Air Quality Arduino Based Monitoring System

Abdullah J. Alabdullah, Badr I. Farhat, Slim Chtourou
King Faisal University, College of Engineering, Electrical Engineering
(214014181@student.kfu.edu.sa, 217044896@student.kfu.edu.sa, slim.chtourou@ieee.org)

***Abstract*— Air quality is a very important health factor. However, there are situations where humans are exposed to poisonous air that has a high concentration of Volatile Organic compounds (VOC), especially indoor environments such as car cabins and offices. It is important for a better health to breathe clean air that has low concentrations of VOC.**

This paper presents a design for a system that aims to notify the residents of VOC's concentration level in both indoor and outdoor environments. The system is Arduino-based, it will monitor and detect total volatile organic compounds (TVOC) and then inform the user via wireless communication system of its levels to take actions.

Keywords: Air Quality, TVOC, Monitoring, Arduino, Bluetooth, sensors

I. INTRODUCTION

Air quality is a major concern for everyone. A survey conducted on 300 people from Saudi Arabia and Oman showed that 64% of people spend between 2-3 hours a day in car's cabins. However, most people do not pay attention of air quality in such places. There are many evidences supporting that the indoor environment's air can be a lot more polluted than the outdoor air even in large industrialized cities [1]. Volatile Organic Compounds (VOC) could be found in concentrated quantities indoor and outdoor. These compounds are very harmful and are easily absorbed by the skin and mucous membranes. That will cause damage to the human's organs and the metabolic system. In addition, some VOCs are related with Sick Building Syndrome (SBS). The United States Environmental Protection Agency (U.S.EPA) estimated that VOC levels in indoor air are typically 5-10 times higher than VOC levels of outdoor air [2]. According to World Health Organization (WHO), polluted air indoor is a major threat to human's health [3].

II. OVERVIEW OF THE PROBLEMATIC

A. VOC and pollutant compounds in closed places and their Sources

There are two main causes leading to poor air quality inside closed places.

i. The existence of VOCs emission sources such as interior materials and indoor materials.

ii. Poor ventilation system, which could highly increase the VOC level inside closed places due to Poor air Exchange Rates (AER) [1, 2].

1) Interior materials

It was found that large amount of VOCs are resulting from the interior and decorative materials indoor.

Table 1 shows a list of some VOCs and their potential sources [2].

Table. 1. Potentital sources of VOC

Potential sources	VOC name
Pesticides	Formaldehyde, Toluene, Chloroform, Paradichlorobenzene
flooring materials,	Formaldehyde, Toluene, Acetaldehyde, Methylene chloride, Chloroethylene
insulating materials,	Formaldehyde, Toluene, Naphthalene
wood-based materials	Formaldehyde, Toluene, Acetaldehyde, Paradichlorobenzene
coatings and paints	Formaldehyde, Methylene chloride, Chloroethylene
adhesives,	Toluene, Ethylbenzene, ketones, esters
gasoline,	Toluene, Ethylbenzene
Glue	Chloroform
Plastics,	Ketones, esters

2) Indoor sources

Newspapers, magazines and books that are left in the place are sources for C_8 aromatics. In addition, dry-cleaned clothes and deodorants are main sources of chlorinated hydrocarbons. Furthermore, tobacco smoke is an important source for VOC emission. Quinones, aromatics, carbonyls, polycyclic Aromatic hydrocarbons (PAHs) are chemical species that were found in cigarette gasses [2,4]. Another source is human metabolism. Acetaldehyde, aldehydes, methanol and Acetone are detected in the respiratory air [2,5]. Table 2 shows some VOC and their potential sources [2].

