Mobile - Air Pollution Monitoring System using Internet of Things (IoT)

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***Abstract*: Internet of Things is a worldwide emerging technique which contains "smart devices" that can able to sense and connect with surroundings and interact with the users and other devices. Environmental pollution problem has been a great threat to the development of society and humans life. IoT technology provides an effective method for solving the environmental pollution problem. To overcome the problems, we propose a three-phase air pollution monitoring system with IoT. An IoT kit was developed using MQ gas sensors, ArduinoUNO, and a Wi-Fi module (ESP8266). This system can be placed in various cities to monitoring air pollution in their surroundings. The MQ gas sensors gather data from air and forward the data to the Arduino UNO. The ArduinoUNO transmits the data to the cloud via the ESP8266 module. We also developed an Android based application termed as Air-Monitoring. So that users can access the air quality data from the cloud. If a user is traveling to a particular destination, with the help of MQ sensor the pollution level of the entire route is predicted and a warning is given to the user if the pollution level is too high. This system will be equivalent to Google Traffic or the Navigation application of Google Maps for pollution Data. Finally, with the available air quality data the AQI (Air Quality Index) levels can be calculated for future Prediction.**

***Keywords*: Air pollution monitoring system; GPS; Cloud; Distributed systems; Android; sensors; Air-pollution safe route; Air quality index**

I. INTRODUCTION

Wireless sensor networks are progressively affecting everyday living. A WSN is a network consisting of sensor nodes. Each sensor can detect certain factors like air pressure, air composition, and water quality. WSNs are used in a wide variety of settings, including personal space, industrial floors, agriculture, home utility monitoring systems, factory automation, automotive, and many other fields. WSNs are related to the concept of IoT. In IoT, devices are interconnected to transmit data via distributed sensor networks. IOT has useful applications in the medical field. Devices such as smartphones and sensing systems can be associated to create an infrastructure that provides access to health care information and services. This approach is referred to as "Mobile-Health" [1]. Mobile-Health can be viewed as the consequence of the convergence of wireless communication systems, WSNs, and global computing tools.

Governments and Citizens are looking for scientific intellect to challenge the common threat of pollution in its many procedures. Currently mobile apps are able to accomplish functions like reporting status of air quality, air quality forecasts, air quality monitoring [2]–[6] in a particular area, and risks highlighting connected with threshold breaking quality, etc.

There are also mobile apps designed for mass polluting sectors like industries. Industries or corporate organizations are now able to integrate and streamline environmental processes [7], including air emissions analyses, water and energy management, and waste reduction specific to them, through such apps.

Around 90 % of the population in low and center wage nations is presented to perilous levels of encompassing air contamination. The World Bank works with creating nations and advancement accomplices to diminish contamination by supporting checking and examination, administrative changes, and ventures. In 2016 for instance, the Bank conferred US$1 billion to enable China to enhance air quality by lessening discharges of particular air poisons from mechanical, transport and country sources in the territory of Hebei, and by expanding vitality effectiveness and clean vitality through imaginative financing in the Beijing-Tianjin-Hebei district (otherwise called Jing-Jin-Ji locale) that covers the capital region and neighboring regions.

Death associated with encompassing air contamination have expanded in intensely populated, quick urbanizing areas, while death identified with cooking and warming homes with strong energizes have stayed consistent in spite of advancement additions and upgrades in wellbeing administrations. Illnesses credited to the two sorts of air contamination caused 1 of every 10 deaths in, at least 2013 than six times the quantity of death caused by intestinal sickness.

The Cost of Air Pollution: Strengthening the financial case for activity, a joint investigation of the World Bank and the Institute for Health Metrics and Evaluation (IHME), looks to appraise the expenses of unexpected losses identified with air contamination, to fortify the case for activity and encourage basic leadership with regards to rare assets. An evaluated 5.5 million lives were lost in 2013 to illnesses related with outside and family unit air contamination, causing human enduring and decreasing financial improvement.

