# Oak Ridge Air Quality Index Computation : a way for Monitoring Pollutions in Annaba City

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**Abstract:** *AQI (air quality index) with a microcontroller have been designed for air quality monitoring in some sensible area in Annaba City East of Algeria. The previous design computes IAP (index of atmospheric purity) at central unit due to processing speed of the microcontroller, However the new design is based on DSPIC-30 as micro-system. The computation of AQI is done on the node in order to reduce transmission data to central unit. The nodes were tested in three main zones where AQI are quite different. We have taken dust, and three major gazes origin in air pollution (Co, NO2 and LPG) to compute AQI, the computation is done on site by microcontrollers based on AQI computation equations.*

*In this work we covered the field of Air quality monitoring electronic Nodes design and wireless transmission of fusion data. The GUI has been designed for simulation of the WSN in controlling the environment air Quality.*

**Keywords:** *Pollution Sensors, air Quality Index, Environment Monitoring, wireless sensor Network*

## 1. Introduction

The lichen bio-estimation of the air pollution remains substitute and sometimes complementary means to the physical sensors [1] and [ 2]. Of all the methods of studies on the bio-estimation of the air pollution by the lichen flora there is no justification choice of one method over another. The consultation of the previous works realized by Hawksworth [3] and Van Haluwyn [4] allowed to us to compare them and methods to better understand their advantages and their limits. These various approaches contribute to the estimation of air pollution index. However these techniques need to be done in the laboratory which takes time to get results.

Wireless Sensor Networks (WSNs) technology [4] is in the front part of the investigation of the computer networks and it could be the next technologic market of with huge sum of money in investment. Sensor nodes can be fixed or mobile, they have limited processing power, storage, bandwidth, limited wireless transmission range and energy powered by battery. This limitation makes provision of the security in sensor networks not an easy task [4].

Sensor networks may consist of different types of sensors [5] such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of environment situations [5] such that: temperature, humidity, air quality, vehicular movement, lightning condition, soil makeup, noise levels, the presence or absence of certain kinds of animals or objects, mechanical stress levels on attached motors, and the current characteristics such as speed, direction, and size of a vehicle. A sensor node is made up of four basic components [5] as shown in Figure 1.a : a sensing unit, a processing unit, a transceiver unit and a power unit.

In this paper, we propose to use a WSN based microcontroller equipped with gas sensors which are actively used for air quality monitoring. The design included several units mainly: DSPIC-30 Microcontroller, MQ-2 Gas Sensors, and the current regulator circuit. The paper is organized as follow: in second paragraph after introduction we define primary pollutants, in paragraph three, we present the hardware proposition design with main components. In section 4, format and communication with the special sensor DHT21 is illustrated, then we finish the paper by presenting results, discussion of simulation and conclusions in section 5 and 6 respectively.

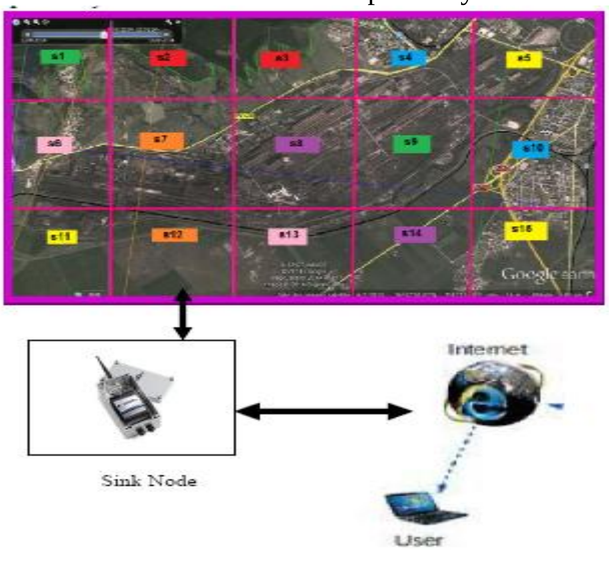


Figure 1.a: The Hardware Design Schematic Diagram.

