British Journal of Environmental Sciences 12(3),1-11, 2024
Print ISSN: 2055-0219(Print)
Online ISSN: 2055-0227(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development–UK

Comparison and Evaluation of Air Quality Monitoring Methods Using Iot Devices

Anxhela Kosta
Department of Computer Sciences, University of Tirana, Albania
Email: anxhela.kosta@fshn.edu.al

Ilma Lili
Department of Computer Sciences, University of Tirana, Albania
Email: ilma.lili@fshn.edu.al

Endri Xhina
Department of Computer Sciences, University of Tirana, Albania
Email: endri.xhina@fshn.edu.al

doi: https://doi.org/10.37745/bjes.2013/vol12n3111 Published April 27, 2024

Citation: Kosta A., Lili I., and Xhina E. (2024) Comparison and Evaluation of Air Quality Monitoring Methods Using Iot Devices, *British Journal of Environmental Sciences* 12(3),1-11

ABSTRACT: *Comparing the efficiency and accuracy of air quality monitoring methods is an important aspect to ensure the protection of the environment and the health of citizens. In this study, we developed a project to measure air quality in several areas using Internet-connected devices built with Arduino and a standardised device such as AirVisual. To evaluate the accuracy and performance of the two monitoring methods, we collected data including humidity levels, temperature, and PM 2.5 (particulate matter) from both devices. Through the analysis of these data, we compared and evaluated the changes in air quality and the performance of the two methods in real time. The results of our study provide a deep understanding of the compatibility and accuracy of different air quality monitoring methods and contribute to the development of knowledge in this field. This study points out the importance of using IoT technology for air quality monitoring and the opportunities for improving existing monitoring methods.*

KEYWORDS: *IoT, arduino, AirVisual, air quality, data, low cost devices*

INTRODUCTION

Air pollution poses a major health challenge to millions of individuals worldwide. The popularity of low-cost air quality sensors has surged significantly in recent years due to their capability to provide real-time, localised insights into air pollution. These affordable sensors enable widespread deployment, fostering dense networks that offer high spatial resolution [1]. While delivering valuable data for various applications, the technology faces challenges such as the need for continuous calibration, sensitivity to environmental conditions, and potential limitations in meeting regulatory standards.

Nevertheless, their accessibility and affordability make them instrumental in increasing community engagement, contributing to informed urban planning, and addressing public health concerns related to air quality. Making inexpensive devices to check the air inside can help us learn about indoor air pollution and might reduce its impact on our health [2]. These low cost devices are easy to carry, need little maintenance, and can provide continuous real-time monitoring. Low-cost air quality monitoring devices have become the preferred tools for many communities and organisations seeking to monitor air quality in an effective and economical manner. Equipped with a wide range of specialised sensors, these low-cost devices can detect air pollutants such as sulphur dioxide, carbon monoxide, particulate matter (PM2.5 and PM10), oxygen, and others. They are suitable for easy installation and use by local communities, schools, non-governmental organisations, and individuals interested in environmental quality. The advantage for using these devices is their ability to transmit real-time data distributed over the internet. This enables citizens and locals to monitor air quality in real-time and take action if necessary. With their cost of up to three orders of magnitude lower than standard/reference instruments, many avenues for applications have opened up.

The primary objective of this paper is to provide a comparative analysis between Arduino-based air quality monitoring systems and AIRVisual devices, which represent standardised monitoring equipment. In this study, we developed an Arduino-based system configured to monitor air quality parameters such as humidity, temperature, and PM (particle matter) levels. We acquired an AIRVisual device [4] to compare its performance with our Arduino setup. By gathering and analysing data from both devices, we aimed to evaluate their accuracy, reliability, and effectiveness in real-time air quality monitoring. This research underscores the significance of utilising IoT technology for air quality monitoring and highlights opportunities for enhancing existing monitoring methodologies.

Methodology and Pollution monitoring

Pollution is the process of introducing chemical, biological, or physical substances into the environment in quantities that cause harmful changes to it and to the health of living organisms. Environmental pollution is a significant global environmental and health problem, requiring concerted efforts to reduce its negative impact on our planet [3]. There are numerous types of pollution that impact our environment, encompassing air, water, and soil pollution, each with diverse causes. The table below provides a concise summary of these pollution types and their respective causes.

