High-Performance Techniques and Technologies for Monitoring and Controlling Environmental Factors

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Abstract: *The impact of air quality inside residential buildings and constructions on the health of residents and workers has been studied very little in recent years. In the school environment, students are constantly exposed to mixtures of airborne substances from a wide variety of sources both in classrooms and in the school environment. Exposure to such factors of students influences, in the long term, physiological development, dynamics, quality of life, life expectancy, without being aware of the dangers in the air and being able to make decisions on reducing exposure to the risk factor. In the short term, poor air quality in classrooms leads to a decrease in attention and concentration, both for the student and the teaching staff. The research is motivated by the following: a) The lack of data and studies carried out in Romania, and their relationship with the change in student behavior during the school program; b) Laboratories and practice workshops in high schools are totally different from classrooms from the point of view of air quality and internal factors that contribute to pollution due to the equipment and specific, different activities carried out in these spaces. The novelty of this study is brought by the fact that, at the same time as the monitoring and data acquisition of air quality (inside and outside), there will be a monitoring and data acquisition of real-time biometric measurements of the subjects directly exposed to this environment, via a bracelet attached to the subject's arm. This bracelet is designed to perform biometric measurements without disturbing the subjects in the activities in which they are involved. These measurements are made with 9 different sensors for: pulse, blood oxygen (SPO_2), air flow (respiration), body temperature, electrocardiogram (ECG), galvanic skin response (GSR - sweat), blood pressure (sphygmomanometer), patient position/movement, and muscle sensor/electromyography (EMG). The data thus obtained will be centralized on a PC and analyzed later. At the end, an ecological equipment capable of ensuring the ventilation of the space and a constant air quality, by monitoring the values of the compounds in the air, will be created experimentally.*

Keywords: *Monitoring, air, quality, data, biometric, measurement, sensor, health, worker*

1. Introduction

The impact of air quality inside residential buildings and constructions on the health of residents and workers has been studied very little in recent years. In the school environment, students are constantly exposed to mixtures of airborne substances from a wide variety of sources both in classrooms and in the school environment. Exposure to such factors of students influences, in the long term, physiological development, dynamics, quality of life, life expectancy, without being aware of the dangers in the air and being able to make decisions on reducing exposure to the risk factor. In the short term, poor air quality in classrooms leads to a decrease in attention and concentration, both for the student and the teaching staff. Students and teachers often complain, after several hours of study, of dizziness and headaches, without specifying a specific cause, even if the window of the study room has been open for a long time. In certain situations, the 10-minute breaks are not enough to recover the student and ventilate the classroom, especially since the quality of the external air is not always accurately known. Temperature, humidity, CO_2 level, oxygen level, etc. are not being monitored, and in certain situations due to the location of the school, these values can be a negative factor for air quality. The same thing happens in some improperly ventilated workplaces.

The reason for this study appeared after a simple experiment carried out in the premises of a school, namely: in the mechatronics laboratories, a small electronic device was made that measured the concentration of oxygen in the air. At the beginning of the class, the device indicated values of 20% oxygen in the air, with the passage of time this value continuously decreased until it reached the value of 18% oxygen in the air. Initially, a malfunction of the equipment was suspected, but the next day it also indicated 20% oxygen in the air initially, gradually decreasing to 17-18% oxygen in the air during the day. If the percentage of oxygen varies so much over the course of a day, what are the values of the other elements in the air, dust, temperature, humidity, carbon dioxide, etc., and what are the influences on the student's behavior and performance? [1], [2]

The mixed monitoring device has 2 components in its structure: one fixed and one mobile. The fixed one continuously monitors the air parameters in the work areas on board the ship, and the mobile one is mounted on the worker's hand to monitor his/her 8 biometric values during the work schedule. Thus, we can have a better view of the working conditions on board the ship and a real-time monitoring of the health (and stress) of the workers on the ship.

The data thus collected can be corroborated for the realization of safety strategies and the creation of low-risk working conditions. Two identical sets were built and fitted into one ship (along with a wide range of sophisticated monitoring and calibration instruments.) The instruments were exposed to common indoor pollution sources in a semi-controlled experiment and during normal ship operation. The results indicate that none of the sensors requires individual calibration. The readings taken by them are within the margins of error specified by the manufacturer.

