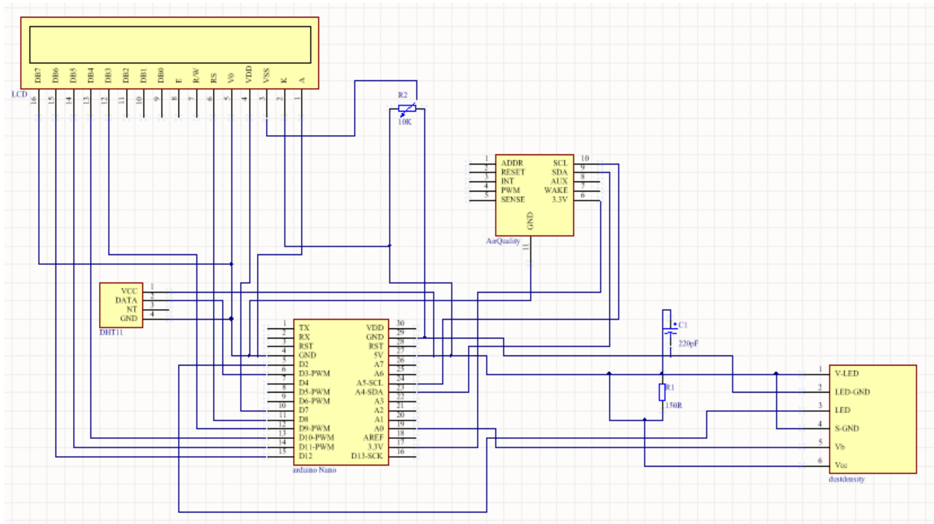

Fig. 1 – Air quality monitoring device scheme.

The Fig. 1 shows the Arduino interconnection scheme with the atmospheric monitoring sensors and the components required for their use. The links between the data acquisition board and the sensors are made through different transmission paths such as I2C protocol, analogue and digital communications.

Fig. 2 – Detection and monitoring device in working time.

The practical model (Fig. 2) of the device was made using a test board on which all sensors were mounted together with the Arduino Nano module. The device comes with an LCD monitor that displays numerically real-time measured data about temperature, humidity, carbon dioxide and dust density, and can be used independently without being connected to a computer; the only thing you need is just connecting to a voltage source or simply connecting to a power bank. For calibration and verification of sensors we used equipment in the laboratories provided by the faculty. We chose to design and build our own detection system as current commercial devices are extremely expensive and in addition, many of them do not allow us to evaluate all the chemical atmospheric compounds we want to analyse (Doroftei *et al.*, 2018). In the following chapter we explain how to connect and use the sensors.

Temperature and humidity sensor

The temperature and humidity data were provided by a DHT11 [Digital Temperature and Humidity] sensor type whose operating diagram is represented by Fig. 3.

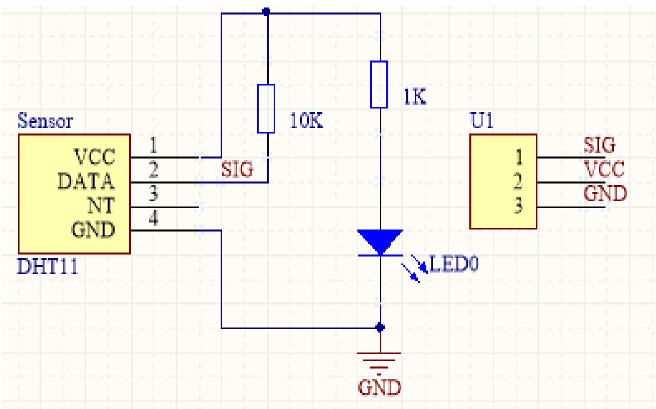

Fig. 3 – DHT11 Temperature & Humidity Sensor.

In order to analysing easily different environment parameters, the DHT11 sensor was used. The temperature sensor has been tested between 5 and 50°C and we notice that in this measurement range given a transit rate from lower temperatures to high of approximately 6°C/sec and the sensor can provide accurate data (Fig. 4).

