# Comprehensive air quality monitoring and notification system

CM3040 Physical Computing and and Internet of Things

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**Abstract**

Air pollution is an everyday problem that affects billions of people worldwide causing countless deaths every year. Since information and prevention are within the reach of everyone's hand, this project proposes a comprehensive domestic system that monitors internal and external air quality and alerts about unhealthy conditions, allowing the user to quickly and painlessly get information. With that information, the user can take proper actions that include using a face mask if leaving the house, refraining from exercising outside, venting the house to freshen the air, letting excessive humidity out, or refraining from opening the windows in high pollution conditions.

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# 1 Introduction

This project is focused on creating an IoT system designed to monitor air quality, in both big scale perspective (regional/metropolitan air quality) and micro scale (domestic spaces), and provide updated and easy to comprehend information to the users, allowing them to take informed decisions. The aim of this project is to design and build a multi-device system for monitoring and displaying up-to-date air quality conditions. For that to happen, the following objectives must be accomplished.

- Data must be obtained locally from system sensors.
- Data must be obtained from reputable remote sources to provide a wider panorama of the situation.
- Collected data must be compared against established threshold levels to asses the situation.
- Information must be communicated efficiently to the end user.

# 2 Methodology

I will review scientific publications for the most common air pollutants, their effects on the health, and actions focused on controlling them. For the effects of these research, the air pollutants are the particle or chemicals present on the air that create pollution, not the natural or artificial processes that create said substances. Then I will cross-compare the list of pollutants with devices available on the market, either as off-the-shelf complete systems or easily-available sensors designed specifically for measuring pollutant concentrations, and already available air quality monitoring services. For published literature on the subject, I used the University of London library search engine to look up for articles using the search terms "carbon dioxide pollution", "carbon dioxide effects", "carbon dioxide", and "pollution".

# 3 Literature review

Table 1 shows the most popular air pollutants mentioned on the reviewed literature along with a brief description of them, so those are the pollutants that should be measured by existing systems and tools.

| **Pollutant** | **Description** |
|---|---|
| Carbon dioxide ($CO_2$) [4–6] | Gas produced naturally by respiration and as a by-product of combustion |
| Particulate Matter (PM) [1, 2, 5] | Small solid particles suspended in the air |
| PM 2.5 | solid particles with a diameter $< 2.5\mu$m, for example combustion particles, organic compounds, and metals |
| PM 10 | solid particles with a diameter $< 10\mu$m, for example dust, pollen, and mold |
| Volatile Organic Compounds (VOC) [1, 5, 6] | Organic chemicals that evaporate at room temperature |

Table 1: Most common air pollutants

Table 2 shows some of the effects that air pollutants produce on people exposed to them. As it can be observed on the list, the health conditions they produce range from mild, short-term conditions to chronic diseases and air pollutants are considered responsible for 16% of all non-communicable diseases deaths globally [3].

| **Effect** |
|---|
| Drowsiness [6] |
| Sleepiness [6] |
| Asthma [2, 3] |
| Hypertension [1] |
| Diabetes type-2 [1] |
| Low weight birth [3] |
| Respiratory conditions (lung damage, impaired lung growth, increased risk for pneumonia and chronic obstructive pulmonary disease) [3] |

Table 2: Health effects caused by air pollutants

Three of the existing systems found are described on tables 3, 4, and 5 along with their more obvious advantages and disadvantages.

| **Canarii device** (`https://www.canairi.io/`) | |
|---|---|
| Indoors' air quality monitoring device dedicated to measuring $CO_2$ concentration and indicating when it is required to vent the room | |
| **Advantages** | **Disadvantages** |
| Easy to interpret interface | Focuses specifically on indoor air quality |
| Plug-and-play | Only measures $CO_2$ concentrations |
| | No battery level indicator |
| | No network connectivity |

Table 3: Canarii monitoring system

| **Mexico City's Air quality web site** (`http://www.aire.cdmx.gob.mx`) | |
|---|---|
| Web application from Mexico City's government showing the measurements of different air quality monitoring stations and pointing out the average air quality conditions for the city. | |
| **Advantages** | **Disadvantages** |
| Government sponsored system | Does not display dis-aggregated readings by pollutant |
| Measures a wide range of pollutants | Provides a single "average" value for all the region |
| Easy to interpret readings | No public API |
| Government sponsored system | Requires active participation for getting data |

Table 4: Mexico City's air quality website

| World Air Quality Index project (https://aqicn.org/) | |
|---|---|
| Chinese non-profit project focused on providing world-wide air quality information. | |
| **Advantages** | **Disadvantages** |
| Citizen Science project | Little information about who is running the project |
| Combines data from official environmental agencies and collaborating citizens | Confusing API documentation |
| Public API for data retrieval | Requires active participation for getting data |
| Allows fetching dis-aggregated data by monitoring station | |

Table 5: World Air Quality Index website

The two main branches of projects either focus on monitoring indoors' air quality, notifying the user when venting the room is required, or monitoring regional air quality, providing no notification whatsoever.

