International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

A Forecasting tool for Air Quality Monitoring Built up on Cloud and IoT

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Abstract*: Air pollution has turned to no less than a monster and is becoming notorious with every passing day. The human race has been solely responsible for taking the world to such a state. With ill effects of pollution becoming glaringly evident it has been instrumental in forcing the world to get up from the deep slumber and act out. Air quality monitoring is a process in which the quality of air is monitored and on the basis of recorded information, it is conveyed to general public about the quality of air they are breathing. Air pollution poses serious problems to persons suffering respiratory disorders and there is a necessity to provide such target group with a tool which helps them to be aware about the pollution scenario and also alarms them with the impending critical situation well in advance. It is elementary for them to avoid situations where in lies a chance of exposure to pollutants leading to attacks which could prove to be fatal at times. This advance information will go a long way in helping such target audience to minimize their exposure to pollutants and thereby helping them to mitigate their ordeal on exposure to pollutants. Apart from getting predictive alarm, it gives a fair idea of the existing pollution scenario to the targeted stakeholders. This work discusses the implementation of cloud based IoT system for air quality monitoring which is available as a web interface as well as in a form of an android application.The developed system uses Nitrogen Dioxide, Sulphur dioxide, Particulate Matter 10 micrometers or less in diameter (P.M.10) sensors along with the temperature and the humidity sensors to form a wireless sensor node. An android application has also been developed which can be installed by the user. Once registered the user can access the data from the application which allows the users to observe the data of sensors along with the air quality index (AQI) and also provide the registered user with an alarm notification one day in advance about the probable level of pollutants as well as the AQI.

Keywords* : *Air Pollution Monitoring , Air Quality Index, Android Application , ANFIS, Cloud, Health Care P.M.10.

I. INTRODUCTION

Air pollution has taken the world by storm and is being prominently discussed because it has modified the ecological cycle like anything. Things have not happened all of the sudden and it has taken years to reach this level where the human race seems to be helpless. The human race finds itself in a situation where they can no longer control the happenings, instead they can only take measured steps which if properly implemented may help to mitigate the effects of air pollution on the human race. Air pollution is one of the major player resulting in climate change which has caused anomalies in the temperature pattern, crops production and has led to advent of newer diseases causing widespread devastation. New Delhi presents a visible example of what air pollution can do, forcing people to go for forced holidays and tweaked schedules [1].

Consistent exposure to high pollution levels results in escalation of suffering in patients effected from respiratory disorders such as asthma and chronic obstructive lung disease leading to impaired lung functioning [2],[3],[4] and increased mortality[5].“Air pollution cut shorts the life expectancy of around 7 million people each year, and nine person out of 10 breathe polluted air on account of traffic emissions, industry, agriculture or incineration”, said WHO Director-General Tedros Adhanom Ghebreyesus[6].Outdoor workers in Delhi are highly vulnerable to respiratory impairment from vehicular exhaust in the workplace[7] . Air pollution charts within the top ten health risk in India [8]. Asian megacities are now getting exposed to pollution level which is seriously affecting the humans and has brought the ecosystem at an edge.[9]

Numerous studies endorse the ill effect of pollutants on the respiratory system (pulmonary oedema, pneumonitis, and bronchitis, shortness of breath and coughing), the immune system, and the cardiovascular system [10]. Increased Mortality rates have been reported on account of prolonged exposure to PM 10 concentrations [11].

With these developments around the world it is enough to frighten a person suffering from respiratory disorder and if this is the speed with which we move on without caring for the environment, the days are not far when we would be paying for the air we breathe.

A. The quantum of the issue

World health organization identifies around 100 to 150 million people around the globe suffering from asthma and is escalating exponentially. World-wide, deaths from this condition have reached over 180,000 annually.

- India clocks around 15-20 million asthmatics.
- In India around 10 to 15% patients lie in the age bracket of 5 – 10 years [12].

B. The socio-economic side of the issue

Though deaths due to asthma are not comparable in size if it is to be measured out. It tends to occurs epidemically specifically in children and youths. The socio-economic burden is tremendously high. At the core asthma is largely avoidable and serious effort both at the national as well as at the international level may help to break even with these possibilities.

- WHO assesses out that the economic costs associated with asthma are estimated to exceed those of TB and HIV/AIDS combined.