Relative humidity can be expressed as the quantity of water in the air and the capacity of air to absorb water from the environment measured in percentage. In the Fig. 5 we can notice difference from the dry and wet environment.

The Fig. 5 explains a transition from two types of environment, in the first part of the graph we can observe a lower humidity which is possible to be obtained from artificially drying; after release we can notice an increase of humidity in natural environment.

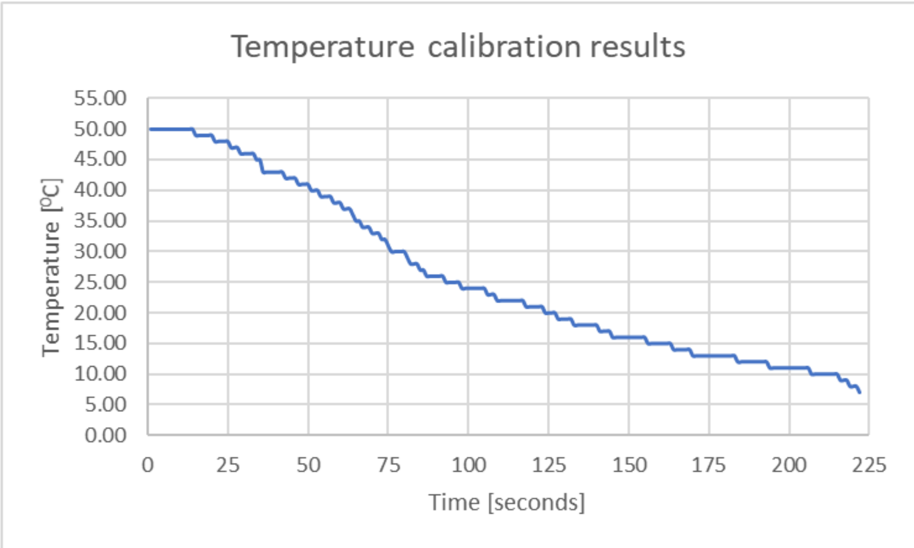

Fig. 4 – Calibration results of temperature sensor.

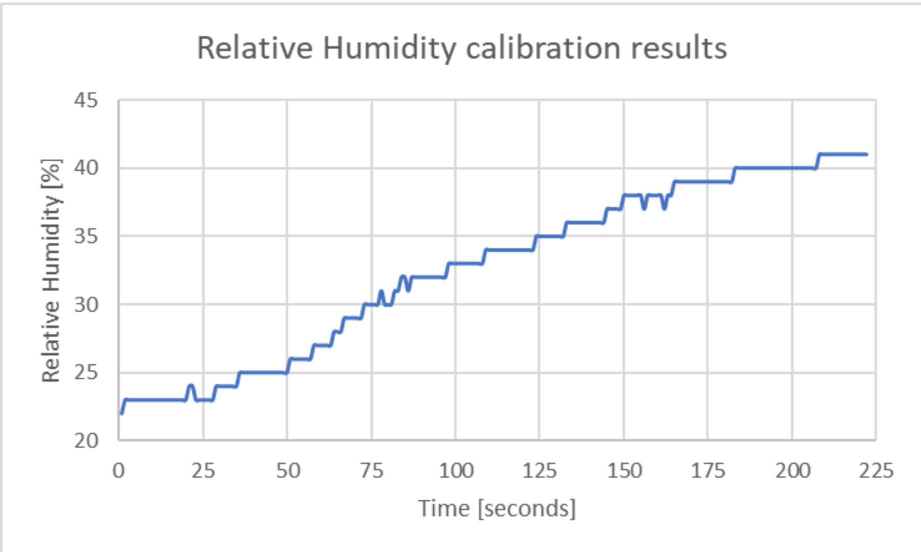

Fig. 5 – Calibration results of relative humidity sensor.

Air quality sensor

Air quality sensor CCS811 showed in Fig. 6 provides a large range of measurements pertaining to carbon dioxide, organic volatile compounds and metal oxide.