## 2. Pollutants

Primary pollutants are those in which the substance emitted is itself hazardous. Some primary pollutants also produce other dangerous substances after undergoing chemical reactions in the atmosphere, and these are known as secondary pollutants. Main primary pollutants to control include the following substances as mentioned in [15]:

*Particulates matter (PM):* This includes dust, smoke, aerosols and haze - any finely divided airborne solid material. Particulates are commonly generated by fires, motor vehicles, some industries (particularly road building, quarries and fossil fuel power stations) and various natural sources including volcanoes, plant and animal matter and dirt. Particulates are aesthetically displeasing, can irritate the eyes and cause respiratory problems. In recent years concerns have been raised about the possible health effects of 'fine' particulate matter (less than 10µm diameter).

*Sulphur dioxide, SO2 :* Sulphur dioxide is often produced by the industrial processes which produce particulates, the primary sources of SO2 being coal, fuel oil and diesel. It can cause respiratory problems.

*Carbon monoxide, CO :* The commonest source of carbon monoxide is motor vehicle emissions, where it results from the combustion of petrol in the presence of insufficient oxygen. It is also a result of some fuel-consuming industries and domestic fires. Carbon monoxide is a colorless, odorless, highly toxic gas that displaces oxygen in human blood, causing oxygen deprivation.

*The oxides of nitrogen, NOx :* NOx refers to the mixture of nitric oxide (NO) and nitrogen dioxide (NO2) formed by the oxidation of nitrogen during the combustion of air. NOx is a contributor to several secondary pollutants, and NO2 is a respiratory irritant that can also corrode metals at high concentrations.

## 3. Air Quality Index (AQI) Computation Methods

Each hour, an air quality index is calculated on the basis of the following five pollutants: ozone, fine particulate matter, sulfur dioxide, nitrogen dioxide and carbon monoxide [17].

For each of the pollutants measured at an air monitoring station, a sub-index is calculated first. The sub-index is calculated by dividing the concentration of a pollutant monitored by its corresponding reference value and multiplying the result by 50. A pollutant's reference value is the concentration at which air quality is considered "poor". This value is determined on the basis of criteria to protect human health.

The results of the highest sub-index are then used as the air quality index for that station. Not all pollutants have to be monitored at one station to calculate the AQI. The following is an example of a calculation where ozone, particulate matter and sulfur dioxide are measured.

Example of AQI calculation

Sub-index $O_3$ = (90 ppb / 82 ppb) X 50 = 55

Sub-index PM = (51 $\mu g/m^3$ / 35 $\mu g/m^3$) X 50 = 73

Sub-index $SO_2$ = (49 ppb / 200 ppb) X 50 = 12

The air quality index is the highest of the sub-indices:

*AQI = 73*

The AQI for a region or city is based on the highest of the air quality indices measured at representative stations in the area.

The AQi is computed within the node as follow:

$$AQI = maxi(\text{ Sub-index } O_3, PM, SO_2, NO2) \quad (1)$$

*A. . AIR QUALITY Indices in the Literature*

*A1. Green Index (GI)[19]*

One of the earliest air pollution indices to appear in literature was proposed by Green (1966). It included just two-pollutant variables - SO2 and COH (Coefficient of Haze). The equations to calculate the subindices were: $ISO2 = 84 * X0.431$

$ICOH = 26.6 * X0.576$

Where :

ISO2 = Sulphur dioxide sub-index

ICOH= Coefficient of Haze Sub-index

X = Observed pollutant concentration

The Green Index is computed as the arithmetic mean of the two sub-indices: $GI = 0.5 * (ISO2 + ICOH)$ (2)

*A2. Fenstock Air Quality Index (AQI)*

Fenstock (1969) proposed an index to assess the relative severity of air pollution and applied it to assess AQI of 29 U.S cities. This was the first index to estimate air pollutant concentrations from the data on source emissions and meteorological conditions in each city: AQI = Wi Ii

Where : Wi = weightages for CO, TSP and SO2

Ii= estimated sub-indices for CO, TSP and SO2

This index is applicable to square urban area with wind always parallel to one side for uniform meteorological conditions under neutral stability with continuous source distributed uniformly. This AQI is not used for daily air quality reports but for estimating overall air pollution potential for a metropolitan area.