While pollution-related deaths strike mainly young children and the elderly, premature deaths also result in lost labor income for working-age men and women. The report finds that annual labor income losses cost [3] the equivalent of almost 1 percent – 0.83 percent -- of Gross Domestic Product (GDP) in South Asia. In East Asia and the Pacific, where the population is ageing, labor income losses represent 0.25 percent of GDP, while in Sub- Saharan Africa, where air pollution [8] impairs the earning potential of younger populations, annual labor income losses represent the equivalent of 0.61 percent of GDP. Every year 3 million deaths as a result of exposure to ambient (outdoor) air pollution. [4] Every year 4.3 million deaths as a result of household exposure to smoke from fuels and dirty cook stoves. The world's population lives in places where air quality exceeds WHO guideline limits of 92%

In this paper, we describe the implementation of an IoT mobile-air pollution detection application. In section 2, existing monitoring systems for air pollution are discussed. Technologies that were used in developing our air pollution monitoring system are outlined in Section 3. The architecture of the proposed air pollution monitoring system is described in Section 4. Development methodology its use in the implementation of the air pollution monitoring system is described in Section 5. Conclusions are reported in Section 6.

A. Wireless Sensor Network

A WSN is an organization of sensor nodes, which gather data using wireless technology. WSNs have limited computation power and memory. WSNs are used to monitor low-frequency data at remote locations.

The sensor network layout is intended to recognize all the gases associated with pollution in a given location. In this paper, CO2, CO, and CH4 gases [5] are considered as parameters of air quality. Unlike the customary wired framework, expenses of WSN would be minimal. By including more devices, the network can be scaled without much re-work or complex modifications. Moreover, WSN can powerfully adjust to evolving situations.

B. Internet of Things

Internet of Things (IoT) [20] [21] encompasses regular objects ("Things") that have network availability, permitting them to send and get information. "Things" include people, information, software agents, or any other virtual participating actors. There are five kinds of "Things" utilized in this paper: Arduino Uno [22] (Microcontroller), ESP8266 (Wi-Fi Module), Cloud service (Ubidots), gas sensors, and Android. These "Things" are coordinated to make a framework such that each "Thing" can work individually and can gather, store, and recover information to address the problem.

Fig.1. Layered Architecture of IoT

The fundamental IoT model is a three-layered design composed of the Application, Network [2], and Sensor Layers (htt1) (Figure 1). In the Sensor Layer, data is attained from the real world. The Network Layer receives data sent by the Sensor Layer. This layer acts as middleware between sensor layer and application layer. Lastly, the Application Layer provides services to incorporate or investigate the data that has been received from the previous two layers. In this work, a 3-layered architecture was used.

C. Global Positioning System (GPS)

GPS sends data to receivers that are installed on the ground. Data is collected from satellites orbiting around the earth. Anyone can utilize GPS for free with a suitable receiver. This technology is used for navigation systems.

Google Maps Navigation was utilized as a part of this research. Google Maps Navigation is a versatile application that has been incorporated into the Google Maps mobile application. Google Maps Navigation utilizes an internet connection to access the GPS navigation system to find the user's location. The user can enter a destination into the application, which will plot a path from source to destination. The application shows the user's advancement along the route and it issues directions.

D. Android Platform

Recently, improvements in smartphone technology have changed the importance of cellular telephones. A phone is not just used for communicating but has also become a crucial part of everyone's daily life. Presently the electronic market is acquired by Android technology.

Over time, smartphones and the Android system are having become more prevalent. In this work, we used Java language, the Eclipse platform, Android ADT, and the Android SDK (htt2) to develop the IoT- android application. The IoT- application uses user location data (via GPS system), the Internet of Things (IoT), sensors, and standard websites to give air quality data. If a user is setting out to a destination, the pollution level of the entire route is predicted, and a warning is displayed if the pollution level is too high so that the user can re-route his journey.

E. Ubidots-Cloud Service

Data measurements in a sensor system are vast and versatile in nature. Therefore, it is necessary to have high data storage and processing capacity. Also, lightweight processing is needed as opposed to heavyweight processing. Currently, various cloud frameworks are available which can be used to process sensor data.

In this work, Ubidots is used as a cloud service to capture and process sensor data. To publish sensor data on the internet, two items are needed: a place that can be used to access and store data, and a way to communicate with it. Typically, these consist of a web application (place) and an API (way of communicating). A web application, like other applications (programs), runs locally on computers but is located on the web (e.g., Yahoo Mail and Google Maps). In this project, Ubidots was selected as the web Application. The API, in this context, specifies the way data is exchanged with the web application. In this work, Ubidots's API was used to exchange sensor data from Arduino to the web application.

The following approach was used to store and process data in Ubidots:

a) The initial step is to create a new account and login on the site “Ubidots.com”.
b) After creating the account, setup the data source “Air Pollution” that will provide the API to publish sensor data.
c) Next, add a variable to the data source “Air Pollution” that will hold the values collected and published by ESP8266.
d) After creating a variable, store the "Variable ID" value such that it can be later substituted in Arduino code.
e) The last step is to generate an "Authentication Token", i.e., a security token. This prevents former users from posting data to the user’s variables that will be utilized further.