Manuscript published on 30 August 2019.
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- Annual asthma care cost in United States alone exceed US$6 billion.
- Britain shells out around US$1.8 billion on health care for asthma number of working days lost due to illness.
- Australia, clocks an expenditure of around US$460 million toward asthma care [12].

With air pollution turning into a serious issue a lot of discussion, research and promotion is being carried out at the academic as well at the social front on how to tackle and reduce air pollution. Way back air pollution was more of a routine practice carried out by the authorities for the sake of it and for numerous of times got unreported too, just because it was not that critical and was singularly catered by government sector only. With air pollution getting critical and series of technological advances over the years have allowed individuals to set up their own monitoring system that too at affordable cost and have been able to play a defining role in the way in which air pollution is being monitored. Amalgamation of smart phones with IoT has further cemented the role of IoT and has taken unmeasurable strides in the field of Bio medical applications [13],[14]. Private monitoring station have moved the perspective of air pollution monitoring to a micro level with a capacity to map whole of the world and have also allowed researchers to predict the climate pattern and have been able generate data which has allowed specific measures to be taken toward mitigating climate change.

The Internet of Things (IoT) is the happening thing and has the world drooling over it. IoT is a worldwide network of objects which communicate using standard communication protocols [15]. The idea exercised by IoT is to make objects responsive, adaptive and omnipresent around us. Radio Frequency Identification (RFID), Near Field Communication (NFC), and Sensor Network (SN) technologies were the precursors to the IoT technology and their success in the real world led to the advent of IoT. Physical entities armed with local intelligence form a network of smart objects and such smart objects are capable of sensing and relaying the sensed parameter over the internet to a remote server, thus making it possible to control the physical object from a distance [16]. IoT has expanded the boundaries of information and communication and has introduced numerous services which have been able to create additional business opportunities. Though prior to IoT also there were system which were able to relay the information over the internet, but IoT proves out to be a system which provide opportunities to map a greater number of devices thus creating a pervasive computing environment.

IoT solutions have been the game changers in the technology sector and has converted working models into smart working models and has taken the health care, smart cities, environmental monitoring, inventory management , product management by storm [17] [18]. IoT also has been able to tremendously downscale the size of the overall system which adds up to its popularity.

This work discusses an IoT tool using Arduino for air quality monitoring named as “Breathe Safe”. This tool uses an android application and a Cloud User Interface to provide the information about pollutants and the air quality index to the users. Once the user registers himself then he gets the privilege of getting a predictive alarm regarding the status of sensors and air quality, helping him to take preventive measures.

The rest of the paper is organized as follows; Section 2 discusses the existing systems and the need to present the proposed system followed by section 3 which presents the overview of an air pollution monitoring system. Section 4 speaks about the choice of sensors and section 5 presents the proposed system. Result and its discussion are presented in section 6 followed by conclusion.

II. DEVELOPMENTS IN AIR QUALITY MONITORING

Air quality monitoring has progressed from a government owned system used by government to a system which has moved right at your bedroom helping you to live a better life.

In the early days the monitoring system were owned only by the government and were bulky, needed huge maintenance and were very expensive. With technological advancement over the years the system became compact and light in weight and inexpensive. Due to this the system moved out from being a government monopolized system to a system for all. This transgression has allowed a lot of fruitful research to take place and has helped the human race to be more aware and more sensitive about the air they breathe. The basic air quality monitoring system were offline based on gas analyzers which were bulky, expensive and had a less efficiency [19]. With technological advancement both in hardware and software domains the system has moved from being offline to online and has been able to take a huge stride in terms of technology improvisation, reduction in size as well as cost and this has allowed individuals to set up their own station and carry on with air quality monitoring. In the early days of online monitoring system, the lead was taken by GSM based systems. The initial progression towards the present day system was initiated by embedded system using the SMS service to provide information to the concerned end users [20]. Online systems upgraded to a server based system with frontend tool like visual basic along with suitable data base were able to receive the data of sensors and were able to display as well as store them [21]. With development of web technologies the system transformed from a standalone based system to a thoroughly online system where the information relayed from the sensor was being displayed on the web page which could be accessed throughout the world[22] .Introduction of Wi-Fi technology added wings to this progression and laced the system with some amount of intelligence and allowing them to forward the measured parameters on to the cloud very easily . The cloud technology supplemented the system by allowing large amount of measured data to be stored on cloud with ease allowing researchers across the world to use the data and substantiate their research [23]. The advent of Smartphone allowed customized App to be developed and moved the system from the confines of labs or research station right at the hand of the end user allowing him to be updated round the clock about the status of air he is breathing. This has helped to break the ice in terms of empowering the general public with information about air pollution which has created an improved sense towards making one’s surrounding a better place and has inspired people to take efforts both in terms of avoiding tasks which aggravate air pollution as well as mitigating the effects of air pollution [24].