*A3.Ontario API*

Shenfeld (1970) developed Ontario Air Pollution Index in Canada. This index was intended to provide the public with daily information about air quality levels and to trigger control actions during air pollution episodes. It includes two pollutants variables:

$$API = 0.2 (30.5 COH + 126 SO2) 1.35 \quad (3)$$

*A4. Oak Ridge Air Quality Index (ORAQI)[21]*

Oak Ridge National Laboratory published the ORAQI in 1971. It was based on the 24-hour average concentrations of the following five pollutants:

SO2, NO2, PM, CO, Photochemical Oxidants.

The sub-index is calculated as the ratio of the observed pollutant concentration to its respective standard. As reported by Babcock and Nagda (1972), the ORAQI aggregation unction was a non-linear function:

$$ORAQI = \{5.7 \Sigma I_i\}1.37 \qquad (4)$$

where, $I_i = (X/X_s)i$

X = Observed pollutant concentration

Xs = Pollutant Standard

I = Pollutant

*A5. Greater Vancouver Air Quality Index (GVAQI)[20]*

The GVAQI is based on Canadian Federal Government air quality objectives that are designed to protect public health and environment. The index includes the following pollutants:

SO2, NO2, O3, TSP, COH, PM10

GVAQI values are divided into ranges. The federal Desirable, Acceptable and Tolerable air quality objectives levels are assigned GVAQI values of 25, 50 and 100 respectively. Intermediate values can be obtained by extrapolation. Each range is associated with descriptor categories.

The overall GVAQI value is determined by calculating a sub-index for each pollutant measurement and averaging time. Each sub-index is calculated by straight-line extrapolation of the break point concentrations corresponding to GVAQI values of 25, 50 and 100 respectively, which are shown in Table 2. The maximum sub-index is reported as the GVAQI, based on the assumption that the combined effect of a number of air pollutants is related to the highest concentrations relative to air quality objectives. The particular pollutant responsible for the maximum Sub-Index is called the "Index pollutant". It is reported with the GVAQI when the index value is greater than 25. Each GVAQI range is associated with descriptor categories, general

health effects and cautionary statements.

TABLE 1.Break point concentration for GVAQI

| Index | $SO_2$ 24-hr (ppm) | CO 8-hr (ppm) | $NO_2$ 1-hr (ppm) | $O_3$ 1-hr (ppm) | TSP 24-hr ($\mu g/m^3$) | COH 1-hr (units) | $PM_{10}$ 24-hr ($\mu g/m^3$) | Descriptors |
|---|---|---|---|---|---|---|---|---|
| 25 | 0.06 | 5 | 0.105* | 0.051 | 60 | 1.7 | 25* | Good |
| 50 | 0.11 | 13 | 0.21 | 0.082 | 120 | 4 | 50 | Fair |
| 100 | 0.31 | 18 | 0.53 | 0.153 | 400 | 6 | 100 | Poor |

## 4. Hardware description

The complete system design is shown in figure 1.b Hardware Design Schematic Diagram. The design include the following major hardware components:

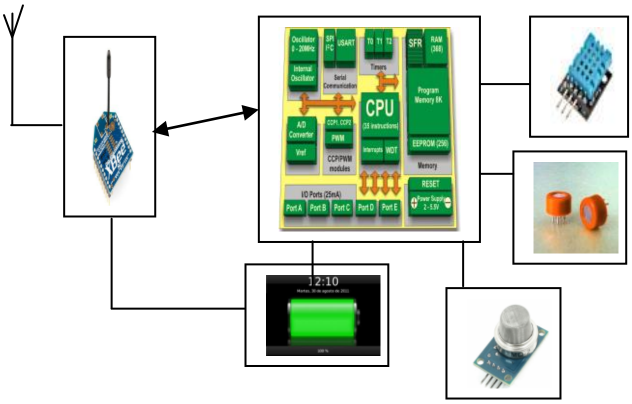


Figure 1.b: Sensor Node main Components

*A. DSPIC-30 Microcontroller* [7]: it is a High Performance Modified RISC CPU with the following main characteristics :