Thus, the sensor responses were very consistent and correlated with much more expensive instruments. The combination of data provided by the sensors is still being analyzed. Classic air quality monitoring technology has reached its technological and cost limits.

As spatial monitoring improves, pollution sources, dispersion patterns and health effects can be better addressed while reducing reliance on predictive models; hence, the need to supplement conventional air quality monitoring networks with alternative, punctual, local approaches capable of capturing fine changes in these levels of variability and in environmental microsystems. Passive sampling ensembles, mobile monitoring, and emerging sensor technologies are all approaches that have been used to address spatial coverage.

The sensor market has boomed in recent years, resulting in economical, low-power, miniature, self-contained (and usually easy-to-internet) air quality monitoring units. Although these units were less accurate when first marketed, subsequent generations demonstrate improved reliability and accuracy. Equipment made with these tools includes real-time, location-specific data collection. The results can be used as an educational tool, promoting air quality awareness, while contributing to changing time activity patterns to reduce harmful exposure to air pollutants. This revolution in sensors and related applications can provide sustainable solutions for applications in monitoring, education, community monitoring, supplementing ambient air monitoring networks or even compliance assessment.

Equipment made with these tools, attached to human subjects, allows the acquisition of data and the creation of a new picture of the compliance of working conditions and the anticipation of undesirable events. It is only a matter of time before shipping vessels have integrated systems to monitor air quality metrics as well as personnel biometrics.

2. Material and methods

In this work we propose to present 3 case studies:

1) monitoring and acquisition of air quality data with the help of a biometric bracelet (one fixed, the other mobile) [3, 4];
2) universal device for monitoring electromagnetic radiation [5];
3) universal indoor air quality monitoring device [6, 7].

All 3 case studies target common aspects of operational performance for the set of tools used:

- low unit cost
- small form factor
- increased reliability
- use of new generations of sensors
- compatibility with the power and communication systems of the study locations

• compatibility with study site monitoring programs
• issuing alarms
• minimal electrical interference with existing systems
• low energy consumption
• operation period without intervention for 5 years
• ability to easily switch to the new generation of sensors (still under development).

2.1 Case study 1: Biometric bracelet for measuring

The equipment is designed for the monitoring and acquisition of real-time air quality data (indoor and outdoor) [3]. Real-time biometric measurements of subjects directly exposed to the air in the study location will be carried out by means of a bracelet attached to the arm of the subject, without creating discomfort to the analyzed subjects involved in current activities. For the measurements, 9 different sensors are used that give information about: pulse, blood oxygen, air flow (respiration), body temperature, electrocardiogram, galvanic skin response, blood pressure, patient position / movement and muscle condition (electromyography sensor). Later this obtained data will be stored on a hard disk and analyzed. The information obtained from the analyzed subjects is applicable and useful in many fields of activity (on ships, especially in the engine compartment, where the air undergoes alterations of the quality parameters). Deterioration of air quality can lead to stagnation of the subjects' activity as a result of the deterioration of the state of health.
The biometric bracelet can be used in two versions: one fixed, the other mobile.
In the fixed version, the sensors used for data transmission are (Figure 1) [4]:
• Optical dust sensor: GP2Y1010AU0F Sharp
• Sensor for NO_3, CO, NH_3: MiCS-6814 SGX Sensortech
• Temperature and humidity pressure sensor: BME 680 BOSCH.