Table . 2. Potentital sources of VOC

Sources	VOC name
Newspapers, magazines and books	C8 aromatics
Dry-cleaned clothes and deodorant	chlorinated hydrocarbons
Tobacco smoke	Quinones, aromatics, carbonyls, polycyclic Aromatic hydrocarbons

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3) *Other sources*

VOCs are not only emitted from indoor sources. They also come from surrounding environment. The most important outdoor sources of VOC are cars exhausts. Even though cars with alternative fuels such as electric cars are invented to reduce pollutant generation, the oxygenated VOC from the cars exhausts is still exist as the number of cars is increasing [2,6,7]. Benzene, Toluene, Methanol, Aromatics, MTBE, Paraffines and Olefins are some VOCs that are released from the car exhausts [8].

B. *Concentration*

World Health Organization considers air inside a car cabin a major threat to human's health because of the high level of VOCs and other compounds in it. It was found that a total of 242 organic compounds in the indoor air inside the cars cabin. Their concentrations may differ from car to another due to some factors. However, the average concentration was approximately 600ug/m3 which exceeds the acceptable limit[9,3]. Xylenes, toluene and benzene concentrations that were found in a car were much higher than the acceptable limits that was set by Chinese Indoor Air Quality (IAQ) standers.[3]. The following table shows concentrations of VOCs were found in a car [3].

Table . 3. concentrations of VOCs were found in a car

VOC	Concentration in ug/m3
Airborne benzene	128.7,
Toluene	320.2
Ethylbenzene	115.9
P-xylene	180.3
M-xylene	103.6
O-xylene	39.5
styrene butyl acetate	52.3
undecane	83.6
TVOC	2253.5

The concentration limitations for some compounds are as follows:

i. Formaldehyde (Residential indoor air guideline [11].
  - For one hour: 123 µg/m3 (100 ppb)
  - For eight hours: 50 µg/m3 (40 ppb)

ii. Toluene (Residential indoor air guideline [12].
  - For eight hours: 15 µg/m3 (4 ppb)
  - For twenty four hours : 2.3 µg/m3 (0.6 ppb)

iii. Total VOCs (Office buildings guideline) [13,14].
  - Comfort range < 0.2 mg/m3
  - Multi-factoral range : 0.2-3.0 mg/m3
  - Discomfort range : 0.3 – 25 mg/m3
  - Toxic range : 25 mg/m3

C. *Relationship between the heat and the VOC level*

As it well known, the interior temperature of closed places such as a car can be more than the ambient temperature. Glass allows sunlight to pass through freely. Once inside the car, much of the light is absorbed by the seats and dash turning it into heat. Heat does not easily pass back through glass, so it is trapped inside the car. A parked car will always end up hotter than the air around it—usually much hotter.

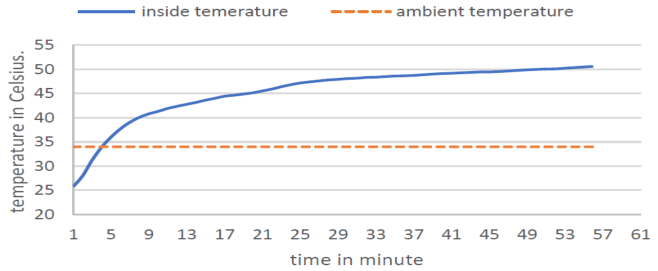

Fig. 1. Temperature inside a corolla VS ambient temperature

Over time, the interior temperature will be higher than the ambient temperature. The increase of heat will be a catalyst for the interior materials to emit more VOCs.

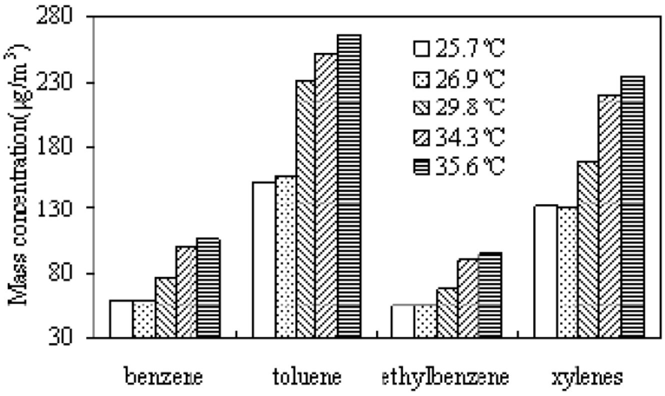

Fig. 2. the effect of increasing temprarure on the TVOC relase [3]

D. *Health effects*

The health effects of VOCs and other compounds can be classified into two categories based on the period.

i. Short-Term Health Effect:

Headaches, sickness, atopic dermatitis, dizziness, sleepiness, eyes irritation, skin irritation and sick building syndrome [10].

ii. Long- term health effect:

Nasal tumors, leukemia, asthma, nasopharyngeal and reduce of pulmonary function [10].