- C compiler optimized instruction set architecture with flexible addressing modes
- 84 base instructions
- 48 Kbytes on-chip Flash program space (16K Instruction words),• 2 Kbytes of on-chip data RAM
- 2 UART modules with FIFO Buffers
- 1 CAN modules, 2.0B compliant ,Motor Control PWM Module Features

*B. MQ-135 GAS Senor [3]* Breakout Board: MQ-135 is one of the series of semiconductor Gas Sensors that is used mainly for gas (such as CO) leak detection for houses, workshops, commercial building, Fire, Safety detection system as well as a gas leak alarm.

This sensor module utilizes an MQ-135 as the sensitive component and has a protection resistor as mentioned in figure 3 and an adjustable resistor on board. The MQ-135 gas sensor is sensitive to LPG, i-butane, propane, methane, alcohol, Hydrogen and smoke. It could be used in gas leakage detecting equipments in family and industry. The resistance of the sensitive component changes as the concentration of the target gas changes.

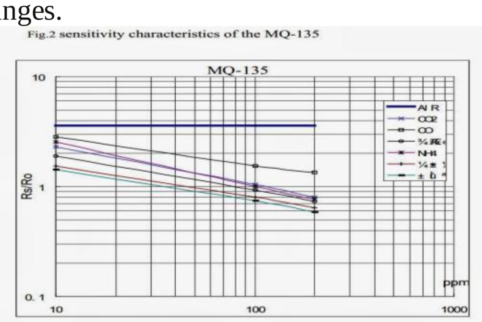


Figure 2.a: shows the typical sensitivity characteristics of the MQ-135 for several gases. in their: Temp: 20_ _
Humidity: 65%_ O2 concentration 21% RL=20kΩ Ro: sensor resistance at 100ppm of NH3 in the clean air.
Rs:sensor resistance at various concentrations of gases.

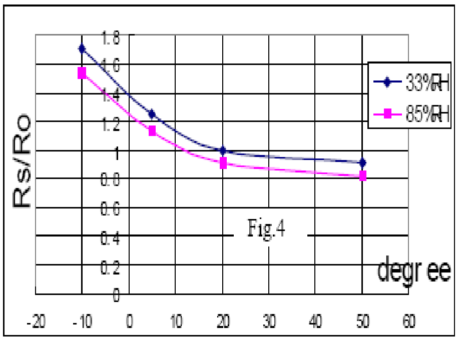


Figure 2.b shows the typical dependence of the MQ-135 on temperature and humidity.
Ro: sensor resistance at 100ppm of NH3 in air at 33%RH and 20 degree.
Rs: sensor resistance at 100ppm of NH3 at different temperatures and humidities.

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*C.. MiCS-2710 $NO_2$ Sensor[18]:*

The detection of nitrogen dioxide (NO2) gas is done using this type of sensors. The recommended mode of operation is a constant power mode. A heater power of Ph = 43 mW is applied. This causes the temperature of the sensing resistor (Rs) to reach about 220 °C. A simple circuit to measure the pollution level is proposed in Fig. 3. The heating voltage Vh is applied to pins 3 and 1. A load resistor Rl is connected in series with Rs to convert the resistance Rs to a voltage Vs between pins 2 and 4. Rs can then be calculated by the following expression:

$$Rs = Rl/(Vcc - Vs) \times Vs \qquad (2)$$

Detection of the pollution gases is achieved by measuring the sensing resistor $R_S$ during operation.