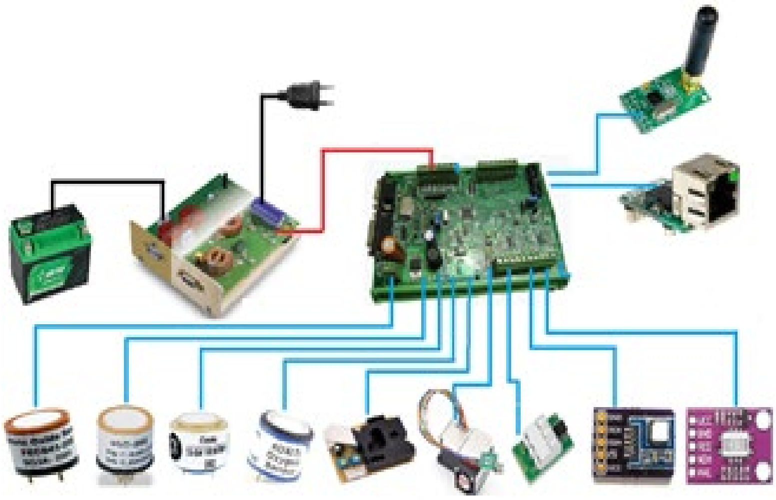

Fig. 1. Fixed unit - Block diagram

In the second version, the sensors used for data transmission are (Figure 2) [4]:
• MAX30100 Maxim Integrated pulse oximeter and integrated heart rate sensor
• Sensor for NO_3, CO, NH_3: MiCS-6814 SGX Sensortech
• Temperature and humidity pressure sensor: BME 680 BOSCH
• Motion sensor (accelerometer): MPU-6000 InvenSense
• Body temperature sensor
• Sweat sensor.

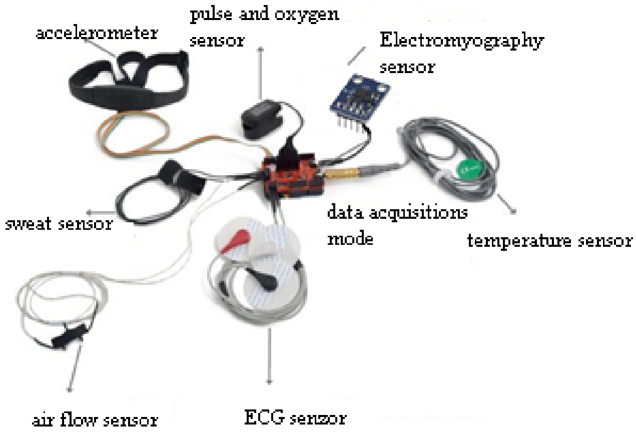

Fig. 2. Mobile unit scheme

Techniques used:

• The Autodesk EAGLE program was used for the electronic design.
• Software development Prototyping ARDUINO I.D.E.
• For creating Office diagrams.
• For PLX-DAQ data acquisition via RS232 converted to USB.

3 tests were performed:

- Test 1, a short series of controlled tests aimed at testing equipment performance;
- Test 2, different variable quantities of the monitored elements were placed in the work area in turn and data was collected from the two equipment pieces;
- Test 3, the equipment was exposed to a series of common sources of internal emissions, specific to the work area.

The results and their graphic interpretation are presented in Table 1, respectively Figure 3, for 1000 values for the NO_2 sensor, the CO sensor and the NH_3 sensor.

Table 1: Results for air quality

Current time	Sensor Values NO_2	Sensor Values CO NH_3	Sensor Values NH_3
16:30:40	0.00	2.00	1.00
16:30:54	12.00	79.00	0.00
17.56.32	15.00	1.00	3.00
17.56.43	8.00	1.00	10.00
17.56.44	0.00	0.00	1.00
17.56.46	0.00	4.00	1.00

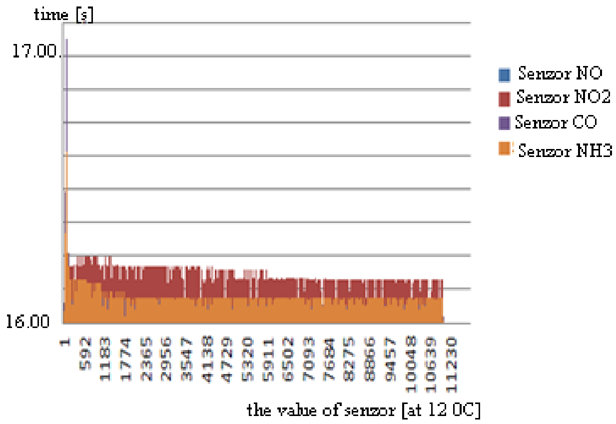

Fig. 3. The values of sensors in current time

Reference values for air quality indicators (according to OG no. 582/2002) measured in air for 1 hour, alert threshold measured for 3 consecutive hours:

- SO_2-350 pg / m^3; Alert threshold-500 µg / m^3
- NO2-200 µg / m^3 NO_2; Alert threshold-400 µg / m^3
- Particulate matter (PM10) - value at 24 h-50 µg / m^3 PM10; Maximum evaluation threshold - at 24 hours - 60% of the daily limit value (30 µg / m^3)
- CO-Maximum average daily value of 8 hours-10 µg / m^3
- Ozone - the maximum daily value of the averages for 8 hours-120 µg / m^3; Alert threshold at 1 hour-240 µg / m^3.

The measured data were compared with the values indicated by the standard certified equipment (gas analyzer) [8, 9].

The experiments showed that the choice of sensors with **I2c** communication was a good, viable, feasible choice. Sensor readings are within prescribed tolerances. No sensor calibration is required. The constructive dimensions of the bracelet were not very small when first realized, but they can be considerably reduced in the case of industrial manufacturing.

2.2 Case study 2: Universal Device for Monitoring Electromagnetic Radiation

It complements the family of universal devices for monitoring Indoor Air Quality Universal Device [7] and Outdoor Air Quality Monitoring Universal Device [10]. "Composed of the basic unit with the role of interpretation, storage, display, online retransmission of information, received from one or more sensory modules, with a narrow spectrum, specialized for the area of interest to be monitored, these sensor modules are connected to the base unit via the I2C communication line via the quick jacks, which allow them to be changed in a few seconds. Thus, one or more sensors can be attached depending on the area or areas to be monitored, thus achieving an exact identification of the area and the source generating electromagnetic radiation" [10]. The design of the electronic scheme of the equipment prototype was developed with EAGLE software. The prototype wiring was made in our own laboratory, following the final, perfected version, to be made in a factory specialized in wiring (Figure 4) [10].

