The use of smart devices (IOT) to monitor the air quality: a case study at the Faculty of Natural Sciences

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Abstract

A city is "smart" if it uses different types of sensors and devices to collect data and provide information that is used to efficiently manage resources. The data can be processed and analyzed in order to monitor and manage traffic and transportation systems, waste recycling, water supply networks, air pollution, and other public services. The use of sensors would enable the collection of these data and their transfer in real time to the users. Based on the information provided online by a Swiss company called IQAir, it appears that Tirana has significant air pollution. Through a web application we could enable the possibility to receive and display data from the sensors and send them to a database so we can use them in different situations. In this paper we will show the use of the Internet of Things (IOT) to monitor pollution levels, especially levels in many positions in the Faculty of Natural Science where the number of students can be considered high. The aim of this paper has a correlation with people heath especially for this case study is students' health. It serves for more detailed studies or evaluate whose are the element causing the greatest air pollution and a prediction of what measures should be taken to prevent it. Creating a suitable environment to make this information to be detailed in real-time of course will affect other fields and aspects of researchers in the future.

Keywords

Air pollution, IOT and Smart devices, IQAir, Particular Matter, Arduino

1. Introduction

Air pollution is the greatest environmental threat to public health globally and accounts for an estimated 7 million premature deaths every year. In 2019, 99% of the world population was living in places where the WHO's strictest 2021 air quality guideline levels were not met. Air pollution is the presence of extra unwanted biological molecules, particulates or other harmful things into the earth's atmosphere. It is a major cause of infections, allergies, and eventually reasons of death to some people [1].

The air problem is something that should not be neglected but more thought should be given to ensure a healthy future for the population. The World Health Organization (WHO) estimated that, in the year 2012, ambient air pollution was responsible for nearly seven million deaths, representing more than 10% of all-cause deaths and more than doubling previous estimates [2]. Based on this information we thought about what to do to identify air pollution sources—where it's coming from and who's responsible. Since we are in the age of technology we can improve and can monitor air quality using smart devices called IOT.

Advanced technological tools such as artificial intelligence (AI), machine learning, blockchain technology, IoT, and geographic information systems are some of the powerful tools that help humanity to effectively address climate goals and

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have a better picture of the actual air quality situation [3].

It is important to analyze the relationship between student activities and PM2.5 in the classroom to provide guidance for air quality improvement. However, modeling and predicting PM2.5 in classrooms remains a challenging problem. Previous studies have mainly concentrated on residential or uninhabited rooms without large-scale crowd conditions and analyzed issues such as temperature, humidity, and outdoor PM2.5 concentrations. Limited studies have focused on quantifying the effect of student activities on PM2.5 in classrooms.[4]

Below, two graphs show the level of the PM2.5 parameter in outdoor environments near the Faculty of Natural Sciences. These results belong to three consecutive days of March 2023 respectively by hours and days. The data is obtained from the website IQair [5] via the published station with longitude 41° north and latitude 19° east at 150 m distance from the buildings of the Faculty of Natural Sciences.

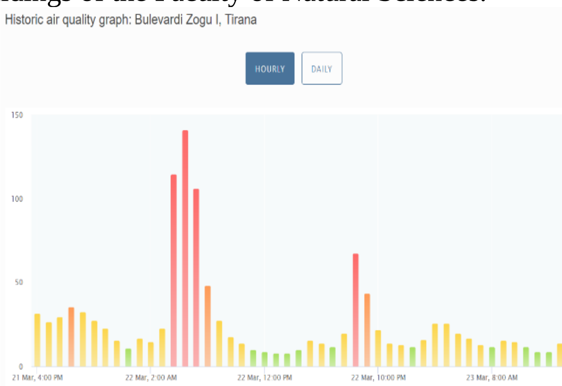


Figure 1: Air quality AQI hourly

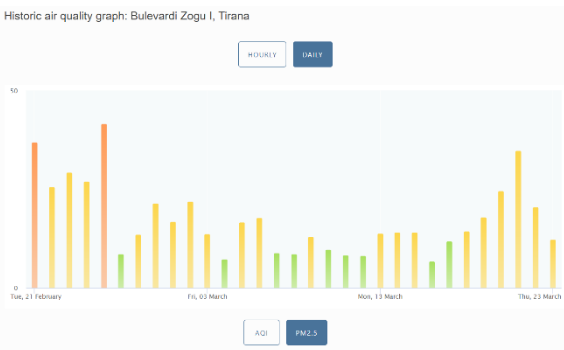


Figure 2: Air quality index (AQI) daily

Previous studies have indicated that indoor PM 2.5 concentrations are strongly correlated with outdoor PM2.5 concentrations.