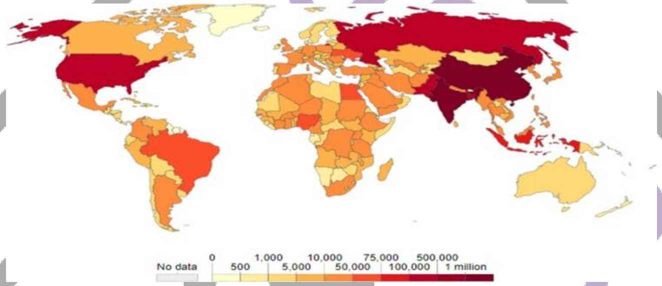

Fig. 2 Absolute number of deaths from outdoor air pollution [23]

Figure 2 is representation demonstrates without a doubt the quantity of death ascribed to outside air contamination by nation from 1990-2016. At the yearly level, the contamination related death is ruled by China and India - each with between 1.1-1.2 million deaths in 2016. In the period since 1990, China's expansion in contamination related death seems, by all accounts, to be moderating with just a little increment since 2010. Interestingly, India's death rate from open air contamination keeps on expanding.

There are numerous approaches to quantify air contamination, however a key indicator is called "PM 2.5" — a standout amongst the most hurtful classes of airborne poisons.

The "PM" remains for "particulate issue," and the "2.5" stands for 2.5 microns in breadth or littler — generally the measure of a solitary bacterium. Such contamination, as Business Insider's Lydia Ramsey clarified in 2016, "is particularly risky in light of the fact that it can get held up in the lungs and cause long haul medical issues like asthma and unending lung infection."

At the point when PM 2.5 levels go above about 35 micrograms for every cubic meter of air, it can turn into a noteworthy medical issue. The WHO prescribes keeping PM 2.5 levels to around 10 micrograms for each cubic meter.

Air contamination happens in indoor (e.g. family unit) settings and outdoor air situations—this information passage centers around encompassing outside contamination. The information passage for indoor contamination can be found here Air contamination can be characterized as the outflow of hurtful substances to the air. This expansive definition consequently, exemplifies various toxins, including:

- Sulphur dioxide (SO2),
- Nitrogen oxides (NOx),
- Ozone (O3),
- Particulate matter
- Carbon monoxide (CO)
- Volatile organic compounds (VOCs).

Carbon dioxide (CO2) and other greenhouse gases are not typically considered within this category and are treated separately on Our World in Data.

III. PROPOSED APPROACH

IoT App for pollution management, industries based specifically, streamline and integrate environmental processes, including air emissions analyses, water and energy management, and waste reduction. Such apps provide visibility for users, specifically industries into the risk of incidents such as chemical leaks, oil spills and toxic substances improper disposal, while compliance strengthening with environmental standards and regulations. Development outsources assistance for such apps that can cover areas like:

•Common platform to track and manage initiative environment across organizations
•Track compliance with ISO 14001 and other industry specific environmental standards
•Real-time environmental processes view, audit incident and findings
•Trigger notifications for threshold breaches
•Risk highlights related with threshold breaks
The app had Air Quality Monitoring [24] following features,
•indices of air quality for a specific city using real-time computation, air quality daily forecasts,
•specific reports for air quality measures based on locations,
•air quality maps generation.

The design of the air pollution monitoring [25] system involves three main phases:

Phase 1: detect the concentration of air pollutants in the area of interest via sensors.
Phase 2: develop a user-friendly and portable interface – an Android application, which the user can use to know the pollution level in his/her particular area.
Phase 3: predict air quality using the analytical module.
The proposed air pollution monitoring system is presented in figure 3. Details of the comprehensive implementation can be visualized in figure 4.

IV. IMPLEMENTATION AND RESULTS

The comprehensive implementation details can be visualized using flowchart as shown in Figure 3.
Phase 1: Detection of air pollutants level
In this section, air pollution detection kit is developed using IoT. This is built in two steps:
Step 1: the first step deals with the collection of data from gas sensors connected to Arduino board and information is sent to a cloud platform (i.e., Ubidots) that stores it.
Step 2: the second step portrays accessing this information utilizing Android platform.
For this purpose, the data is generated by gas sensors (viz. Carbon monoxide, Carbon dioxide, Methane) that read concentration of gas in the region. The details about gas sensors used have been tabulated in Table 1