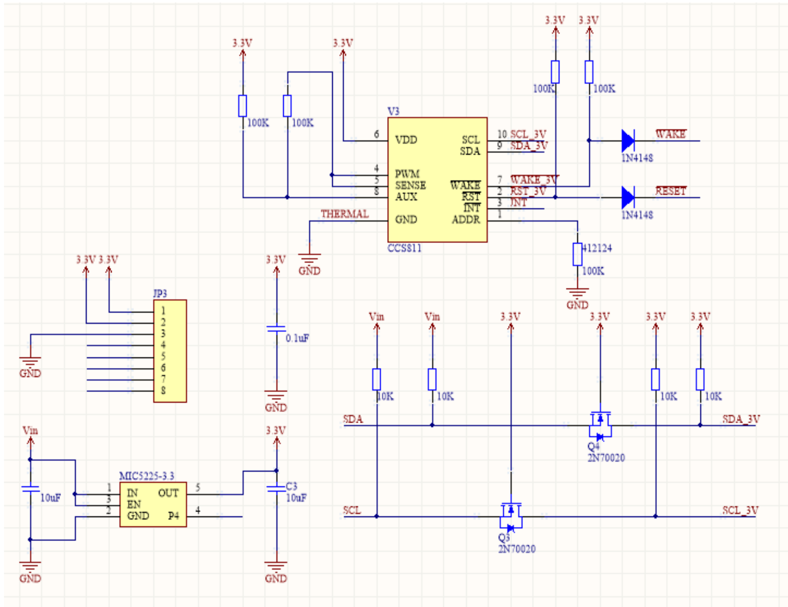

Fig. 6 – Scheme of Air quality sensor CCS811.

After indoor and outdoor measurements, we concluded that the sensor is very responsive to all used sources of CO_2.

In order to test the sensor sensitivity and the response time, various CO_2 concentration was obtained by heating different resins released a large amount of CO_2 in the ambient air (Needhidasan *et al.*, 2014) (Fig. 7).

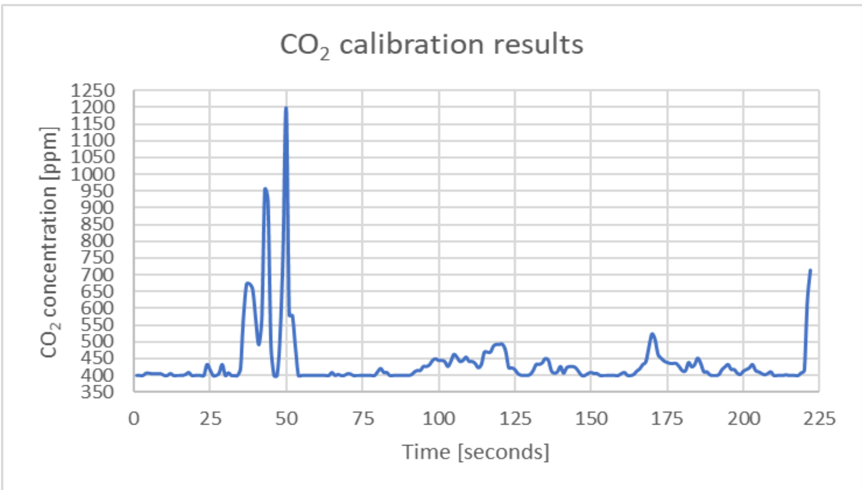

Fig. 7 – Calibration of the Air quality sensor.

In the first quarter of the graph Fig. 7 we notice a rise in the number of parts per million (ppm) of CO_2, generated as a by-product by heating equipment for soldering, after which a period when the sensor was extracted from the polluted environment to see how CO_2 stabilizes in an unpolluted environment.

Sharp Dust Sensor

Dust sensor showed in Fig. 8, has an important role in measuring air parameters as well as determining air, for this reason we test the sensor in normal condition and in dusty conditions.