In this paper we will show the use of the Internet of Things (IOT) to monitor pollution levels, especially at different points inside the buildings accompanied by different volumes of students at the Faculty of Natural Science. The aim of this paper is directly related to the health of the students. It serves for more detailed studies of which elements causes the greatest air pollution and a prediction of what measures should be taken to prevent it. Also, we will show a comparison between IQ Air devices with Arduino which is the best for monitoring air quality. This demonstration creates the suitable environment for this information to be detailed and used in other fields and aspects of research in the future.

2. Air pollution challenges

Air pollution is one of the main environmental problems in major Albanian cities, especially in Tirana. The pollution has come as a result of the increase in cars, the reduction of urban greenery, the burning of garbage, the economic activities of enterprises, the use of low-quality fuels, etc. The concentration of PM10 and NO2 particles in Tirana exceeds the national standards and those of the World Health Organization [6]. Air pollution has a direct impact on human health and has long-term consequences. Technology has an important role in shaping the world, countries, society, economy and also the environment. All the organizations are working on how to reduce pollution, and scientists are thinking about using technology to reduce pollution.

3. Methodologies and technologies

The methodology used is mainly based on the initial study of the environment where the measurements were made. The two important moments were the location of the points where the measurements would be made and their frequency. Subsequently, other helpful attributes were determined, for example, for the location of the building, the area, the floors, etc. and for the frequency, it includes the weather forecast, measurements at different times of the day, halls filled with students. All these analyzes are presented with the schematic coded below

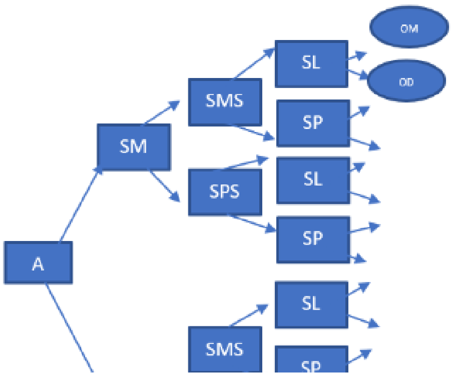


Figure 3: Schematic analyses of the environment at different times of the day.

Air quality index is a parameter calculated based on other values gathered during data collection. Our tools include USA AQI.

Air quality in the classroom is crucial to the student's health.
In the beginning data were obtained by two sources. The first was the perception of the air quality by the students and the second was the concrete evaluation for air quality through estimating the level of CO2, humidity and temperature.
The methodology used helps clarify the correlation between human perception and real measurement.
Air quality perception data was collected through an online questionnaire fulfilled by students. The questionnaire included not only the students' opinion on the current air quality but also a general framework of their health situation. After analyzing the environment, the workflow continued with two parallel processes. 1. Assessment of air perception by students by completing an online questionnaire. 2. Concrete air quality measurement using two devices, one built-in Arduino tool and the other standardized device for measuring air quality

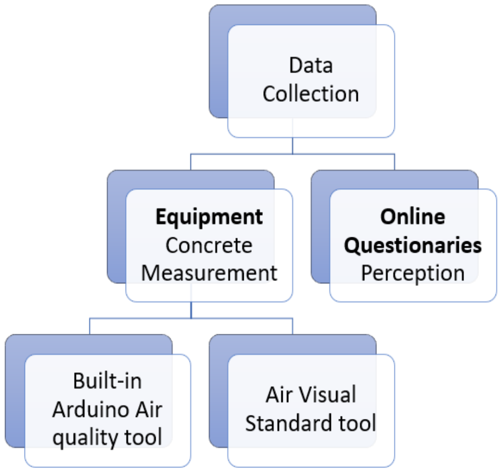


Figure 4: Process workflow

The built-in air quality Arduino tool used to measure air quality included the assessment of PM 2.5, PM 1.0, PM 10 and AQI (air quality index). The constituent elements part of this built-in tool is:

Grove - Laser PM2.5 Dust Sensor - Arduino Compatible - HM3301 which is a sensor for measuring the level of PM 2.5 particles classified as dangerous particles for human health when they exceed the limit of normality.