*D. Temperature and Humidity sensor DHT21*

Due to the effect of humidity and temperature on calibrating of gas sensors MQ-2 and MQ-135 as shown in figure 2.a and 2.b, we added temperature and humidity sensor the DHT21. DHT21 and DHT22 are relative cheap sensors for measuring temperature and humidity. In reference [6] and [7] there is a description of library for reading both values from these sensors. we contacted the manufacturer to get the details of the differences between the two DHT sensors to build a lib that supports both. The DHT21/22 is quite similar to the DHT11 however it has a greater accuracy (one decimal) and range (negative temperatures). The hardware pins and handshake are identical but it uses a different data format.

Data consists of decimal and integral parts. A complete data transmission is 40 bit, and the sensor sends higher data bit first.

*E.. Trasmission module*

Based on Zigbee protocol, the Xbee modules are used in transmission and reception, they are also used as gateway node to provide data to the central unit.

The gateway node uses two Xbees modules one for reception from different nodes and the other for retransmission of the collected data to the end-user i.e central unit. The Xbee modules are programmed to communicate on same cannel as other Xbees on nodes using XCTU software.

*X-CTU software*: XCTU is a free multi-platform application designed to enable developers to interact with Digi RF modules through a simple-to-use graphical interface. It includes new tools that make it easy to set-up, configure and test XBee® RF modules. XCTU includes all of the tools a developer needs to quickly get up and running with XBee. Unique features like graphical network view, which graphically represents the XBee network along with the signal strength of each connection, and the XBee API frame builder, which intuitively helps to build and interpret API frames for XBees being used in API mode, combine to make development on the XBee platform easier than ever. Figure 3.b illustrate the configuration of Xbee module using X-CTU software.

Figure 3.b: Transmission-reception using Module ZigBee protocol

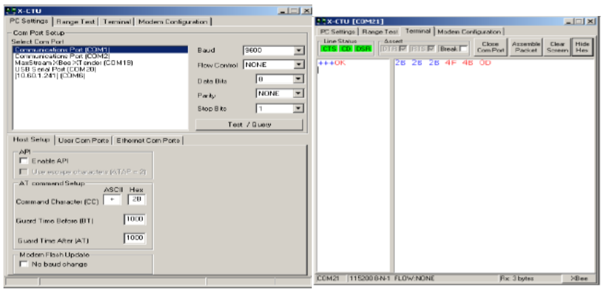

Figure 3.c X-CTU GUI for configuration and verification of Xbee Module

## 5. Results and Discussion

The proposed design were used to measure the air quality in several places inside the Annaba City and included different gases levels but focused mainly on measuring three main gases: Carbone Monoxide (CO) and Liquid Petroleum Gas (LPG) and NO2.

*A. Results*

A sample of obtained results from both clean environment, Annaba city center where there is a crowed circulation and Asmidal premium chemical transformation firm in Annaba, the results are shown in figures 3.d, 3.e and 3.f.

Based on the normal gas levels of the clean air [2], the results indicate that there is a big difference in the gas levels of both gases (LPG and CO) which obtained from the several tests and circuit runs. However, the acquired results show no risky situation to be considered for further actions.

