A Novel Approach for Indoor Outdoor Air Pollution Monitoring

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Abstract

Current increase of atmospheric air pollution rates in developing and developed countries requires efforts to design more cost effective and affordable devices. In developed countries pollution monitoring chambers are available to aid the monitoring process. The culture and the society are aware of the polluted environment side effects and measures have been taken to reduce pollution amounts. Most developing countries lack these chambers and they do not have cost effective tools for measuring pollution amounts for indoor and outdoor environments. Here, an effort has been made to modify low cost available pollution devices to work for indoor and outdoor pollution monitoring and a simple cost effective approach has been carried out. Indoor carbon monoxide gas level monitoring using cheap alarm's sensor, supported by a car oxygen sensor for oxygen gas level monitoring. The same approach is used for outdoor gas pollution monitoring. A computer program has been designed to facilitate computer based monitoring process and logging of pollution data.

Keywords: *Air quality monitoring, CO detection and measurement, Outdoor gas pollution monitoring, Computer based pollution measurement.*

1. Introduction

Minute after minute the industry is feeding the markets by thousands of air pollutant products. Customers are happy in buying these products and they are not aware that they are destroying their living environment. Public awareness in developed countries with the availability of air quality measurement chambers accompanied by the availability of larger amount of green areas reduces air pollution risks from these countries. In developing countries neither the public awareness nor the air quality monitoring chambers are available. People are more eager to buy products from developed countries without paying attention to any side effects these products may have. Some countries still buy and produce automobiles without catalytic converter installed in (to reduce emission gases). In most of these countries traffic control directorates do not have regulation and legislation for emission control. In some cases the excuse is the unavailability of simple or low cost devices or devices that are using easily available components and simple to use.

Here a step has been taken toward designing a computer based system that utilizes easily available sensors in commonly used systems and devices. The availability of these sensors makes the task of applying the results of this work affordable by most countries.

Two gases have been considered as a measure of pollution amount, carbon monoxide (CO) and oxygen (O2) and by measuring the amount of these gases an indication of pollution amount will be given. The higher the CO gas amount the higher the pollutant gas amount will be in the area. The lower the O_2 gas amount, the bigger is the amounts of combustion engines and gas pollutants in the surrounding area.

2. Scope of the Work

This work is the outcome of two previous works in the direction of pollution monitoring and measurement [1] and [2]. It combines the work of combustion engine gas emission monitoring and indoor CO gas monitoring.

The proposal is to use the designed system for both outdoor and indoor environment gas pollution monitoring. The system logs pollution data in a text file for analysis purposes.

3. Available Devices

Through searching the internet several devices that could be used for CO pollution measurement were found. Samples of these devices are described below:

The link HTTP://WWW.CONSUMERSEARCH.COM/ CARBON-MONOXIDE-DETECTORS contains a description of different CO sensors. The price ranges from 35$ to 75$. These devices has no computer connectivity and there main use is to alarm when CO level raises to above acceptable levels.

Another device was found on Wikipedia at the link HTTP://EN.WIKIPEDIA.ORG/WIKI/FILE:DETECTOR_ FOR_GAS.JPG. The brand is ITX and it monitors several gases but its connectivity to a computer system for data exchange was not clear.

4. Literature Survey

Below are a literature reviews on related works in the field of pollution detection and measurement.

In [1] attempts for the use of easily available sensors have reached the point of using car oxygen sensors for the purpose of monitoring combustion engines gas emission amounts. The same approach was adopted for environmental monitoring. The higher the O_2 gas amount the less polluted the environment is. A USB interface card, a designed hardware and a designed C# program has been used to allow computer based pollution monitoring.

Hussein in [2] found another affordable sensor for pollution monitoring. A sensor available in a cheap indoor environment gas sensor was adopted, the MQ7 CO gas sensor. Instead of taking out the sensor from the CO alarm the author adopted to utilize the CO alarm circuitry for feeding the MQ7 sensor. The outcome of the work was the design of a cost effective computer based CO gas monitoring system.