Grove Base Shield V2.0 for Arduino serving as a base that connects Arduino Uno devices and other versions such as Arduino Leonardo and Mega. 4-pin connectors ensure simple and quick connections.

Seeeduino V4.2(ATMega328P) The Arduino board that comes with the development environment

Grove - Universal 4 Pin Buckled 20cm Cable Connections between Base Shield, Arduino and sensor 2.5

Lipo Rider Plus (Charger/Booster) - 5V/2.4A USB Type C Connecting part between the board and the lithium battery.
The following components and their relationship is presented through figure below

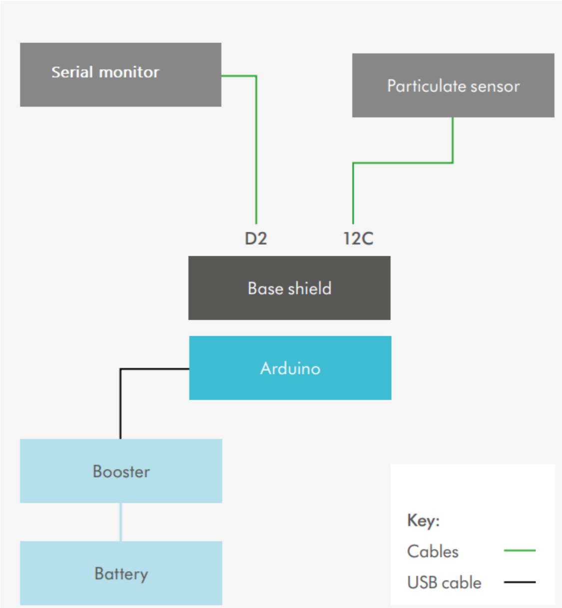


Figure 5: DIY Air Quality monitor components and their relationship.

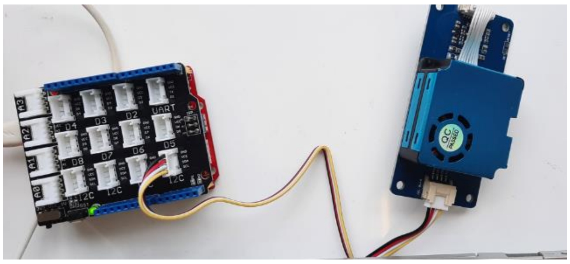


Figure 6: DIY Air Quality monitor

The environment where Arduino code is developed is divided into two important groups:
• void Setup, • void Loop
One serves for the initialization of the functionalities while the other for the execution of these functions depending on the situations. The results of code execution can be displayed in the Serial Monitor using the basic command for example:

Serial.println("Message").

The main part that helped display some test metrics is:
aqi_pm = mapPMAQIValues(&pmReadings); Serial.println(aqi_pm);

Where the variable that is taken as a parameter pmReadings reads the information from the sensor, and by means of the mapping function mapPMAQIValues connects the value in mg of PM and converts it to AQI.

There are some libraries that need to be included at Arduino IDE as described by the picture below.

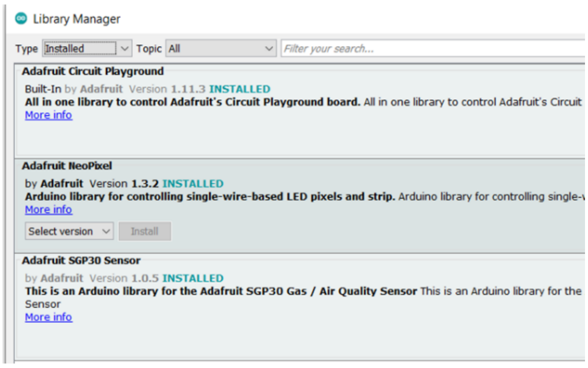


Figure 7: Library included on Arduino IDE

```
10:03:42.822 -> 2430
10:03:42.822 -> 1
10:03:42.822 -> 2430
10:03:42.822 -> 1
10:03:42.822 -> 2430
10:03:42.822 -> 1
10:03:42.822 -> 2430
10:03:42.822 -> 1
```