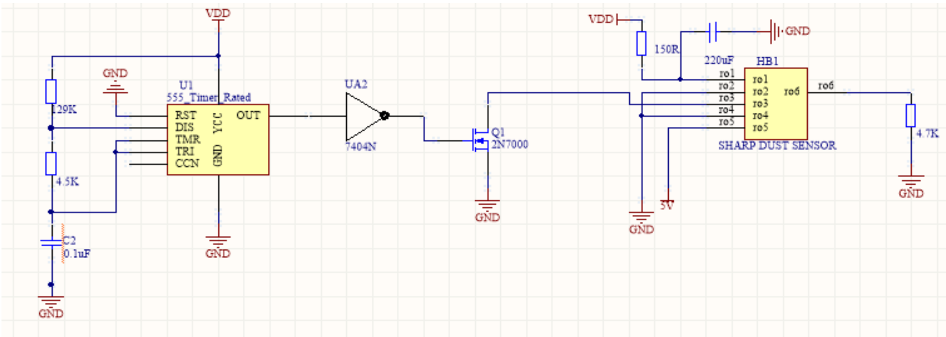

Fig. 8 – Scheme of dust sensor.

The results confirm the functionality of the dust sensor and provide a graph with all parameter from low density of the dust to high level. We observe in the graph shown in Fig. 9 the level of the dust in normal quantity for environment after simulating dust particles with chalk powder, results reaching the maximum value of 0.5 mg/m³.

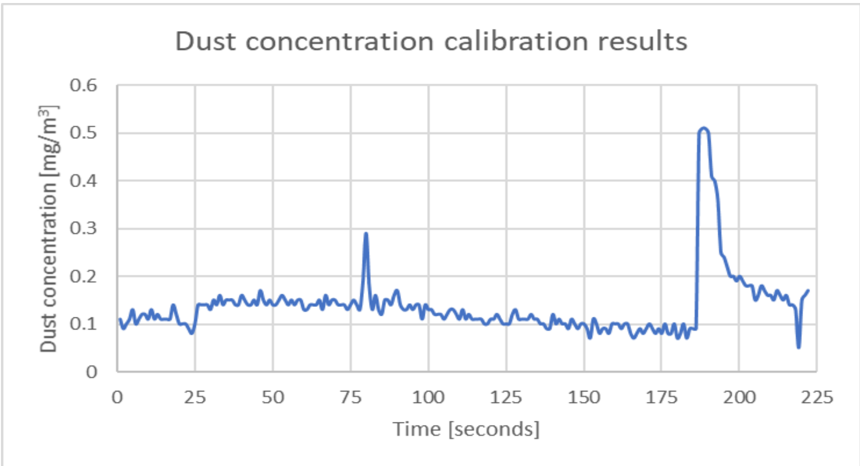

Fig. 9 – Calibration of the dust sensor.

3. Results

The designed monitoring system has been tested under different temperature and humidity conditions. In order to have an overview, experiments were conducted both in enclosed spaces where various activities were carried out, but also in an open environment. The outside environment measurements were performed before and after precipitation periods (Kahn, 2006). The data clearly show the times when our breathing air is simply contaminated with dust particles and various chemical compounds but also episodes, especially after rainfall has taken place in the form of snow, in which the atmosphere becomes considerably cleaner.

Inside data processing

In order to be able to make a clearer analysis of the data obtained in closed populated areas, we have collected data on temperature, humidity, CO_2 level and particle level in the air.

The data was collected over an equal period ranging from 7 to 9 min. In Fig. 10 we can observe the temperature variation produced during the measurements (Douglas *et al.*, 2009); the variation is produced during measurements by opening and closing the door in which the sensor was located.