TABLE 1 SENSOR DETAILS

Sensor	Gas	Description	Range
MQ7	Carbon Monoxide	Suitable for sensing CO concentration in the air. It can detect CO-gas concentration anywhere from 20 to 2000 ppm CO is detected by method of cycle high and low temperature	0-100 (No effect) 100-800 (Risky) 800-2000 (Very high)
MQ2	Methane	Useful for gas leakage detection in home and industry. Can detect LPG i-butane, Propane, methane, alcohol, hydrogen and smoke	0-1000 (Normal) 1000-15000 (Risky) (15000 - 50000 Very High)
MQ135	Air Quality	Responsive to a wide scope of harmful gases like alcohol, acetone, thinner, formaldehyde and so on	0-500 (Normal) 500-1500 (Risky) 1500-2000 (Very high)

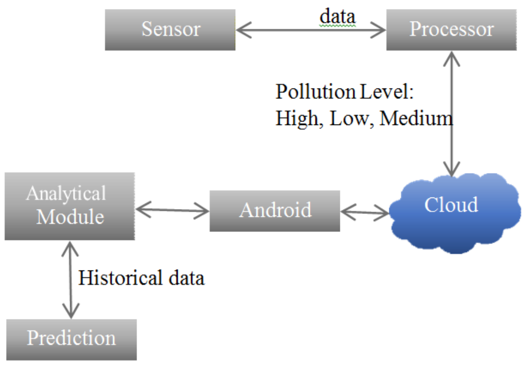

Fig. 3. System Overview

Step 1: Connecting Arduino to Cloud

In step 1, IoT Kit is constructed in which the data generated by sensors is sent to the cloud, where it is processed and displayed to the user in the appropriate form. The overview of phase 1 can be represented as shown in Figure 4.

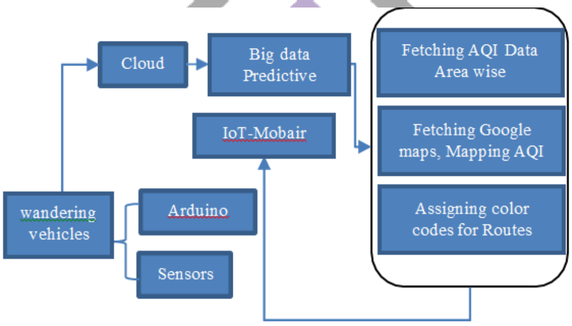

Fig. 4. IoT Design Overview

First, the Arduino sketch is setup, and the connections are drawn. A program in Arduino is written that can find air quality based on gas sensor readings. For example, a methane sensor (MQ-4) is used to sense methane gas in the air. The output of the MQ-4 sensor is displayed as an analog value on the COM screen of Arduino.

The MQ-4 sensor is connected to the Arduino board. Arduino, in turn, uses an ESP8266 Wi-Fi module to connect to the network to send data.

Algorithm 1 for Designing App module and connecting past information to real-time current location information prediction.

Input: Measure pollution and air quality measures and condition prediction

Output: IoT- APP with all features pollution control and alert system

Algorithm

Step 1: Read the values from sensor
Step 2: The value sent for Arduino for processing value higher to threshold process then step 3
Step 3: AQI classified as high then step 7
Step 4: Value less than are equal to threshold AQI classified as Normal then goto step 7
Step 5: Value is less than min/max expected then step 6
Step 6: Sensor is damaged
Step 7: Data is stored appropriate format based on (Latitude, Longitude) the pollution at the place is determined then goto step 13 and 14
Step 8: Android application design components are divided in to phases step 9 and step 10
Step 9: To find the pollution level at particular area then step 11
Step 10: To know the path is taken is pollution safe then step 12
Step 11: Using GPS, (Latitude, Longitude) of the place is determined
Step 12: Source and destination is entered and intermediate place are determined
Step 13: Data displayed in appropriate form with help of current and past stored data
Step 14: Pollution path is drawn using suitable color conversion

In above mentioned algorithm 1 are contain two scenarios are there one is real-time pollution, air quality, and CO2 sensor deployment to Arduino board for collecting current pollution state. To processing an android app design with first, fetching current location and predicting current and future status of pollution and air quality using coloring system it is shown clearly in table 2. After making the required hardware connections, gas sensor data is collected as shown in Figure 5.

```
YourDuino.com MQ Gas Sensor Test
Analog value = 231.00   Digital value = 0 ALARM!
Analog value = 231.00   Digital value = 0 ALARM!
Analog value = 237.00   Digital value = 0 ALARM!
Analog value = 226.00   Digital value = 0 ALARM!
Analog value = 225.00   Digital value = 0 ALARM!
```