All of these negative effects happen because of contamination of the indoor air.

The Monoxide (CO) can cause discomfort, poor hand – eye coordination, fatigue and drowsiness. According to the Australian National Occupational Health and Safety Commission (NOHSC) exposure standard for CO level is 30 PPM time weighted average over an 8-hour period [15].

The Carbone dioxide (CO_2) causes fatigue, drowsiness, slow reaction of actions. According to the Department of Occupational Safety and Health Malaysia (DOSH) the acceptable limit of Carbone dioxide should be kept below 1000 PPM [16].

The Benzene causes headaches, dizziness, drowsiness, confusion and loss of consciousness. In addition, eyes and skin irritation. According to International Agency for Research on Cancer (IARC) benzene is a well-established cause of cancer in humans. In addition, the exposure to benzene can reduce the production of red and white blood cells. Which results in aplastic anemia. According to World Health Organization (WHO), there is no safe level to benzene exposure. However, the concentration of airborne benzene that are related to an excess lifetime risk of leukemia of 10^{-4}, 10^{-5} and 10^{-6} are 17, 1.7 and 0.17 ug/m^3 respectively [17].

The formaldehyde causes irritation of the eyes, nose and throat. Asthma, damage to the lining of the nose and throat, nose and throat cancer. According to the Department of Health and Human Services (DHHS) and the International Agency for Research on Cancer (IARC) considered formaldehyde as a human carcinogen [18].

III. SOLUTION IMPLEMENTATION

A simple solution to the problem is to implement an air quality monitoring system whether it is indoor or outdoor. The sole purpose of the system is to notify the user of the abnormal increase in the above-mentioned parameters whether it is an increase in Temperature, CO2, TVOC, or all of the parameters at once. The design of the system is presented in Figure 3.

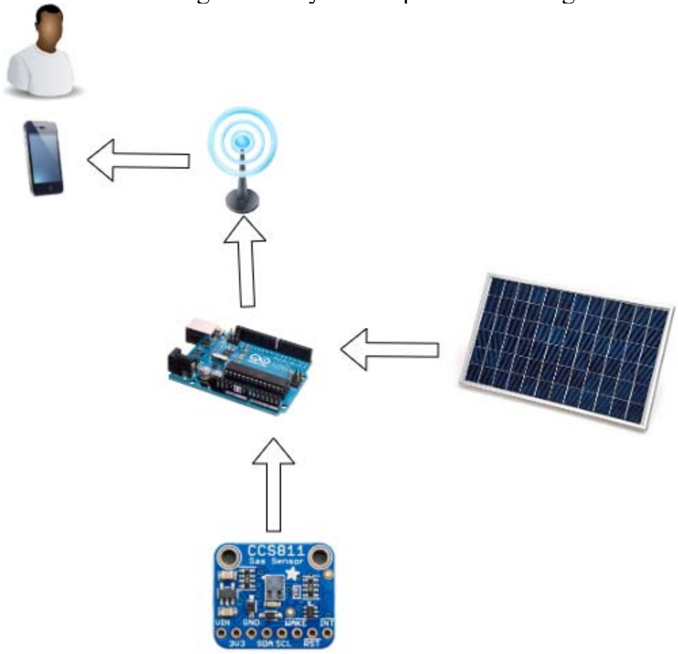

Fig. 3. Overview of the prototype to develop

The system is composed of a 12v solar panel to power up the Arduino. We are going to use a voltage regulator to bring the voltage down to 5V. A multi-function sensor (CCS811) will detect temperature, CO2 and TVOC.