Cordoa and et al. [3] in their work describe technical characteristics, test results, and a concluding application for methane and carbon monoxide sensors. Detection method as well as the apparatus functional sketch has been presented. This work is based on the use of a sensor manufactured by Japanese company named FIS and the sensor is the SB95 sensor. The SB95 is a semiconductor sensor that has two main advantages: it's built on very small dimensions opposite to those of its predecessors and detects, on the same sensitive element, two gases, methane and carbon monoxide (CO), with very low energy consumption opposite to classic sensors. The conclusion of the work is that The SB-95 sensor has the optimal technical and functional characteristics for detecting methane and CO gases in rooms where these gases can appear accidentally.

Zhu and et al. [4] focus on the relaxation process of acoustic waves in polyatomic gases, and build up a multi-relaxation algorithmic model of a gas mixture of nitrogen, oxygen, water vapor and carbon monoxide. The paper quotes that by computing acoustic velocity and relaxation attenuation, which depend on the composition of the gas mixture, acoustic frequency, temperature, and pressure, we notice that changes in carbon monoxide concentration have great influence on these acoustic characteristics of the mixture. Thus it proves the feasibility of detecting carbon monoxide by means of molecular acoustic method. Finally a detailed model to measure proportion of carbon monoxide is described. This work is related to modeling for the purpose of measuring CO levels more than CO levels measurement, but it's included because it relates to carbon monoxide gas level measurement techniques.

Mello and et al. [5] describe the use of optical sensor for measurement of CO levels. In the work a photo detector based on gallium nitride (GaN) and an UV light source are integrated for the purpose of measuring CO level in exhaust manifold of combustion engines. UV light source consists of a spark produced by an arc discharge which induces transitions in the gas, causing a modification of the light intensity as a function of gas composition. These transitions modify the fraction of light in the UV spectral region which is detected by the GaN photo detector, as a function of the species concentration. By virtue of its structural properties, gallium nitride (GaN) allows to operate at high temperatures and high speed and to work in situ in the exhaust manifold of combustion engines at temperatures as high as 600°C.

Homer and et al. [6] describe the use of polymer-based sensors to detect volatile organics and inorganics as they are not usually used for smaller gas phase molecules. They report the development and use of two types of polymer-based sensors for the detection of carbon monoxide as low as 150 ppm at room temperature. Further understanding of the experimental results is also obtained by performing molecular modeling studies to investigate the polymer-carbon monoxide interactions. They used two types of sensors that show good, repeatable and reversible response to carbon monoxide at room temperature.

[7] Presents the use of a dynamic gas sensor network for air pollution monitoring, and its auto-calibration to achieve maintenance-free operation. Although the gas sensor outputs generally show drift over time, frequent recalibration of a number of sensors in the network is a laborious task. To solve this problem a dynamic gas sensor network is proposed. By placing sensors on vehicles running on the streets or placing some of them at fixed points and the others on vehicles. Since each sensor in the dynamic network often meets other sensors, calibration of that specific sensor can be performed by comparing the sensor outputs in such occasions. The sensors in the whole network can thus be calibrated eventually. The simulation results are presented to show that adjusting the sensor outputs to the average values of the sensors sharing the same site improves the measurement accuracy of the sensor network.

Branzila et al. [8] in their work present a cheap, high-speed digital data acquisition system that combined with LabView software give the possibility to easily monitoring the environmental parameters. The author quotes "there are many applications where the system can be used like: toxic waste identification, combustible mixture analyze, industrial emission monitoring and noninvasive medical analyzes". This system can be adapted for an intelligent electronic nose with data transfer directly through the internet and it is called Web E-Nose by the authors.

5. The Current Work

In this work two commonly available sensors are used for indoor outdoor gas monitoring. The monitoring is done through designing a system for that purpose and the system compromises from four modules. The modules are:
5.1- A CO alarm sensor.
5.2- A car oxygen sensor.
5.3- A USB (Universal Serial Bus) interface board.
5.4- A software module.

5.1 The CO Alarm Sensor Module

Figure 1 shows the used CO alarm sensor which is a home based device.

Fig. 1 The used CO alarm with air ump tube

This CO alarm uses the MQ7 [9] sensor. This sensor requires alternating the heater voltage from low to high. In low it detects the CO gas and in high it clears the gas to start another cycle. Since, the alarm device contains all the necessary support circuitry for heater voltage toggling; there was no need to design any special circuit for that. A wire is connected to the sensor output voltage pin and brought out of the device. The other end of the wire is connected to a voltage divider and then to the USB interface card analog port one input pin. The PCB of the CO alarm is shown in Figure 2.