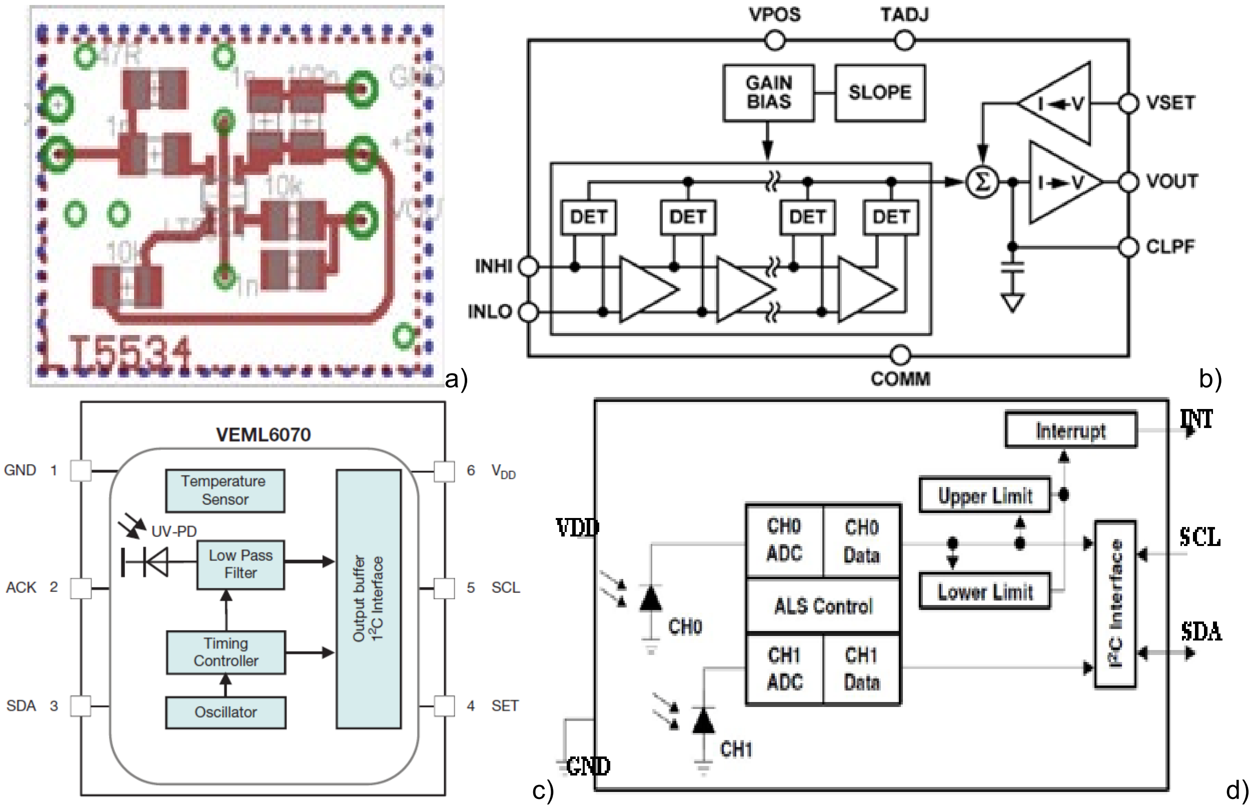

Fig. 4. The block diagram of device

Where:
a) the electrical equipment; b) communication equipment; c) UV radiation sensor; d) converter light intensity into a digital signal output.
The data obtained can be synchronized with local time (LT) or with Coordinated Universal Time (UTC) and can be imported into table programs for further analysis. The data acquisition was made through the "Tera Term" program, which offers the possibility of accessing data both on a serial local communication and accessing the data over the Internet. The following were monitored in the four study locations: the variation of the daily average of electric field strength during a week, daily average of density of power for electromagnetic radiation during a week (Table 2) [10]. The obtained values were compared with the values imposed by the legislative restrictions (Table 3) [10].

Table 2: Results for monitoring electromagnetic radiations

Current time	Frequency Domain			
	Zone 1 ***100 kHz - 7 GHz*** ***S (W/m²)***	***Zone 2*** ***925 MHz – 960 MHz*** ***S (W/m²)m)***	***Zone 3*** ***1805 MHz – 1880 MHz*** ***S (W/m²)***	***Zone 4*** ***2110 MHz – 2170 MHz*** ***S (W/m²)***
Day 1	0.0539	0.0495	0.0010	0.0095
Day 2	0.0495	0.0584	0.0013	0.0099
Day 3	0.0398	0.0500	0.0012	0.0082
Day 4	0.0384	0.0512	0.0013	0.0072
Day 5	0.0046	0.0489	0.0010	0.0070
Day 6	0.0024	0.0006	0.0003	0.0001
Day 7	0.0023	0.0005	0.0003	0.0001

where S (W/m^2) is the power density for electromagnetic radiation during a week.

Table 3: Results for monitoring power density for electromagnetic radiation - Comparative analysis

Frequency Domain	S (W/m²)	
	Restrictions on exposure to time	***Measured average weekly value***
Zone 1 100 kHz-7 GHz	-	0.0282
Zone 2 925 MHz - 960 MHz	-	0.02612
Zone 3 1805 MHz - 1880 MHz	-	0.00131
Zone 4 2110 MHz - 2170 MHz	-	0.006

As it results from the comparative analysis in the areas where the measurements were performed, the persons are not exposed to the danger of electromagnetic irradiation, the registered values being below the standard values recommended by the European legislation. "*The need to monitor electromagnetic emissions on areas of interest has led to the design and implementation of this versatile, adaptable, easy-to-use and maintenance equipment that can be used in different environments to be monitored*" [10].

2.3 Case study 3: Universal indoor air quality monitoring device

The design and manufacture of this device aims to create a versatile, adaptable, easy-to-use and maintain equipment in different environmental area.
This device works with a wide variety of sensors: gas sensor (volatile organic compounds, carbon dioxide), digital gas sensor for air quality breakout (Total Volatile Organic Compounds, CO2, metal

oxide), sensor which operates over a wide supply range, combined temperature and barometric pressure sensor, a 3-sensor device suitable for gas leak detection air quality monitoring (for unhealthful gases like Carbon monoxide, Nitrogen dioxide, Ethanol, Hydrogen, Ammonia, Methane, Propane, Iso-butane).
The data are acquired using the TeraTerm program and stored in **xls**. format [11]. After this, they can be numerically or graphically visualized (Figure 5).