# 4 Proposal

My proposal combines both currently available approaches by monitoring both indoors' air quality through the active active use of sensors and outdoors by fetching the local air quality information from existing and proven sources. Combining those two data information sources, a broader perspective of the situation is presented to the end users via visual notifications allowing them to know things like if the room needs venting, if the air quality outside is worst than inside, if physical activities outdoors are advisable, or what is the air quality forecast for the day. This approach turns the end user into a passive participant, not requiring further involvement in the process other that looking at the notifications and interpreting them.

The system will be comprised by the two kinds of nodes shown on tables 6a, 6b

| **Main node** |
|---|
| **Tasks** |
| - Displays system wide notifications<br>- Receives information from existing sensing nodes<br>- Fetches information from sources outside the system |
| **Features** |
| - Compulsory<br>- Unique<br>- High energy consumption<br>- Stationary<br>- Requires a fixed power supply |

(a) Main node tasks and features

| **Sensing node** |
|---|
| **Tasks** |
| - Senses surrounding conditions<br>- Displays local notifications<br>- Processes data from sensors and relays it to the main node |
| **Features** |
| - Optional<br>- Varying in number according to requirements<br>- Portable<br>- Battery operated |

(b) Sensing node tasks and features

Table 6: System nodes

## 4.1 Functional requirements

- Should be able to measure air quality conditions in the immediate surroundings.

- Should be able to fetch local air quality conditions.
- Should combine and compare the information from several data sources.
- Should actively notify the user of the air quality conditions.
- The devices should be able to communicate between themselves.
- The devices should be able to operate independently from each other in case of a communications failure.

### 4.2 Non-functional requirements

- Notifications should be displayed via colors.
- Notification colors should be customizable.
- Pollutants' threshold levels should be customizable.

## 5 System Design Documentation

For both node types an ESP8266 will be the microcontroller used for development. The main node will use a temperature + humidity sensor, a sensor for measuring PM concentration, and an RGB led matrix for displaying notifications. It will also fetch external data using the World Air Quality Index (WAQI) project's API. The sensing node will use a $CO_2$/VOC sensor, a temperature + humidity sensor, and an RGB led for displaying local notifications. The communication between the nodes and between the main node and the WAQI platform will be performed with HTTP requests in JSON format as shown on figure 1. This will simplify the debugging process along with allowing communication with third party devices and systems via a REST API.

## 6 Test Plan

For testing each of the established goals, the testing criteria will be:

- Is the system able to retrieve data from the local sensors?
- Is the data from the local sensors accurate? (check data accuracy)
- Is the system able to retrieve data from remote sources? (check connectivity)
- Is the data retrieved from the remote sources by the system identical to the same data retrieved using a reputable device? (check that the system is not corrupting the data)
- Are the devices capable of communicating between themselves?
- Are the devices capable of operating independently with limited functionality in case that there is no connectivity?
- Is the system behavior changing according to the data and the established thresholds?
- Is an average user able to interpret the output the system is generating?

# 7 Development Progress

The system is currently capable of connecting to the WAQI servers and fetching the air quality information for the area based on the IP location of the client. It can then process the raw data obtained from the server and obtain the numeric value for the metropolitan air quality. The sensors that will be directly connected to the microcontroller will be:

- Plantower PMS5003 PM 2.5 sensor for measuring local air quality.
- CCS811 $CO_2$ and VOC level sensor
- DHT11 humidity and temperature sensor.

Regarding the led matrix that will out put the status on the main node, it will be composed by WS2812 RGB leds. An 8 by 8 matrix will be used for prototyping but the size could change along development. Connection diagrams are shown on figures 2 and 3.