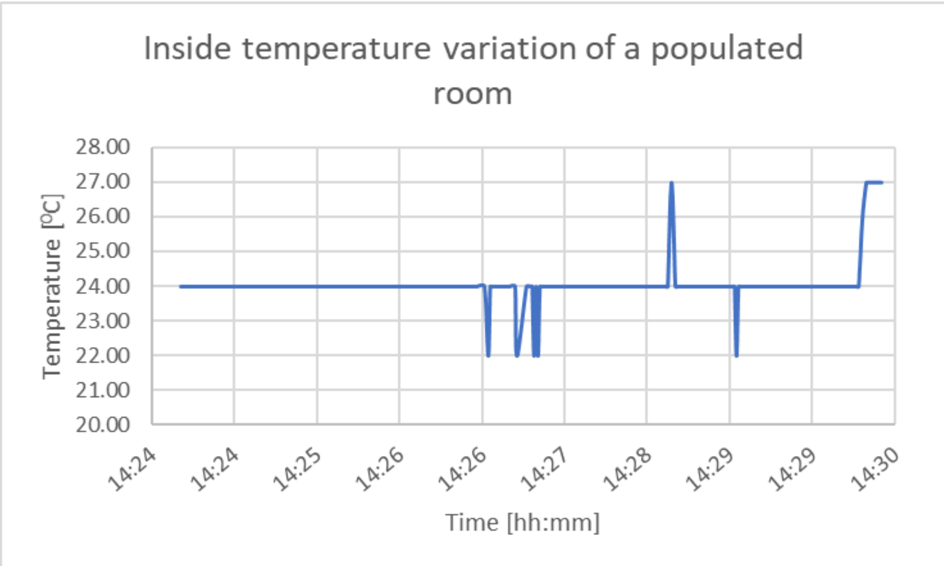

Fig. 10 – Variation of temperature in a populated room.

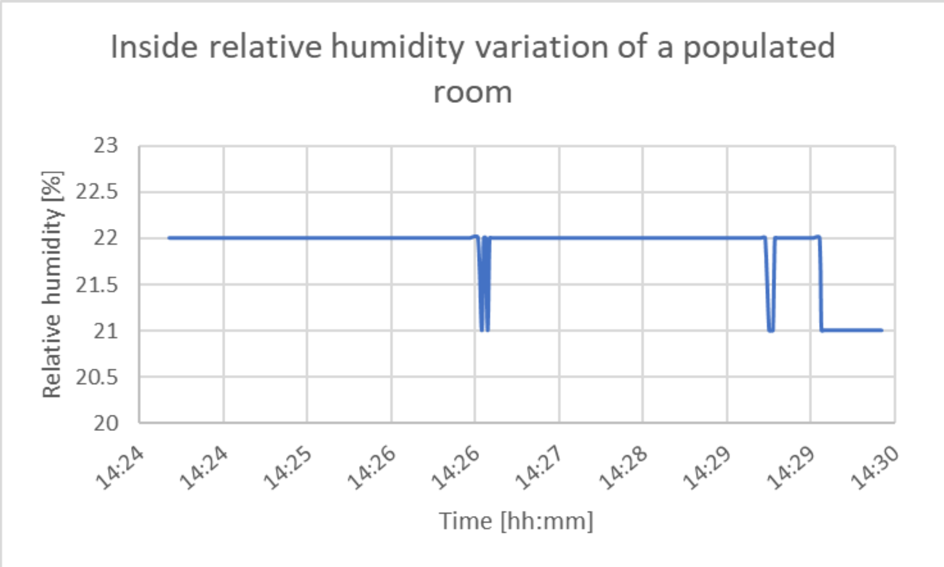

Fig. 11 – Variation of humidity in a populated room.