Fig.5 COM Screen showing the values of Sensor Data

IoT- To ensure that all the sensors are working as expected and the values are being retrieved correctly, it is essential to check each of these conditions in the Arduino sketch by an appropriate algorithm. A sample algorithm for a CO sensor in the Arduino sketch is shown below:

Algorithm 2 for monitoring CO (Sample Sensor)

Input : Pin numbers
Output : CO Level in the environment
Setting : Menu bar □ Tools□ Set Board Type as Arduino Uno Menu□ Tools□ Set serial Port as COM 20.
Variables Used ɵ: - C o-level in the atmosphere
µ: - The value of the same gas clean air.
Ψ: - The value above which the pollution is considered high
α: - The time after which the user wants to re-read the value again from the sensor.

ALGORITHM:

Step 1: Read the CO value with delay of α. This data is logged to an excel file (So that they can be sent to a cloud).
Step 2: if (ɵ >ψ && ɵ< µ)
Then the value is sent to the cloud and is marked as normal in the range column
Step 3: if (ɵ<ψ)
Then send value to the system with value as high
Step 4: Sensor is not in correct working condition. Kindly re-Check it.

Once the correct sensor values are retrieved, they are sent to the cloud. In Arduino, an Arduino HTTP client is created that calls a JSON service passing the data to cloud and stored in the cloud. After creating the Arduino HTTP client, a project is configured in Ubidots using the Ubidots web interface so that the client can send data along with an authentication token. In the Ubidots web interface, variables are created to store gas sensor values. Once the variables are configured, they can be used to send data. In the cloud, data is stored in the following format:

- Location ID
- Latitude
- Longitude
- Timestamp
- Concentration of CO
- Concentration of CH4
- Concentration of CO2
- AQI

For each Location ID where sensors are placed, the corresponding latitude and longitude and the concentration of various gases are stored. Based on the concentration of gases, the AQI is calculated. AQI is India's new color-coded index to describe the air quality, which is the same index we have used in our project.

Step 2: Connecting Ubidots to Android

In the previous step, Arduino was connected to the cloud (i.e., Ubidots) such that sensor data is sent from the Arduino board to Ubidots. In this step, the developed Android application IoT- receives sensor data sent by Arduino using Ubidots services. The following steps are undertaken in order to accomplish these tasks:

•**Develop Android client:** To handle the HTTP connection to the Ubidots server, an Android client is developed. For security purposes, the authentication token is used.

•**Handle JSON format to read data:** After requesting remote services by the android application, a JSON response is received that is analyzed to extract data, i.e., the variable value (sensor information), timestamp, and AQI.

•**Detecting Air Pollution Level:** In India, the government reports air quality as AQI (Air Quality Index). The main components for indexing are: particulate matter (diameter <10 µm and <2.5 µm), ozone (O3), nitrogen dioxide (NO2), and carbon monoxide (CO). From the cloud, the concentration of these pollutants is retrieved. The Indian government has set standards to provide appropriate warnings messages when the pollutants increase above a specific level. The AQI-color code is shown in Table 2.

TABLE 2 AQI – COLOR CODE

AQI	Remark	Color Code	Remark
1-50	Good		Minimal impact
51-100	Satisfactory		Minor breathing discomfort to sensitivity people
101-200	Moderate		Breathing discomfort for the people with lungs, asthma, and heart diseases
210-300	Poor		Breathing discomfort to most people on prolonged exposure
301-400	Very Poor		Respiratory illness on prolonged exposure
401-500	Severe		Effects healthy people and serious impact to those who existing diseases
0-0	No DATA available for this region		No Data yet created for this area. Therefore, it is necessary to get the air of that area tested

Phase 2: Creating the front-end Android interface

These steps are described below:

Step 1: Draw route from source to destination

For a user traveling from a source to a destination, the pollution level of the entire route is predicted and a warning is displayed if the pollution level is too high so that the user can re- route his journey.

The data collected from the sensors and other trusted websites is made as are placed in a large database. When the user enters his destination of travel, the IoT- android application first converts the address into corresponding latitude/longitude form. The latitude and longitude are searched in the cloud-based database. Intermediate places between the starting and finishing location are also displayed. Suitable colors as shown in Table 2 are used to indicate the pollution level on the map. The route is drawn as shown in Figure 6.