1	DATA	TEMP	HUM	PRES	ALT	CO2	Tvoc	NH3	CO	NO2
2	[2020-01-:	26.22	32.63	724.95	396.52	400	0	0.68	4.39	0.14
3	[2020-01-:	26.23	32.63	724.95	396.52	400	0	0.68	4.39	0.14
4	[2020-01-:	26.3	32.53	724.95	396.52	400	0	0.68	4.39	0.14
5	[2020-01-:	26.24	32.53	724.95	396.52	400	0	0.68	4.39	0.14
6	[2020-01-:	26.29	32.43	724.93	396.74	400	0	0.68	4.39	0.14
7	[2020-01-:	26.33	32.43	724.93	396.74	400	0	0.68	4.39	0.14
8	[2020-01-:	26.3	32.33	724.95	396.52	400	0	0.68	4.39	0.14
9	[2020-01-:	26.33	32.33	724.95	396.52	400	0	0.68	4.39	0.14
10	[2020-01-:	26.33	32.23	724.96	396.29	401	0	0.68	4.39	0.14
11	[2020-01-:	26.39	32.21	724.96	396.29	401	0	0.68	4.39	0.14
12	[2020-01-:	26.46	32.12	724.96	396.29	401	0	0.68	4.39	0.14

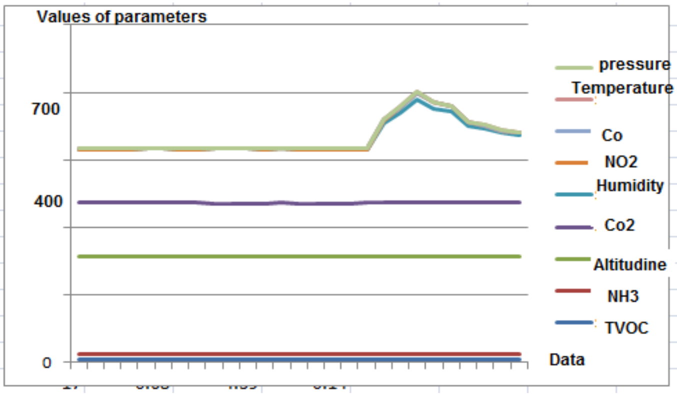

Fig. 5. The values of parameters in current time

The average values of the monitored parameters are calculated and taken into consideration, and these values are centralized. Finally, the values obtained with calibrated devices are checked. Choosing such a device is advantageous because: sensors can be chosen from the profile industry depending on the lowest price and the most reliable design, data can be accessed locally or online, as many sensors as possible can be mounted on the base plate depending on the number of parameters desired to be monitored, various databases can be created for different air quality parameters.

3. Conclusions

Atmospheric emissions, with potential impact on natural ecosystems and a human well-being, may result in potential impact at local and regional levels, in a cross-border context and on a global scale.
Due to the dispersive nature of the offshore environment and the lack of receptors in the vicinity of the offshore infrastructure, locally high concentrations of emissions will last a short time and are unlikely to be detectable, except in the immediate vicinity of activities. The concern regarding atmospheric emissions, implicitly air quality in the offshore area, has increasingly focused on global warming and climate changes that can modify the average values of air quality parameters. An increase in CO_2 in global gas concentrations greenhouse can increase temperatures at the soil surface. An increase in methane will involve global climate changes and contribute to air quality deterioration at a regional level, through the production of ozone at a reduced level, which can be to the detriment of health and may have an impact on vegetation, crops and ecosystems. CO can have direct effects on human health (asphyxiation), and may indirectly contribute to climate change. NOx emissions generate photochemical pollution in the presence of solar radiation. The reduced level of ozone is the main chemical pollutant formed, with by-products including nitric and sulfuric acid and settleable dusts of nitrates.

These devices are useful in the land and offshore area to assess the volume of gases emitted by each source of pollution in the atmosphere. They allow the estimation of the worst case of emissions to be put in the context of the inventories of national and international emissions and to evaluate the global contribution of these gases, because the potential impacts from atmospheric emissions are globally cumulative.

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