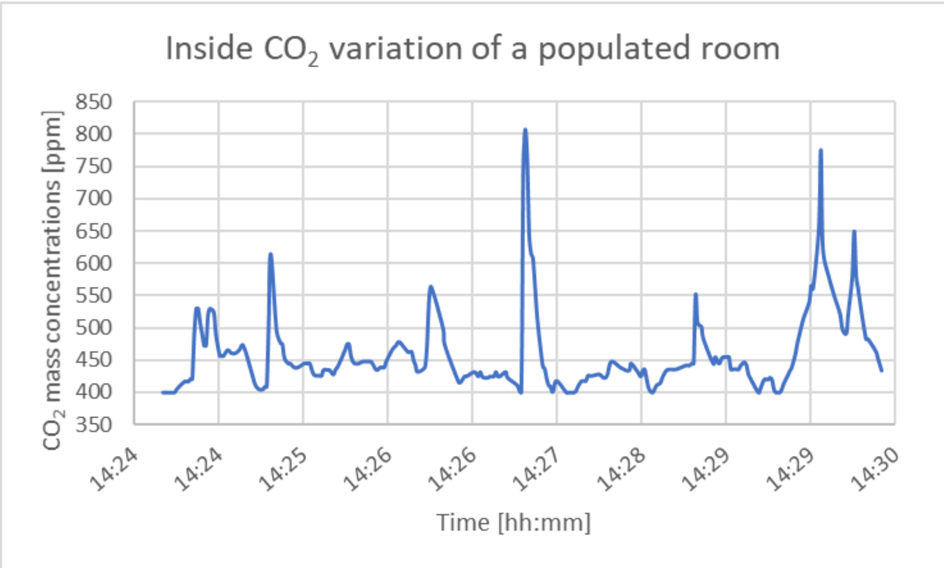

Fig. 12 – Variation of CO_2 level in a populated room.

The changes in the values of the parameters was not only of temperature but also of humidity Fig. 11, CO_2 level in Fig. 12, and the dust particles in the air Fig 13. In the above graph shown in Fig. 11 we observe the humidity in a climatic environment controlled by a district heating network, which has negative effects, the humidity drop being a major one at about 22 percent which can create a respiratory discomfort or dry skin.

The carbon dioxide (Fig. 12) in the environment measured in the enclosed space with an artificially controlled climate confirms that it has normal values (Raw *et al.*, 2002). In terms of sensitivity, this sensor has the most sensitivity in closed spaces, being very easily influenced by disturbing factors such as heat and touch of the sensor.

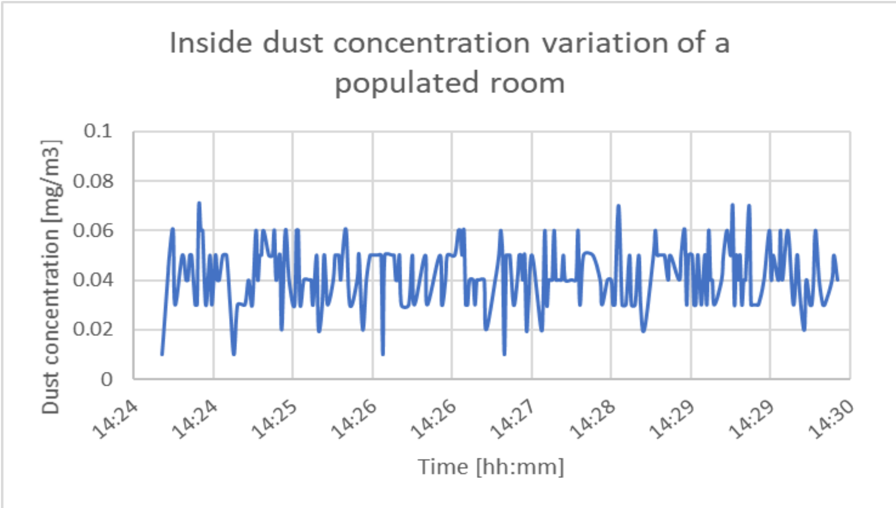

Fig. 13 – Variation of dust particles level in a populated room.

The presence of dust particle sensor in a closed environment results in an almost non-significant value (Fig. 13) from the point of view of respiratory comfort, being a clean environment. The variation of the amount of dust observed by the sensor situated inside the room may be explained by the people movements which determine the lifting of the dust in the air.

Outside (Ambient Air) Data Processing

The following data was taken in the ambient air in the presence of a various meteorological and pollutions parameters. Our aim was to test both the responsive processes of data measurement and data transfer in various conditions for a short time (few minutes).