Table 1. The main types of pollution in the environment

Type of Pollution	Description
Air Pollution	• Industrial Pollution Emission of smoke gases, sulphur dioxide, nitrogen oxides, and other pollutants from factories and industrial processes. • Transportation Pollution Emission of smoke gases, carbon dioxide, nitrogen oxides, and other heavy air pollutants from vehicles and public transport • Residential Heating Pollution Use of fossil fuels for heating residential environments.
Water Pollution	• Runoff Pollution Destruction of natural habitats due to the discharge of hazardous waste into the waters of rivers, oceans, and lakes. • Industrial Waste Pollution Discharge of chemical substances and industrial waste into water sources. • Drinking Water Pollution Use of pesticides, fertilisers, and other chemicals that may contaminate water sources.
Soil Pollution	• Industrial Waste Pollution Use of hazardous chemicals and solid waste that may contaminate and degrade soil. • Urbanisation Impact Urbanisation of open areas and the exploitation of the free soil layers for various constructions, causing soil degradation and loss of vegetation. • Waste and Landfills Pollution Disposal of solid waste, plastics, and other non-biodegradable materials spreading contamination in soil.

Pollution monitoring is very important because it has to do with understanding the sources of these pollutants, where they come from, how they are related to human and natural activities. In our projects our primary focus was on monitoring air pollution, considering the significant increase in air pollution in Albania in recent years.

The results from periodic measurements for air quality at 400 stations in the Municipality of Tirana indicate that pollutant levels exceed the allowed norms. The measurements were conducted by a consortium of organisations during September 2022, revealing a panorama that has not been made public by the National Agency of Environment, which is the responsible institution in this regard [5]. The main air pollutants are carbon dioxide, nitrogen dioxide, as well as particulate matter PM10 and PM2.5. Instat [5] did a comparison with the European Union's normal standards, and according to measurements conducted three months ago in Albania, it resulted that these pollutants exceed the allowed norms. For this reason, in our project we focused first in identifying in which area we had to measure the air quality and what to use for monitoring. This is shown in our first paper that we have published [6]. First of all we did Online Questionnaire for identifying these groups:

- People with permanent and temporary problems.
- Air pollution in relation to the number of students
- Air pollution in relation to the level of carbon dioxide and soil
- Air pollution in relation to the premises of the halls, etc

The objective was to understand the health status of the student and to monitor the air quality in their editors. We make survey some questions:

- Do you suffer from any respiratory disease?
- Are you allergic?
- At the moment, how is your state of health?
- Do you think there is humidity in the room where the lesson is taking place?
- Does the air feel heavy where you are conducting the lesson?

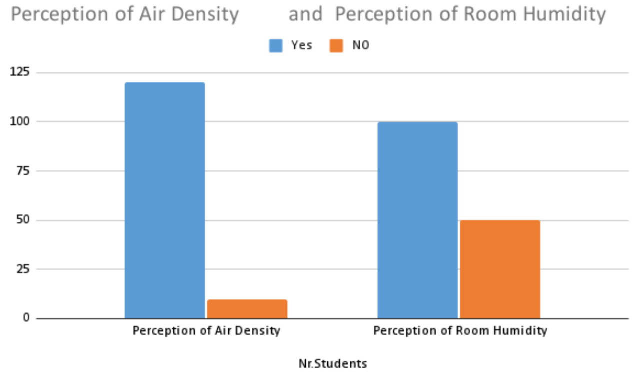

Figure 1. The graph has the responses of students regarding the perception of air density and room humidity in the classrooms

Following this, we aimed to explore IoT devices for real-time monitoring of air quality. We approached this from two perspectives: firstly, by considering low-cost devices that can be configured independently, such as Arduinos, and secondly, by examining standardised low-cost IoT devices such as AirVisual.

Categorization of online input data

The need to have comprehensive information regarding air quality is crucial due to its fundamental impact on health and the environment. To better understand this situation, it is essential to have a regular and tailored approach to monitor and collect the necessary data. The data collection process is a critical phase, and in this context, a key source is the use of low-cost devices designed to gather data on air quality. This process aims to be automated, involving the installation of these devices and configuring them through a specific algorithm. The goal of this effort is to ensure a sustainable and efficient means of collecting and storing air quality data, thereby creating a reliable and ongoing source to comprehend and address challenges related to air pollution and quality.