Figure 8: Execution results on Arduino IDE

The second equipment used was a standardized one. AirVisual is a device that measures pollution to PM1.0 (µg/m3), PM2.5 (µg/m3), PM10 (µg/m3) particles and derives the AQI (Air Quality Index) result from them. Additionally, the device measures temperature (˚C), humidity (%) and air pressure (mbar). It is designed to be used for particle pollution up to 1,000 µg/m3. AirVisual performs these measurements through two already installed sensors.

Figure 9: Commercial Air Visual Device

Certificate used FCC, IC, UL, ROHS, CE. The AirVisual Outdoor is manufactured in IQAir's state-of-the-art manufacturing location in Southern Germany. AirVisual provides three Internet connection options. Ethernet, Wi-Fi and USB 4G. Results collected by air visual device are displayed by the application installed on phones:

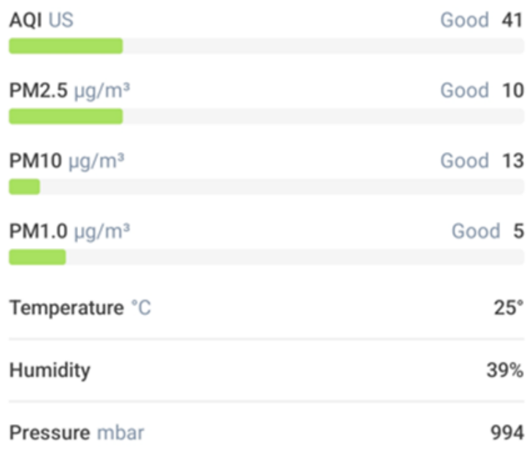


Figure 10: Results displayed by the Air Visual Application

4. Comparison between Air Quality devices.

In the market there are so many air quality sensors with different features and functions. It is hard to pick which air quality sensor will fit the best. For this reason, we have done a comparison between the Arduino air quality built-in device and Air Visual Device that we bought. The IoT devices are divided into three execution types:

- Processing time (the system is working)
- Sending processing time (the system activated the GPS/GPRS sensor and sends data to the Edge).
- Resting time (the system is in sleep mode, saving battery).

We must consider this specification when choosing the smart device.

- Operating Voltage
- Operating Temperature
- Operating Humidity
- Particle Size 3 channels

During the working process which includes the two devices, several changes were identified, starting from the moment of configuration until receiving the results. Those changes are summarized in the table below.

Table 1
Comparison between devices

	DIY Air quality monitor	Commercial Air Visual Device
Cost	Low	High
Implementation	Yes	No
Simplicity in usage	No	Yes
Application	Arduino IDE	Air Visual App
Standards	No	Yes
Results interface	Complicated	Simpler
Connectivity	No (add components)	WIFI-direct access

5. Advantages and disadvantages between air quality devices

Based on the data collected from the questionnaire on the perception of air quality and the concrete measured results performed by the air quality standardized devices, a direct correlation was noticed between them. It means that what is perceived by people for the quality of air is in the right way with the results of the equipment.

As a sum up the advantages and disadvantages for using smart devices to monitor air quality are summarized in the table below [8].

:

Table 2
Smart devices pros and cons.

Pros	Cons
It detects many different air pollutants	An air quality monitor does not clean the air
Shows exactly how your air is doing	It does not show the source of the pollutants
Allows you to take action based on data and knowledge	The average consumer grade monitor costs up to $100

Helps create the most healthy and comfortable class	Helps create the most healthy and comfortable home

6. Data flow process

The real-time measurement results were included on a website created by us[9] , by which students will identify air pollution sources in the school environment, analyze air pollution data collected in real-time and think about ways to reduce exposure to air pollution on their journey to school and use them for further analysis and projects. Using the API key from the commercial device a JavaScript code was involved on www.airqualityfshn.info website.