In Figs. 14 and 15 we can observe a slight temperature decreasing (two Celsius degrees) and an increasing of the atmospheric relative humidity due to the initial stages of the precipitation. Concerning the sensor response time testing in case of CO_2 concentration variation, the data from the first part of the graphic from the Fig. 16 is due to breathing of the smoking person which is implicated in this experiment. The large peak shows that the sensor has reached high values in a few seconds, and after that it returned to the normal values recorded in the ambient air. We mention that the location of data measurements is not affected by the others pollution agents like industry and traffic so it may be observed that the measured level of CO_2 is situated around the background value of 400 ppm in the urban area (IPCC, 2013). Also, referring to the dust amount measured in the atmosphere (Fig. 17), our experimental detection system has not noticed big variations because the area where the measurement was carried out is the Ștefan cel Mare University's Park, which is certainly considered one of the cleanest areas in Suceava city. With our system, we identified big amounts of dust near construction areas, or even in the crowded traffic.

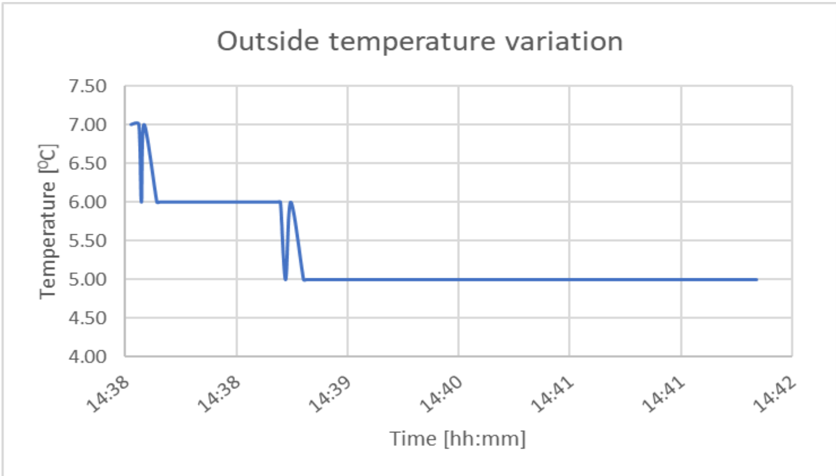

Fig. 14 – Variation of temperatures values in the ambient air.

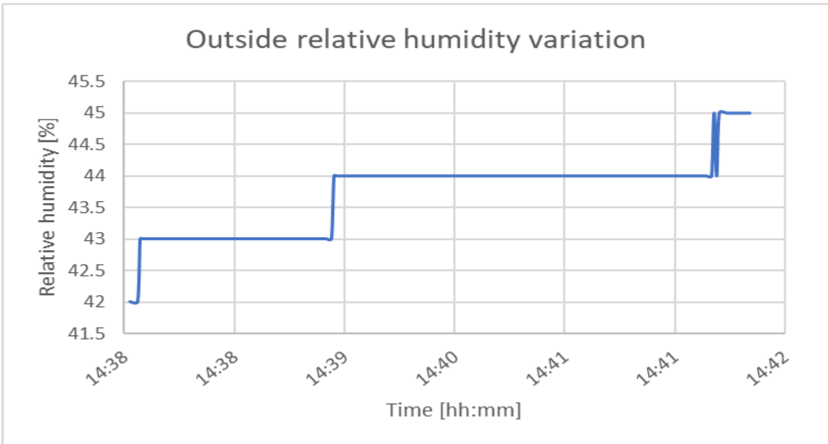

Fig. 15 – Variation of humidity in natural environment.