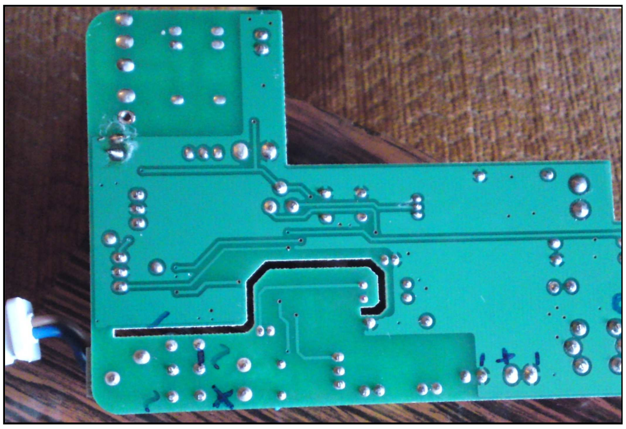

Fig. 2 The PCB of the CO alarm

The MQ7 sensor is a gas sensor with a high sensitivity to carbon monoxide. The SnO_2 of the sensor is with lower conductivity in clean air. It makes detection by method of cycle high and low temperature, and detect CO when low temperature (heated by 1.5V). The sensor conductivity is higher along with the gas concentration rising. When high temperature (heated by 5.0V), it cleans the other gases absorbed under low temperature.
The sensor could be used to detect different gases that contain CO, it is with low cost and suitable for different applications.

5.2 The Oxygen Sensor Module

An oxygen sensor, or lambda sensor, is an electronic device that measures the proportion of oxygen (O_2) in the gas or liquid being analyzed. It was developed by the Robert Bosch GmbH company during the late 1960s. The most common application is to measure the exhaust gas concentration of oxygen for internal combustion engines in automobiles and other vehicles. Divers also use a similar device to measure the partial pressure of oxygen in their breathing gas. Figure 3 shows the O2 sensor (upper part) and its module (lower part). The sensor is installed in a used desktop computer power supply unit.

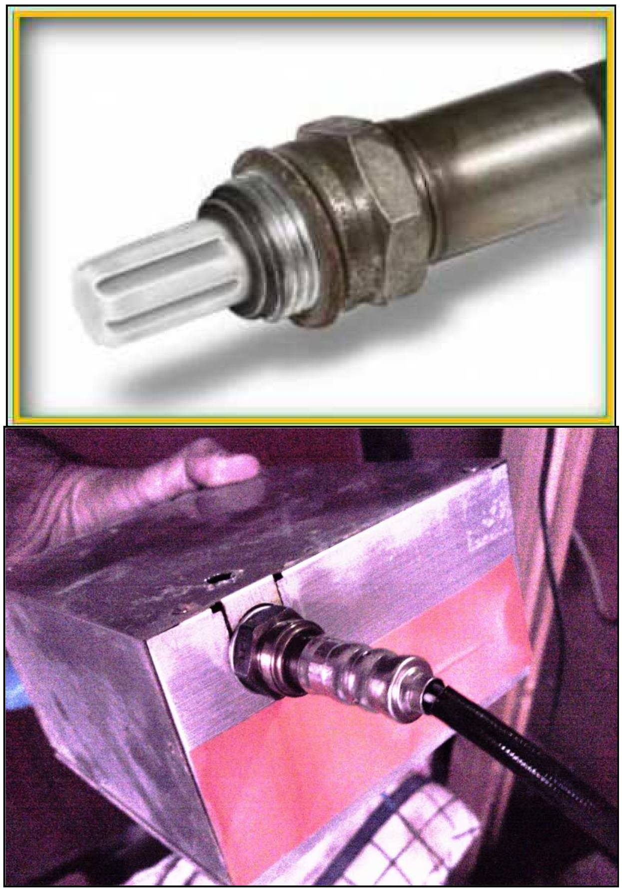

Fig. 3 A car O_2 sensor and a power supply unit for holding it

The zirconium dioxide, or zirconia, lambda sensor (Figure 3) is based on a solid-state electrochemical fuel cell called the Nernst cell. Its two electrodes provide an output voltage corresponding to the quantity of oxygen in the exhaust relative to that in the atmosphere [10].
The O_2 sensor is available in most modern cars. After the 80's of the previous century most cars exhaust systems are equipped with oxygen sensors. The oxygen sensor monitors the car emission and feedbacks a signal to the car controller to reduce emission and improve performance.
Here we are using the sensor to measure the relative amount of oxygen in the air. The power supply fan draws air and pumps it inside the power supply to be analyzed by the oxygen sensor and give a voltage relative to the amount of the air inside the power supply chamber.