Low cost devices- IOT

Data collection is important for several key reasons. Numerous studies have concluded that the deployment of low-cost devices for air quality monitoring will have a significantly positive impact on[11]:

- Public awareness, fostering increased awareness within the community and local authorities.
- It positively influences scientific research since, by gathering data, numerous statistics can be generated regarding the analysis of the impact of air pollution, identifying the causes and understanding the reasons behind its occurrences. This enables a more comprehensive exploration into the scientific aspects of air quality issues, facilitating a deeper understanding of the sources and dynamics of air pollution.
- Having control over air quality data, local and central authorities can implement legal measures to improve air quality.

In various countries worldwide, affordable devices have been developed to monitor air quality effectively. One notable tool in this effort is the Air Quality Index (AQI), which translates air quality data into numerical values and color codes, aiding individuals in understanding when precautionary measures are necessary to safeguard their health [7]. These budget-friendly devices are equipped with air quality monitors that measure various airborne particles, including dust, pollen, smoke, and liquid droplets, in the vicinity of their installation every hour. There exist multiple types of gas detectors or sensors utilized for air quality measurement. With the assistance of these cost-effective devices, it becomes feasible to assess both indoor and outdoor air quality. They facilitate the determination of whether air quality is satisfactory or if it is contaminated with elevated levels of carbon dioxide (CO_2), carbon monoxide (CO), or volatile

British Journal of Environmental Sciences 12(3),1-11, 2024
Print ISSN: 2055-0219(Print)
Online ISSN: 2055-0227(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development–UK

organic compounds (VOCs) like ethanol, amines, or aromatic hydrocarbons [8]. Before choosing the low-cost device to use, we need to consider several parameters and also the type of environment in which you will place the device, whether it is an outdoor or indoor environment. First, we need to determine what you will focus on monitoring, such as sulfur dioxide, carbon monoxide and PM2.5/PM10.

Air quality index

The Air Quality Index (AQI) serves as a dynamic scale, offering real-time insights into the levels of air pollution. Originating from the U.S. Environmental Protection Agency (EPA), this index serves as a direct communication tool for informing the public about air quality concerns [9]. It encompasses measurements of five primary air pollutants, regulated by the EPA to safeguard public health under the Clean Air Act [10]:

- Carbon monoxide→A colourless, odorless gas emitted during combustion processes, such as from stoves and industrial facilities, as well as from natural events like wildfires.
- Nitrogen dioxide→A reddish-brown, highly reactive gas predominantly originating from the combustion of fossil fuels, notably from vehicles and power plants.
- Ozone→A significant component of smog, formed when nitrogen oxides and volatile organic compounds react in the presence of sunlight.
- Particle pollution→ Minute airborne particles—PM2.5 and PM10—that are emitted directly or formed in the atmosphere. Major sources include vehicle emissions, industrial activities, construction dust, and wildfire smoke.
- Sulfur dioxide→ A colorless gas emitted from the combustion of fossil fuels in industrial facilities and power plants, contributing to air pollution concerns.

AQI, or Air Quality Index, is a system for translating sometimes confusing or unintuitive pollutant concentration measurements, into one easy-to-understand scale to clearly represent the health risk posed by ambient air pollution [11]. The index formula usually considers up to 6 main pollutants (PM2.5, PM10, carbon monoxide, sulfur dioxide, nitrogen dioxide and ground level ozone), and calculates the respective health risk (or AQI number) for each one at any given time. The overall AQI number at a given moment is dictated by the "riskiest" pollutant, with the highest A [13]

Figure 2. QI number.

Print ISSN: 2055-0219(Print)

Online ISSN: 2055-0227(online)

Website: https://www.eajournals.org/

Publication of the European Centre for Research Training and Development–UK

The index ranges from 0 to 500, where high index values indicate higher levels of air pollution and higher potential for adverse health effects. Any value larger than 300, is considered to be hazardous, while an AQI value of 0-50, on the other hand, represents good air quality [15].