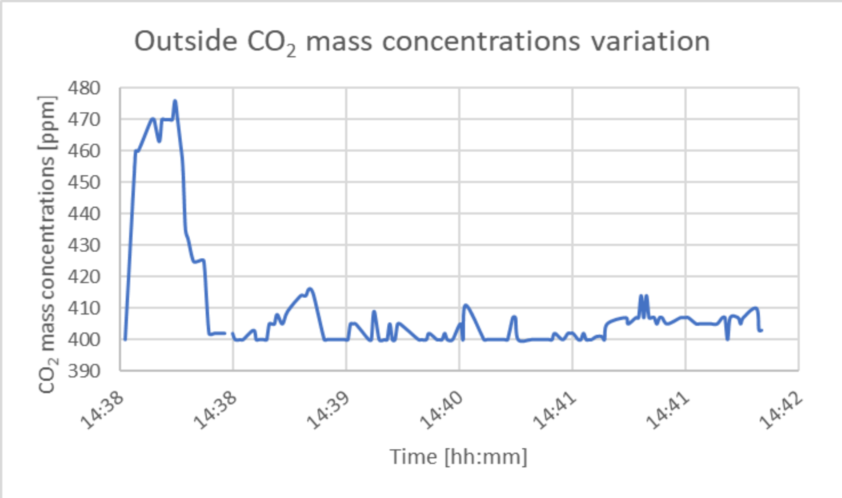

Fig. 16 – Variation of CO2 in natural environment.

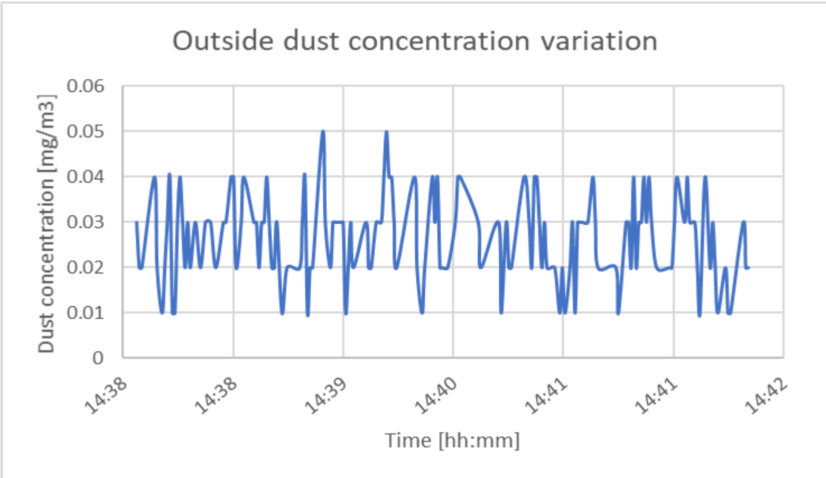

Fig. 17 – Variation of dust particles concentration in natural environment.

3. Conclusions

We have constructed a new experimental approach of atmospheric pollutant compounds monitoring system. Sensor control is performed by the Arduino plate using a specific coding language, the code provided by the manufacturer of each sensor individually and calibrated in the laboratory according to the needs and functions required in the work. One of the advantages of this method is that we do not need special manufacturing equipment; absolutely all the devices have been interconnected using the equipment provided by the faculty lab. It was determined that the work was reproduced very easily by a person without experience in the field. It was also intended that the equipment would be one with a minimal budget and offer maximum performance that was successfully accomplished.

In conclusion, we can say that our experimental system can show us the real value for the main parameters of different pollutants, in the inside or outside environmental. In addition, the long-time monitoring offers the possibility to detect the artificial abnormalities produced by the human body or minor environmental actions.

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NOUĂ ABORDARE EXPERIMENTALĂ A DETECTĂRII COMPUȘILOR POLUANȚI ATMOSFERICI

(Rezumat)

Odată cu dezvoltarea societății umane a devenit evident faptul că activitatea umană influențează mediul atmosferic. Managementul mediului a devenit un capitol esențial pentru orice tip de dezvoltare, indiferent de scala la care se pot manifesta impactele asupra mediului. În scopul asigurării unei conduceri eficiente a tuturor activităților sociale, chiar dacă uneori aspectele de mediu par a cădea pe un plan secundar, s-a impus necesitatea proiectării unor sisteme de supraveghere şi evaluare continuă a calității mediului. În articolul de faţă am realizat în laborator un sistem compact de monitorizare a calității aerului și ne-am axat în principal pe evaluarea cantității de praf prezente atât în interior cât și exterior. Măsurătorile efectuate demonstrează utilitatea sistemului realizat, iar datele înregistrate au dus la conceperea unor analize cu ajutorul cărora pot fi explicate unele efecte ale poluanților atmosferici.