A. Sensore configuration

we are using CSS811 air quality sensor which has eight pins. To connect it to the Arduino we are going only to use 5 pins which are Vin pin which is power supply pin and the GND which is used to ground the sensor with the circuit. We can use either 3.3V or 5V ,SCL I2C clock pin (3-5 V) connected to SCL pin in the Arduino ,SDA I2C data pin (3-5 V) connected to SDA pin in the Arduino, GND pin which needs to be connected to common power/data ground and WAKE wakeup pin for the sensor (3-5V) which is connected to the ground in Arduino. It's recommended to run this sensor for 48 hours when you first receive it to "burn it in", and then 20 minutes in the desired mode every time the sensor is in use. This is because the sensitivity levels of the sensor will change during early use.

B. sketch supporting information

After the connection is done, we need to install the sketch into the Arduino IDE software to upload the sketch in the Arduino. It must be noted that we need to install external library called Adafruit_CCS811 library to be able to use the sketch. First of all, we must initialize the serial connection at 9600 bits per second using ***Serial.begin(9600)***. Second, we need to calibrate temperature sensor using ***float temp = ccs.calculateTemperature().*** Then, we can return the TVOC and CO2 using Serial.print***(ccs.getTVOC())*** and ***Serial.print(ccs.geteCO2())***

C. Reading using serial monitor PC

By using serial monitor feature in the IDE software, we can see the readings directly if there is no need to transmit it for a long distance.

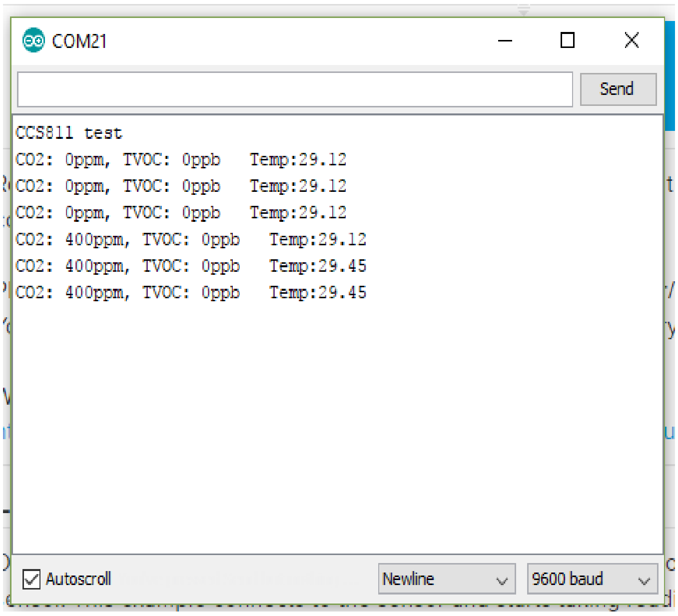

Fig. 4. sensor readings via serial monitor

D. Readings using Bluetooth module

The Arduino will process the readings from the sensor. Then, it will send the data to the user via Bluetooth. The data can be seen on a smartphone, using for example the Bluetooth Terminal HC-05 software.