The demonstration - Configuration of Arduino and AirVisual

To monitor air quality at our faculty, we decided to purchase an Arduino and configure it to connect to a PC device, allowing us to measure air quality in real-time. The Arduino we bought is the SDS011 Nova PM Sensor Laser PM2.5 Air Quality Detection Sensor Module Dust Sensor Air Conditioning Monitor Module, which provides functionality for effectively measuring air pollution levels. One of the main advantages of this Arduino is its relatively low cost, making it an economical choice for us. After acquiring the device, we built its connection to the computer using the C programming language(some libraries #include "Seeed_HM330X.h" #include "Adafruit_SGP30.h" #include "Adafruit_NeoPixel.h")
This enabled us to obtain real-time air quality data and analyse it to effectively monitor our environment.

```
typedef struct PMSensorReadings
{
    u16 pm1_0_cf1;
    u16 pm2_5_cf1;
    u16 pm10_cf1;
    u16 pm1_0_ae;
    u16 pm2_5_ae;
    u16 p10_a3;

} PMSensorReadings;

// Set the basic colors for the "AQI Thermometer"
uint32_t ledStrip_blue = ledStrip_1.Color(0u,0u,255u);

uint16_t hueValue = 21846u; // Arbitrarily chosen to start at green

bool isH330Connected = false;
bool isSGP30Connected = false;
bool hasSGP30IDBeenWritten = false;

// Timekeeping for SGP30 startup
uint32_t startTime;
// Elapsed time kept in the loop scope to discard
// when out of scope

// Function prototypes:
void colorWipe(byte red, byte green, byte blue, int SpeedDelay);
err_t inspectChecksum(u8 *data);
err_t parse_result(u8 *data, PMSensorReadings *pmReads);
uint16_t mapPM2_5(uint16_t value);
uint16_t mapPM10(uint16_t value);
uint16_t mapTVOC(uint16_t value);
uint16_t getTopHueColor(uint8_t mapIndex);

void determineSetupStateBeforeLoop();

void initH330();
```

Figure 3: Connection arduino with the PC

We used a modular architecture to create the connection between the Arduino and the computer for air quality measurement that is presented in the first paper [6].

Figure 4: Arduino configuration

The second device was the Air Visual Device, a standardisation and certifications IOT devices. This is a standardisation device that costs more than an arduino. This Is great for measuring air pollution exposure from traffic, industry, agricultural burning or wildfires. View real-time and historic air quality via the free mobile app[17]. AirVisual Outdoor monitors up to 8 environmental parameters

- AQI PM 1
- PM 2.5
- PM 10
- Optional CO_2
- Temperature Humidity
- Barometric Pressure

After setting up the Arduino IOT device and Air visual iot Devices, we identified specific outdoor locations for its installation to monitor air quality and gather data. We installed the iot devices around our campus (Faculty of Natural of Science(FSHN)[18]. The map below illustrates the areas where we deployed the Arduino device and Air Visual.

Figura 5. Aerial view of the positioning of the sensors within the territory of the FSHN

The IoT devices are positioned, installed and configured within the territory of the Faculty of Natural Sciences. Measurements were carried out for each building:

- Building A: east facade
- Building B: B1 (inner courtyard), B2 (south facade)
- Building C: C1 (west facade), C2 (inner courtyard)
- Building D: inner courtyard next to the street

After positioning, installation and configuration, we collected the data for more than one year and proceeded with a comprehensive comparison between the data obtained from Arduino and that from Air Visual. The table below presents the collected data from both devices for analysis.

Table 2. Result of monitoring air quality with Arduino and Air Visual Iot Devices

Devices	AQI	PM2.5	PM10	PM1.0	Temperature	Humidity	Pressure
Arduino	51µg/m³ (moderate)	35µg/m³(moderate)	54µg/m³ (good)	25µg/m³: (good)	23 grad	30%	900
AirVisual	37µg/m³:(good)	9µg/m³ (good)	13 µg/m³:(good)	4µg/m³: (good)	23 grad	41%	993

Based on the results that we have collected from devices we can conclude the Arduino device is characterised by its low cost compared to the higher cost of the AirVisual device(even its low cast devices). In terms of implementation, the Arduino device requires code modification, in the C language, while the AirVisual device does not require any implementation effort, offering simplicity in this respect. When it comes to the application, the Arduino device uses the Arduino IDE, while the AirVisual device works through the AirVisual application. We can also say that the AirVisual device adheres to the standards, while the Arduino device does not. In terms of historical data, the AirVisual device provides a historical perspective, which is not available with the Arduino device. The output format from the Arduino device is relatively complicated compared to the simpler format provided by the AirVisual device. In terms of connectivity, the Arduino device lacks connectivity options, while the AirVisual device offers direct WIFI access for enhanced connectivity. To conclude, we can say that the AirVisual device is more reliable for measuring data quality than Arduino since the margin of error is not large and gives the accuracy of data..