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Air pollution monitoring system can be divided into three categories [25] viz.

A) Systems based on analyzers [26],[27],[28],[29],[30],[31].

B)Systems based on available historical data from monitoring agencies [32],[33],[34],35].

C)Systems based on wireless sensor nodes [36],[37],[38],[39],[40],41].

Guidelines regarding installation and commissioning of an air pollution monitoring system disclose that setting up such a system is tedious and expensive [42] . With central authorities being the sole agencies carrying on with the task of measuring and maintaining data pertaining to air, it kept the general population aloof from the system. With research and technological advancements, systems have moved from being government owned and controlled one to system which can be owned and controlled by anyone who is concerned. Such systems have shown satisfactory performance and have an acceptable accuracy level. We still observe that there is a need to enhance the existing system to a level where they are more user friendly, cater to what the end user needs and provides him a tool in terms of some alarm or notification which helps him to have an idea of the status of pollution status well in advance ,thus allowing him to plan his movements as per his needs.

III. AIR QUALITY MONITORING SYSTEM

This section discusses what an air quality monitoring system is all about.

A. Air Quality Monitoring

Air quality monitoring is a process of analyzing the existing air quality on basis of recorded data and extracting trends which may help to plan out remedy measures and formulate legislation which may help to mitigate pollution.

B. Objectives of Air Quality Monitoring [42]

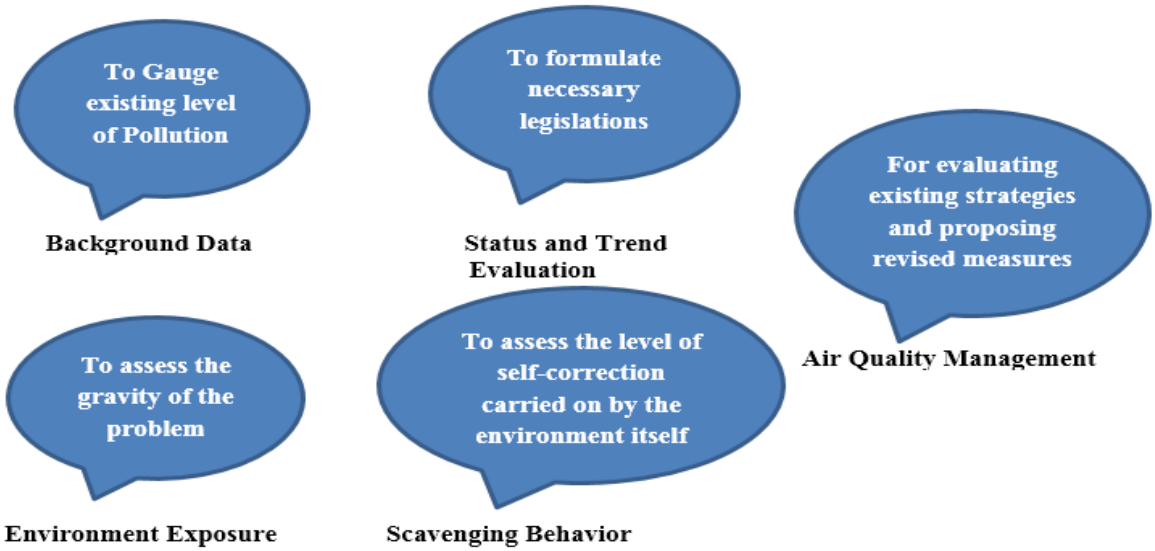

Fig 1 Objectives of Air Quality Monitoring Systems

C. Guidelines for Air Quality Monitoring [42]

For an Air Quality monitoring station to be setup one needs to be armed with background information and an assessment of components of monitoring