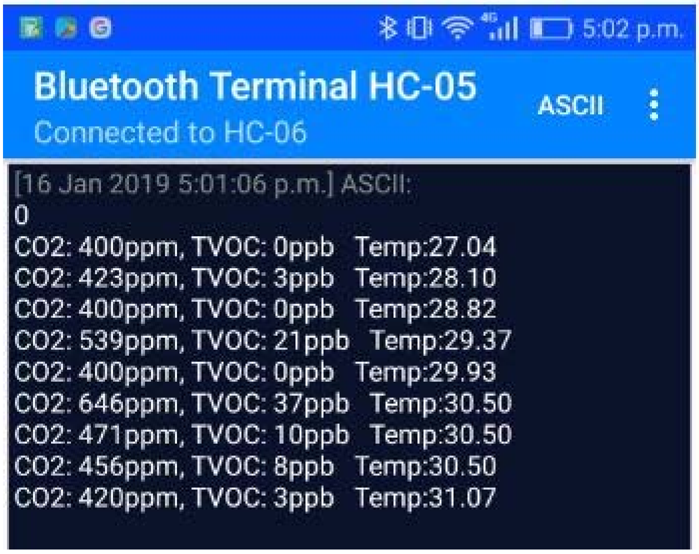

Fig. 5. Data shown to the user by Bluetooth Terminal HC-05

IV. EXPERIMENTAL RESULTS

The first experiment was conducted indoor to observe the change of the CO2 level changes in the atmosphere. The device was switched on and left inside an unoccupied office with a volume of 25.2m^3 for approximately 30 minutes. As seen in figure 5, the CO2 level remains constant at 400 PPM. After 30 minutes, the office was occupied with two persons. After occupying the room, the CO2 level began to increase proportionally with time. After approximately 74 minutes, the CO2 level has reached 1000PPM, the maximum acceptable range of CO2 recommended by DOSH Malaysia [16].

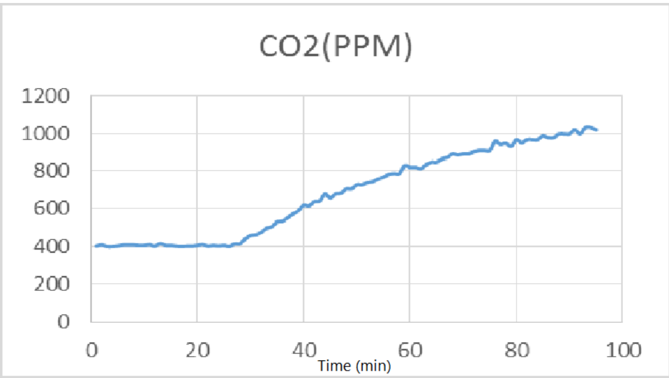

Fig.6. CO2 measurements indoor

The second expriment was conducted both indoor and outdoor to observe the TVOC level changes. For the indoor observation, the TVOC monitoring device was held inside an unoccupied office with a volume of 25.2m^3. the device was switched on and left insdie the unoccupied office for approximately 30 minutes as seen in figure 6 the TVOC level remained zero. After 30 minutes, the office was occupied with two persons and the TVOC level began to increase rapidly. At approximately 75 minutes have passed, the TVOC level has reached approximatley 100 PPM. As for the Outdoor readings of the TVOC levels, the experiment was conducted at Jawatha Park. The first observation in the outdoor TVOC levels, it is never zero (typically). The second observation is that the levels of TVOC are fluctuating.

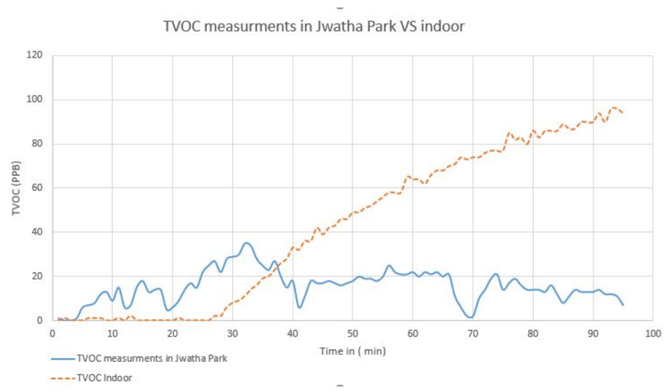

Fig.7. TVOC measurements indoor/outdoor.

V. CONCLUSION

Air quality is an increasingly alarming issue, especially in Gulf countries. Harmful TVOC exist heavily in indoor places such as cars cabins and office and even in outdoor places such as parks. By using an Arduino based TVOCs detection system, we can know the level of TVOC indoor/outdoor. This will help in improving human's health. The system will send TVOCs level in real time to the user so that he can take actions based on the readings.

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