5.3 The USB Interface Board

A USB card that has two analog input ports has been used. The two ports are used for reading the sensor instantaneous signal value. The driver of the USB card allows engaging it to the C# program through special function calls provided by the USB card designer. The cost of the used card is about 45 USD.

5.4 The Software Module

The software module is a C# based program that reads the sensors data and monitors them in a continuous way. The data are shown in an easy to read window (Figure 4). It also logs the sensors readings into two text files (CO1 and CO2 text files) in a directory with the name "log". CO1 is used for carbon monoxide and CO2 for oxygen.
The window (Figure 4) contains four text boxes that are used to show the oxygen sensor reading, the instantaneous MQ7 reading, the peak values for the MQ7 sensor and the average of these peaks (respectively top to bottom).

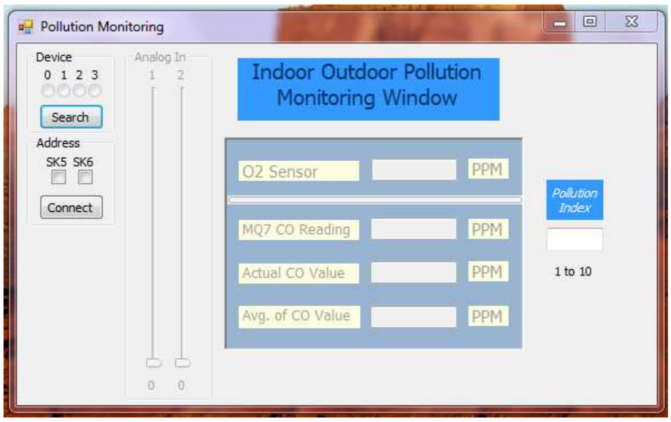

Fig. 4 Indoor-Outdoor pollution monitoring window

The program stores the readings, the time and the date of the reading in a comma delimited text file. The content of the text file could be easily converted to graphs through the use of MS-Excel.
For the MQ7 sensor an algorithm that tracks the MQ7 instantaneous sensor value to get the maximum value is written. The actual value of the CO gas could be deduced from these values after multiplying it by a factor and then showing them in the text box with name "Actual CO value".
The "Avg. of CO Value" text box shows the average of these peaks till the average deviate from the maximum by 15%. The purpose is to add a filtration process for the peak values that are close to each other.

6. Outdoor Monitoring

As the oxygen sensor is installed in a metal case power supply unit and it's a heavy duty sensor designed to be used in cars exhaust system, it could be used for both outdoor and indoor oxygen gas levels monitoring.

The CO alarm is an indoor device and it's not designed to be used for outdoor CO gas monitoring, hence to tackle this problem outdoor air has to be pumped close to the sensor if outdoor monitoring is desired. To achieve this, a cheap aquarium pump is used to pump outside air to inside the alarm if outside air monitoring is required (Figure 1 shows the tube taken from the aquarium pump to feed air to inside the alarm).

7. Results and Discussions

The system has been tested to measure the amounts of CO and O_2 gases in indoor and outdoor environments. As a start we begin our analysis with outdoor gas monitoring and consider carbon monoxide gas. Figure 5 shows the sensor voltage values with time.