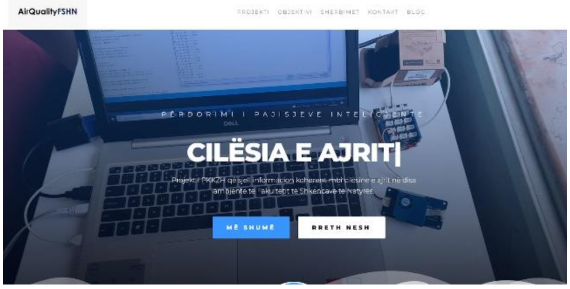


Figure 11: Website view

In order to monitor the air quality in real- time and to have a history for each measurement that is made, we built a database whose main purpose was to feed our website with the data obtained from the devices. The database we used was MySQL and it has two tables (devices, air_cities). The table device saves all data that identifies in a unique way the air quality commercial equipment with their location. The table *air_cities* hold the necessary information sent to us by the air quality device with the elements that identify the air quality.

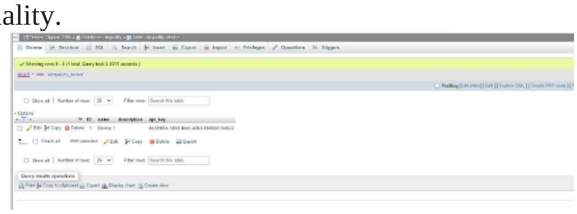
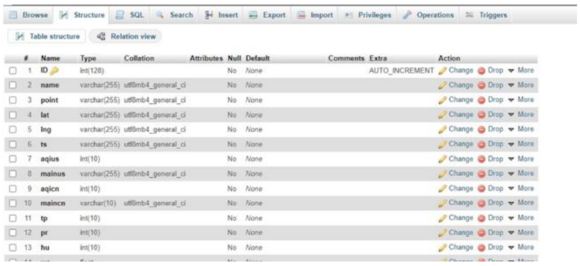


Figure 12: Table devices



#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
1	ID	int(128)			No	None		AUTO_INCREMENT	Change Drop More
2	name	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
3	point	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
4	lat	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
5	lng	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
6	ts	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
7	aqius	int(10)			No	None			Change Drop More
8	mainus	varchar(255)	utf8mb4_general_ci		No	None			Change Drop More
9	aqicn	int(10)			No	None			Change Drop More
10	maincn	varchar(10)	utf8mb4_general_ci		No	None			Change Drop More
11	tp	int(10)			No	None			Change Drop More
12	pr	int(10)			No	None			Change Drop More
13	hu	int(10)			No	None			Change Drop More

Figure 13: Table air_cities

After creating the database, it was necessary to develop a script which receives the data automatically from the device and stores it on the database. The device has an API key (provided by the commercial). By sending a request to POSTMAN using API Key: 4a28fd8e-1d3d-4aec-a0b4-8b98d416e532 we could get the necessary data to save on our database

The technology used to send the device request is the Php programming language. We build the AirQuanity class which sets the device's API key and the get methods for receiving data. API key sends the data showing the air quality in JSON format. With a function save(data) we read data from the smart device in real time and insert it into the database as soon as we have a new request from the API key, that is, when a new measurement is encountered. When the database is populated with real-time air quality data, we present this data on a website by using a Php script. The figure below shows the request to the Air Quality Database to read the air quality data and present them on the website. The general architecture used during these activities is presented in a schematic way below.