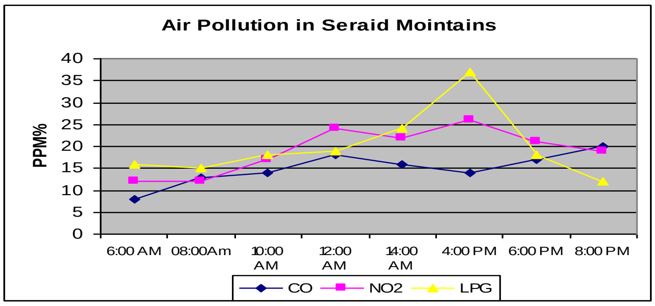


Figure 3.d Situation of air pollution in Seraidi Mounteans Annaba

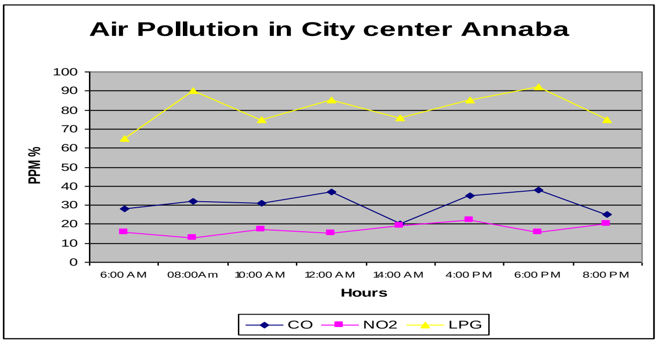


Figure. 3.e Situation of air pollution in City center of annaba

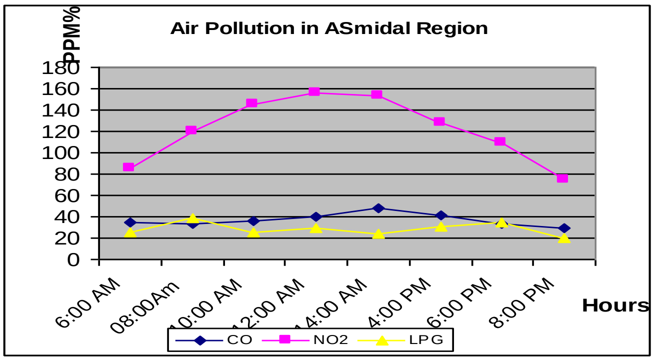


FIGURE:3.f Situation of air pollution in Asmidal Region ( perolium Transformation Unit ) In Annaba

*B. Simulations*

Simulation results: for simulation of WSN nodes, the area is divided into parts where each part can be controlled by a node, in this case the area is divided into 9 regions, and the transmission circuit is chosen so that it can provide the adjacent nodes with the information with minimum consumption of energy.

Simulation were done using a graphic user interface, the proposed simulator contains four sliders as inputs of gas type and level ($CO_2$, $SO_2$, NO 2 and $O_3$) for the model the index of air quality is presented by a colored square in the corresponding area. Figure 4.a and figure 4.b illustrates two scenarios.

Scenario 1: by adjusting the sliders for CO, SO2 NO2 and O3 Gas, we obtained the yelow color of the region , which illustrates by node 6 the values sensed: Co=179ppm SO2=175 ppm , NO2=179 ppm and O3=176 ppm, and based on ORAQI the level of pollution is represented with color yellow.

Figure 4.a: node 6 sensed Co=206ppm SO2=160 ppmand NO2=200 ppm levels the central control unit

Scenario 2: by adjusting the sliders for CO, SO2 NO2 and O3 Gas, we obtained the brown color of the region , which illustrates by node 3 the values sensed: Co=53ppm SO2=49 ppm , NO2=52 ppm and O3=74 ppm

Figure 4.b: Concentration of Carbon Monoxide Levels in Clean Air using WSN

Based on the normal gas levels of the clean air [2], the results indicate that there is a big difference in the gas levels of both gases (LPG and CO) which obtained from the several tests.

## 6. Conclusion

Air Quality monitoring System Design to asses the pollution of air in some parts of Annaba city using a micro-system, as a node in Wireless Sensor Network (WSN), is proposed in this article. WSN enhanced the process of monitoring many environmental phenomena such as the air pollution monitoring issue in proposed this paper. The air quality index is computed on site within the microcontroller ,when an excess of Index is detected then the node with transmit the information AQI to the central unit. It provides a real-time information about the level of air pollution in different regions, as well as provides alerts in cases of drastic change in quality of air. Based on collected information, such data can then be used by the authorities to take prompt actions such as evacuating people or sending emergency response team. The proposed design is enhanced by several ways such as: selecting adequacies' sensors, calibrating these sensors for gas detection, integrating them in a WSN system controlled by an DSPIC-30, and finally transmission to the central unit using Xbee modules. A Graphic used interface has been presented in this work to simulate the effect of sensors on selected area. The results are interesting, improvements can be done: in providing a web service page that can provide these data to users, as well as more sophisticated sensors could be used such as MQ-135, MQ-136 and Mics-2710 for sensing $NO_2$.

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