Future works and recommendations

Based on the data we have collected for air quality monitoring, we can suggest that there is a need for the permission of Arduino IoT devices to increase their access and usability. Also, academics who deal with data analysis and visualisation can extract different statistics from air quality data. Our equipment has been in operation for more than 2 years and we collect data every day, this is done in order to increase public awareness and engagement in an effort to monitor air quality. In future work, we are in collaboration with the University of Sorbonne (France) [19] and we are making a book about low cost Iot devices for air quality monitoring.

CONCLUSION

Our study provides valuable insights into the comparison and evaluation of air quality monitoring methods using IoT devices, specifically Arduino and AirVisual. Through the deployment of these devices and the collection of data on various air quality parameters, including humidity, temperature, and particulate matter levels, we were able to assess the performance and reliability of both monitoring methods. Our findings indicate that while Arduino devices offer cost-effective solutions for air quality monitoring, they require code modification and lack standardisation compared to AirVisual devices. On the other hand, AirVisual devices provide simplicity, adherence to standards, historical data and data accuracy. Our study underscores the importance of utilising low cost IoT technology for air quality monitoring and highlights the potential for improving existing monitoring methodologies to better address environmental and public health concerns related to air pollution.

REFERENCES

[1]. Steven J. JohnstonPhilip J. Basford, Florentin M. J. Bulot, ,Mihaela Apetroaie-Cristea,Natasha H. C. Easton,,Charlie Davenport,Gavin L. Foster ,Matthew Loxham, Andrew K. R. Morris and Simon J. Cox: City Scale Particulate Matter Monitoring Using LoRaWAN Based Air Quality IoT Devices
[2]. N. Marchetti, A. Cavazzini, L. Pasti, and M. Catani, "A Campus Sustainability Initiative : Indoor Air Quality Monitoring in Classrooms," pp. 1–4, 2015
[3]. World health organisation: https://www.who.int/
[4]. Air Visual IQair: https://www.iqair.com/
[5]. Institute of Statistics - Tirana: https://www.instat.gov.al/
[6]. Lili I, Kosta A, Xhina E: The use of smart devices (IOT) to monitor the air quality: a case study at the Faculty of Natural Sciences, 2023
[7]. A. ZiauddinN.A. Siddiqui: Air Quality Index (AQI) - A tool to determine ambient air quality
[8]. H. Chojer, P.T.B.S. Branco, F.G. Martins, M.C.M. Alvim-Ferraz, S.I.V. Sousa: Development of low-cost indoor air quality monitoring devices: Recent advancements
[9]. Environmental Protection Agency (EPA) : https://www.epa.gov/

[10]. Clean Air Act:
[11]. J hanvi Aroraa , Utkarsh Pandyaa , Saloni Shaha , Nishant Doshia: Survey-Pollution Monitoring using IoT
[12]. Antonella Plaia, Mariantonietta Ruggieri: Air quality indices: a review
[13]. Bishoi B, Prakash A, Jain VK (2009) A comparative study of air quality index based on factor analysis and US-EPA methods fo an urban environment. Aerosol Air Qual Res 9(1):1–17
[14]. Cogliani E (2001) Air pollution forecast in cities by an air pollution index highly correlated with meteorological variables. Atmos Environ 35:2871–2877
[15]. World Air Quality Index: https://www.aqi.in/
[16]. Pranvera Kortoçi, Naser Hossein Motlagh, Martha Arbayani Zaidan, Pak Lun Fung , Samu Varjonen, Andrew Rebeiro-Hargrave, Jarkko V. Niemi, Petteri Nurmi, Tareq Hussein,, Tuukka Petäjä, Markku Kulmala, Sasu Tarkoma: Air pollution exposure monitoring using portable low-cost air quality sensors
[17]. Air visual Devices IOT: https://www.iqair.com/air-quality-monitors
[18]. Faculty of Natural Science: https://fshn.edu.al/
[19]. Paris-Sorbonne University : https://lettres.sorbonne-universite.fr/