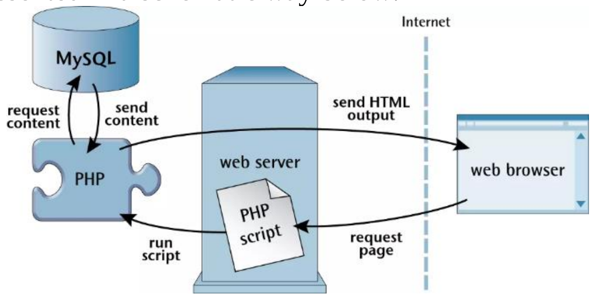


Figure 14: MYSQL connection-Schematically

```
<?php
namespace Airquality;

use Symfony\Component\HttpClient\HttpClient;

class Airquality
{

    const API_KEY = '4a28fd8e-1d3d-4aec-a0b4-8b98d416e532';

    public function __construct()
    {
        $data = $this->getData();
    }

    public function getData()
    {
        $data = $this->request();
    }

    public function request()
    {
        $raw_data = file_get_contents(sprintf('http://api.airvisual.com/v2/nearest_city?key=%s', self::API_KEY));
        return $raw_data ? json_decode($raw_data) : [];
    }
}
```

Figure 15: Airquality.php function

The results after executing the code are displayed according to the table below as a data collection.

Air Quality FSHN

Name	Point	Latitude	Longitude	ts	aqius	mainus	aqicn	maincn	tp	pr	hu	ws	wd	ic	created_at	device_id
Tirane		41.3209955	19.8181953	2022-08-31T21:00:00.000Z	34	p2	12	p2	15	1021	73	1.54	70	01n	2022-08-31 21:30:02	1
Tirane		41.3209955	19.8181953	2022-08-31T21:00:00.000Z	34	p2	12	p2	15	1021	73	1.54	70	01n	2022-09-01 14:57:35	1
Tirane		41.3209955	19.8181953	2022-09-04T15:00:00.000Z	21	p2	7	p2	23	1021	58	2.06	320	01d	2022-09-04 17:13:44	1
Tirane		41.3209955	19.8181953	2022-09-04T15:00:00.000Z	21	p2	7	p2	23	1021	58	2.06	320	01d	2022-09-04 17:13:50	1
Tirane		41.3209955	19.8181953	2022-09-04T15:00:00.000Z	21	p2	7	p2	23	1021	58	2.06	320	01d	2022-09-04 17:13:51	1
Tirane		41.3209955	19.8181953	2022-09-04T15:00:00.000Z	21	p2	7	p2	23	1021	58	2.06	320	01d	2022-09-04 17:14:05	1

Figure 16: Data collection

7. Recommendation

The work process cannot be called complete, considering that the work consists of continuous measurements, and by means of them, the difference in the accuracy of the measurements using the two devices can be clearly distinguished and of course analyzed in a convenient way.

Normally, the addition of commercial and DIY Arduino devices in other points of the faculty will bring parallel evaluation of the measurements, including the effect of other external factors.

In the future, there will also be the construction of a platform with alpha numerical and geographical data to create an image as user friendly as possible for every user of the airqualityfshn.info website.

8. Conclusions

The main purpose of this paper is to convey the work done during the development of a project for air quality monitoring system by using smart devices. Retrieve data from IOT devices (air quality monitoring device and Air Visual monitor) handle for further analysis and correlation between air pollution factors and the impact it has on different fields, but also serves as a source for the development of an online application that apprises in real time air quality for the internal and external environments at the Faculty of Natural Sciences. An important role is played by the creation of an air quality device based on Arduino at an acceptable cost and which also empowers the management of the application created in C language. No comprehensive air quality legislation exists in Albania. The most commonly measured compounds for air pollution are:

- Particulate matter (PM2.5-PM10)
- Volatile organic compounds (VOCs)
- Carbon dioxide (CO2)
- Radon gas

The development of an online platform which currently presents some air quality elements, in a standardized format by IQAir, will be an important impetus to build an online real-time application using webservices.

This study shows measurements of carbon dioxide (CO2), particulate matter (PM2.5) and volatile organic compounds (VOCs) on indoor environment at Faculty of Natural Science and discusses the concentration levels of these parameters on indoor air quality. The data is made actionable by performing advanced analytics. The sensor-based systems are low-cost, compact, and easy to install compared to conventional analyzer-based systems, making them an ideal system for scalable monitoring. Levels of carbon dioxide and volatile organic compounds in some points we measure in faculty were not too polluted. There are some future improvements that could be made to this project including monitoring the air quality not only at faculty but also in other areas that are more popular and in we look forward to implementing cameras and robust ML analysis to both improve the obtained results and test the maximum number of allowed sensors

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