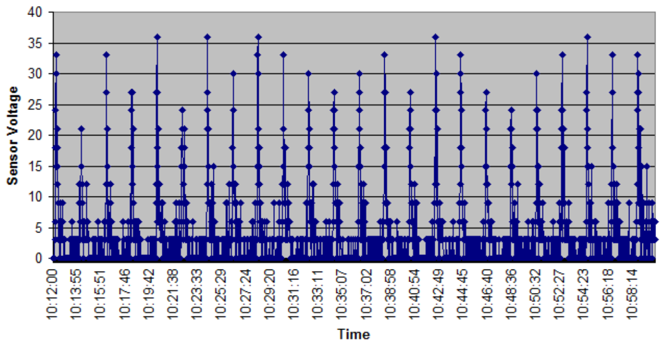

Fig. 5 Carbon monoxide level in outdoor environment

It's clear from the figure that the majority of the values are in the range of 30 to 36. These values are the peak values for the MQ7 sensor output voltage and represents CO gas concentration. In Figure 6 we have the same timestamp but for indoor carbon monoxide gas levels (1st floor of a two floor house, time is summer and inside temperature is about 29 C).

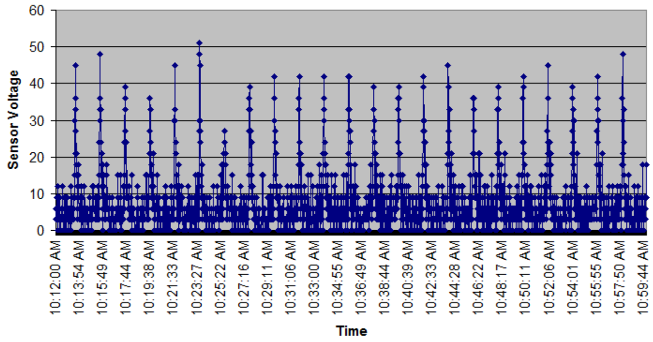

Fig. 6 Carbon monoxide level in indoor environment

In this case it's clear from the figure that the majority of peak values are in the range of 41 to 51. By comparing both figures we can deduce that CO concentrations are higher at the indoor environment than the outdoor environment. Taking the fact that the time is summer and the readings have been taken on the start of June and no Kerosene heaters were used. Results from the two figures indicate the applicability of the system for both outdoor and indoor carbon monoxide gas level monitoring, as it indicates CO gas levels variations between outdoor and indoor readings for the same timestamp.

Another CO levels comparison for another timestamp are shown in Figure 7 and Figure 8, respectively. Comparison clearly indicates higher CO levels at indoor and the applicability of the design for both indoor and outdoor CO gas levels measurements.

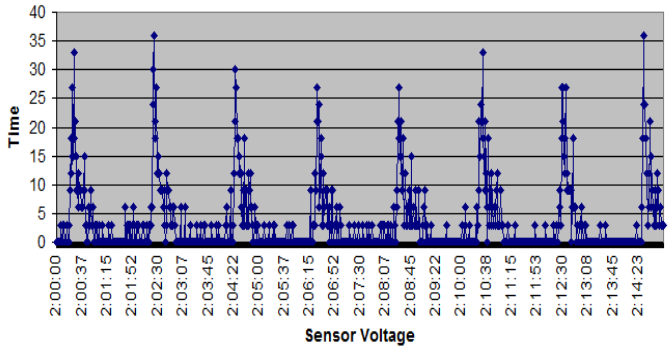

Fig. 7 Carbon monoxide level in outdoor environment, other timestamp

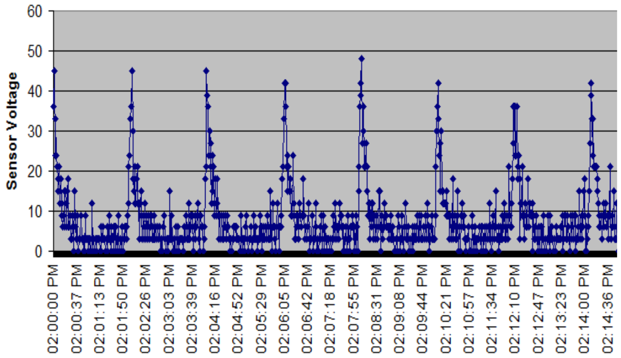

Fig. 8 Carbon monoxide level in indoor environment, other timestamp

For oxygen gas levels measurements, Figure 9 shows the sensor readings for outdoor and indoor as they are imposed on the same graph.