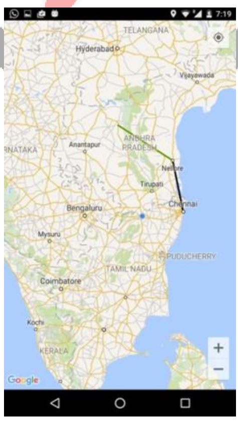

Fig. 6. Android Application showing Pollution Level in the Route

Step 2: Create charts to display data collected by IoT

Based on data retrieved by the sensor, using external libraries charts are drawn by android app as shown in Figure 7.

Fig. 7. Chart representing the Pollution Level as shown by the Sensor

Step 3: Prediction and Analysis

Historical data can be used to predict pollution levels for subsequent days.

A dataset (Figure 8) is maintained so that an evaluation of consecutive days can be done. Suppose AQI is mapped to 7 consecutive days at a particular time such that on

Day 1: From time 12:00-15:00 the AQI is 423 (High)

Day 2: From time 12:00-15:00 the AQI is 500 (High)

Similarly, for the next five days, the AQI is very high from 12:00-15:00. Therefore, we can predict that the pollution level on the eighth day at the same place and time will be high (i.e. ~400-500). Therefore, if the system is capable of logging daily data, it can be used to warn the user not to travel during that time. This same data can be represented in the form of scatter plots and histogram in order to make the analysis easier. In Table 3 the high concentration of dots in the time duration 12-15 shows that during this time particular region is highly polluted.

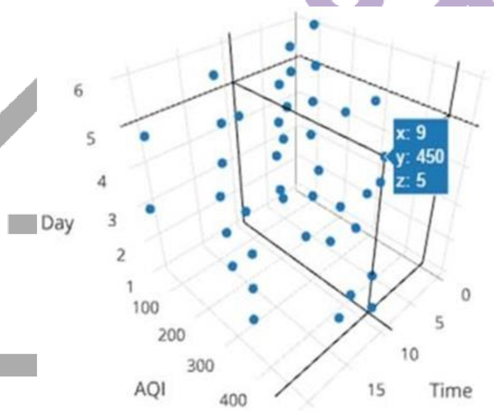

Fig. 8. Scatter Plot of AQI of Air

Table 3 Sample dataset

S. No	AQI	Time	Day
1	100	0	1
2	50	3	1
3	100	6	1
4	400	9	1
5	423	12	1
6	150	15	1
7	300	18	1
8	101	21	1
9	120	0	2
10	70	3	2
11	110	6	2
12	450	9	2

Pollution level at regular time instances in a day can be represented using histogram as shown in Figure 9.

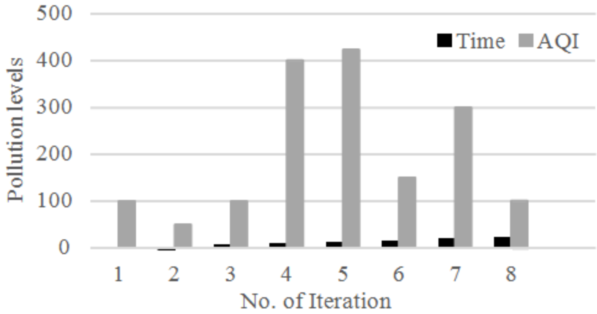

Fig 9. Histogram representing the Pollution Level

Energy efficiency: the proposed model works with small devices, such as sensors, Arduino board, Ubidots (for Cloud)., which all are low energy devices. Comparing with traditional pollution monitoring systems, it is more efficient and consume less energy.

CONCLUSION

Pollution in earlier days was negligible. Currently, however, pollution is increasing day-by-day because of various reasons such as industrial growth, development of automobile industries, and chemical industries. Therefore, to reduce the level of pollution from such sources and to protect humans and the environment from harmful gasses, this air pollution kit was developed that helps a person to detect, monitor, and test air pollution in a given area. The kit has been integrated with the mobile application IoT- that helps the user in predicting the pollution level of their entire route. Further, data logging can be used to predict AQI levels. This proposed air pollution monitoring kit along with the integrated mobile application can be helpful to people suffering from respiratory diseases. The app had following features, indices of air quality for a specific city using real-time computation, air quality daily forecasts, timing outdoor activities for different recommendation of generation, air quality dips related to health risks, specific reports for air quality measures based on locations, air quality maps generation. The proposed system faces with computational complexity particularly when we are dealing with big sensor data. One solution could be using fog computing, instead of cloud computing to reduce computation complexity and enhance the performance of the system. We can also implement zero tolerance fast big data real-time stream analytical tools to process such a complex system.

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