# 8 Appendices

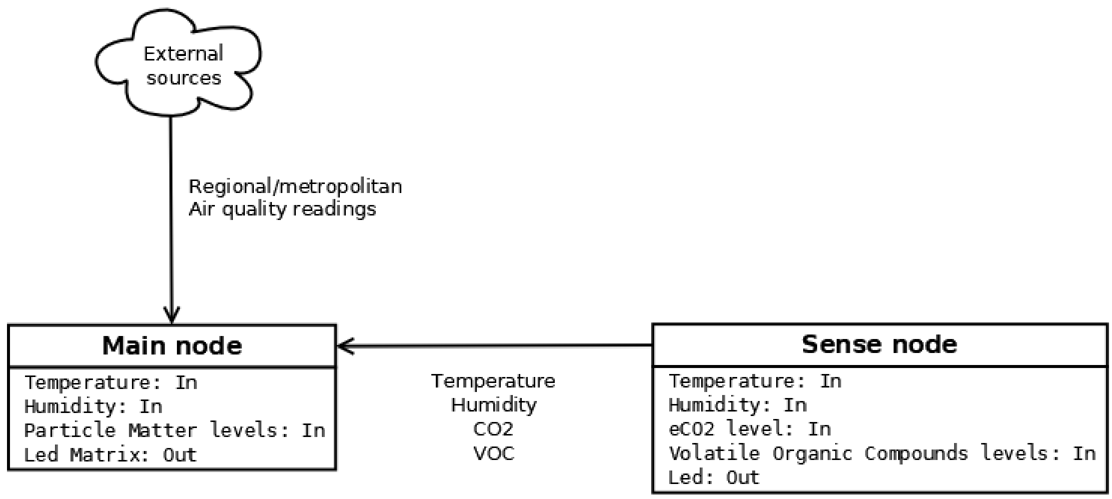


Figure 1: System diagram

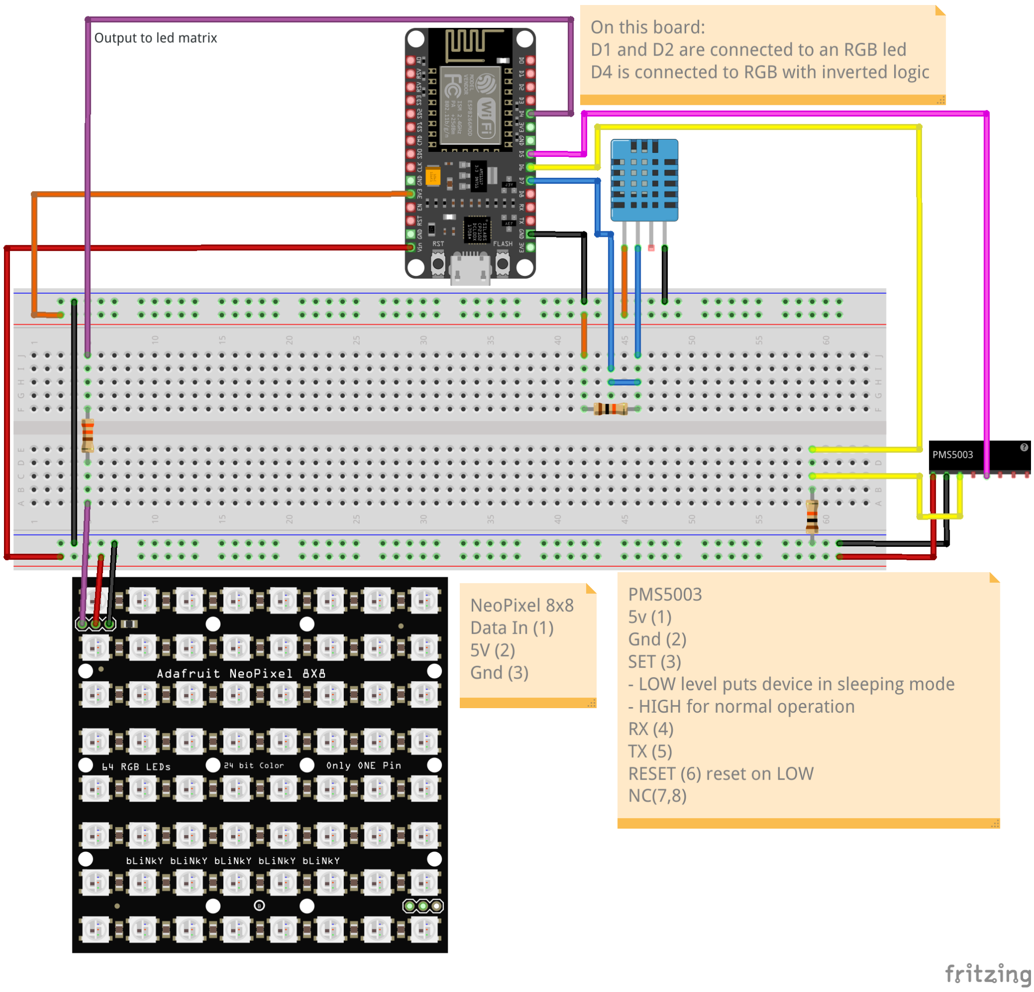


Figure 2: Main node connection diagram

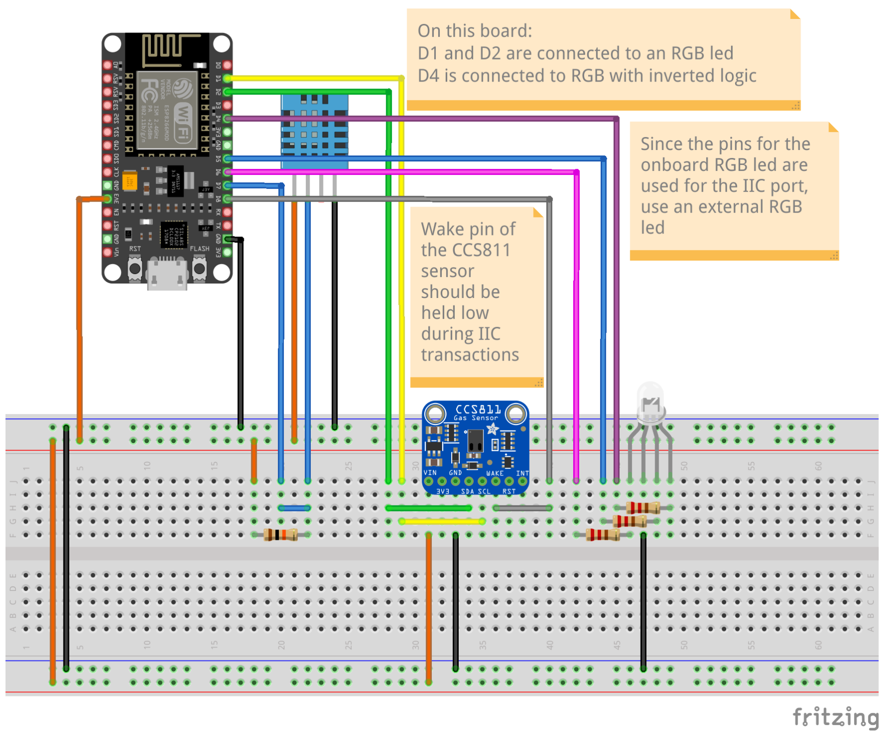


Figure 3: Sense node connection diagram

# 9 References

[1] Robert D. Brook, Zhichao Sun, Jeffrey R. Brook, Xiaoyi Zhao, Yanping Ruan, Jianhua Yan, Bhramar Mukherjee, Xiaoquan Rao, Fengkui Duan, Lixian Sun, Ruijuan Liang, Hui Lian, Shuyang Zhang, Quan Fang, Dongfeng Gu, Qinghua Sun, Zhongjie Fan, and Sanjay Rajagopalan.
Extreme air pollution conditions adversely affect blood pressure and insulin resistance.
*Hypertension*, 67(1):77–85, 2016.

[2] Michael Guarnieri and John R Balmes.
Outdoor air pollution and asthma.
*The Lancet*, 383(9928):1581–1592, 2014.

[3] Philip J. Landrigan, Richard Fuller, Samantha Fisher, William A. Suk, Peter Sly, Thomas C. Chiles, and Stephan Bose-O'Reilly.
Pollution and children's health.
*Science of The Total Environment*, 650:2389–2394, 2019.

[4] Scott D. Lowther, Sani Dimitroulopoulou, Kerry Foxall, Clive Shrubsole, Emily Cheek, Britta Gadeberg, and Ovnair Sepai.
Low level carbon dioxide indoors—a pollution indicator or a pollutant? a health-based perspective.
*Environments*, 8(11), 2021.

[5] Kamal Jyoti Maji, Victor OK. Li, and Jacqueline CK. Lam.
Effects of china's current air pollution prevention and control action plan on air pollution patterns, health risks and mortalities in beijing 2014–2018.
*Chemosphere*, 260:127572, 2020.

[6] Bambang Wispriyono, Elia Yulaeva, Budi Hartono, and Satria Pratama.
Indoor air pollution (carbon dioxide and total volatile organic compound) and pulmonary disorders in junior high school students in depok, west java.
*Global Journal of Health Science*, 11:45, 10 2019.