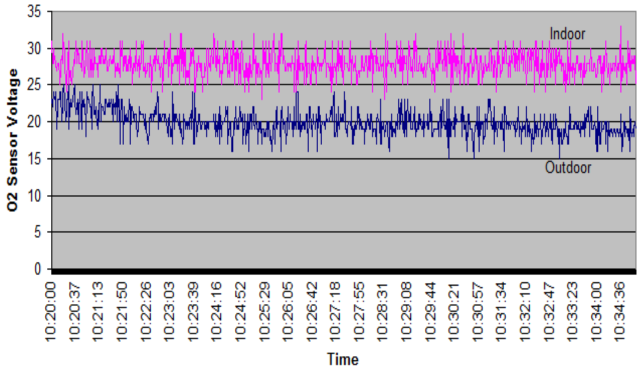

Fig. 9 Oxygen gas levels in indoor and outdoor environments

The figure indicates that oxygen level concentrations are higher at outdoor and lower at indoor. The lower the O_2 sensor voltage is, the higher the oxygen gas levels is. The outdoor part indicates the variation in oxygen gas levels with time but it's not the same for the indoor environment, and this seems rather logical as the indoor environment is closed and less liable to oxygen gas levels variations for this short period of time.

8. Conclusion

In this work commonly available sensors are used to achieve indoor and outdoor pollution monitoring. Two gases are considered, oxygen and carbon monoxide. By having values of these gases an index on pollution amount has been generated. The higher amount of oxygen and the less amount of carbon monoxide means the least amount of pollution, and the less amount of oxygen and the higher amount of CO means higher pollution values.

The simplicity of the approach in using commonly available sensors and tools makes it applicable in wide application areas. The cost of the complete unit that enables computer based monitoring is in the range of 100 to 150 USD and this is a reasonable amount of money for having a computer based monitoring and analysis system. The cost effectiveness of the approach allows expanding the project by having multiple sensing units in different areas to create a number of pollution monitoring nodes.

References

[1] Mohammed A. Hussein, "Design and implementation of a cost effective gas pollution detection system", in CCCE'12, July 3-5, 2012, pp. 7-12.

[2] Mohammed A. Hussein, "Using inexpensive home alarm for computer based carbon monoxide monitoring", Asian Transaction on Engineering, ISSN: 2221-4267 Vol. 2 Issue 2, May 17, 2012, pp. 1-6.

[3] Emil Cordos, Ludovic Ferenczi, Sergiu Cadar, Simona Costiug, Gabriela Pitl, Adrian Aciu and Adrian Ghita, "Methane and carbon monoxide gas detection system based on semiconductor sensor", in IEEE International Conference on Automation Quality and Testing, 2006, pp. 208-211.

[4] Ming Zhu, Shu Wang, Shu-Tao Wang, Dong-Hai Xia, " An algorithm for carbon monoxide concentration detection based on molecular multi-relaxation model", in Proceeding of the 2007 International Conference on Wavelet Analysis and Pattern Recognition China, Nov. 2-4, 2007, pp. 332 – 337.

[5] M. Mello, A. DeRisi, A. Passaseo, M. Lomascolo and M. DeVittorio, "Carbon monoxide real time monitoring in combustion engines by an optical detection system", Ph.D. Research in Microelectronics and Electronics, ISBN 1424401577, 2006, pp. 433-436.

[6] M. L. Homer, A.V. Shevade, H. Zhou, A. K. Kisor, L. M. Lara, S.-P.S. Yen and M.A. Ryan, "Polymer based carbon monoxide sensors", in IEEE Sensors 2010 Conference, 2010, pp. 1504-1508.

[7] Wataru Tsujita, Hiroshi Ishida and Toyosaka Moriizumi, "Dynamic gas sensor network for air pollution monitoring and I's auto-calibration", IEEE, 2004, pp. 56-59.

[8] Marius Branzila, Carmen Alexandru, Cristian Ciobanu and Cristina Schreiner, "New DAQB and associated virtual library included in LabVIEW for environmental parameters monitoring", in IEEE International Conference on Virtual Environments, Human-Computer Interfaces, and Measurement Systems, Istanbul, Turkey, 14-16 July 2008, pp. 121-124.

[9] "MQ7 data sheet," MQ7 Gas Sensor, HANWEI, China.

[10] Bosch Oxygen Sensors, Service Tech Magazine, May 2001, Retrieved from http://wbo2.com/lsu/oxygen13-17.pdf.

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