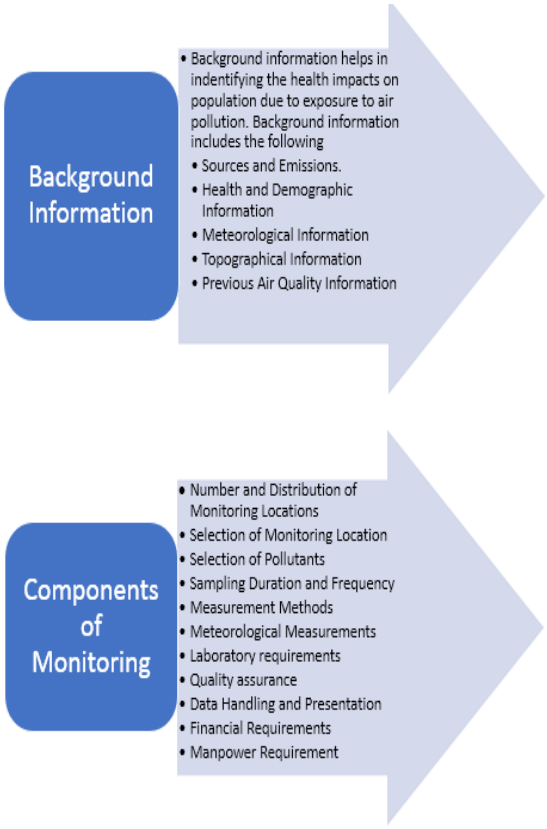

Fig 2 Significance of Background Information and the specified components of monitoring.

IV. SELECTION OF SENSORS

Sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), respirable suspended particulate matter (RSPM), suspended particulate matter (SPM) along with many others are recognized as criteria pollutants and play a defining role in deciding the air quality. The Particulate matter is a combination of small particles and liquid droplets having the capacity to impair lung functions, vision and may lead to deaths too [43].

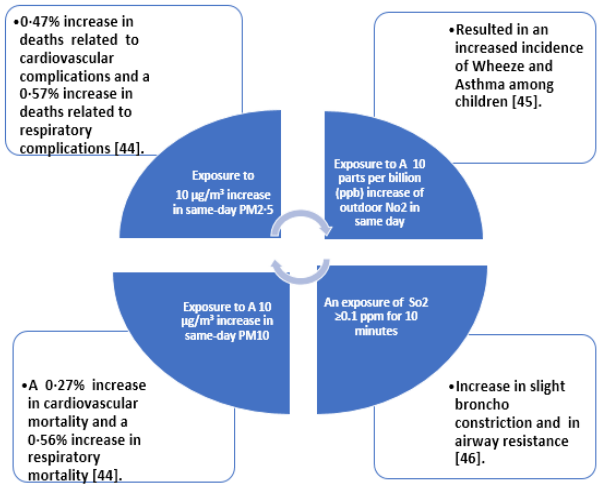

Fig 4 Gravity of exposure to pollutants

- An exposure to Nitrogen dioxide, Sulphur dioxide, Particulate Matter, and traffic aggravates the risk of exacerbations of asthma symptoms and facilitates induction of Asthma in both children and adults. Young kids exposed to shoddy living conditions become soft targets and there is a need of concrete efforts from government to alleviate this burden for them [47].
- Prolonged Increased exposure to airborne particulate pollution can trigger asthma exacerbation [**48**], with an increased risk of lung and heart disease along with a shorter life expectancy [**49**].

For Air Quality Index to be calculated there is a need to record the concentration of minimum three pollutants out of which one of should be PM10 or PM2.5[50]. Thus for our system we include Sulphur Dioxide (SO_2) , Nitrogen Dioxide (NO_2), Particulate Matter (Size less than 10µm) or PM_{10} such that we are able to calculate the AQI correctly and we include temperature and Humidity Sensor to measure the environmental parameters too.

V. PROPOSED SYSTEM

The proposed system employs Arudino along with Sulphur Dioxide (SO_2), NO_2 and PM-10 Sensor along with the temperature and humidity sensor to achieve the task of air quality monitoring . The sensors sense the values and with the help of Arduino forwards the value to the cloud. The data management module at the cloud as well at the App suitably disseminates the information to the desired users.

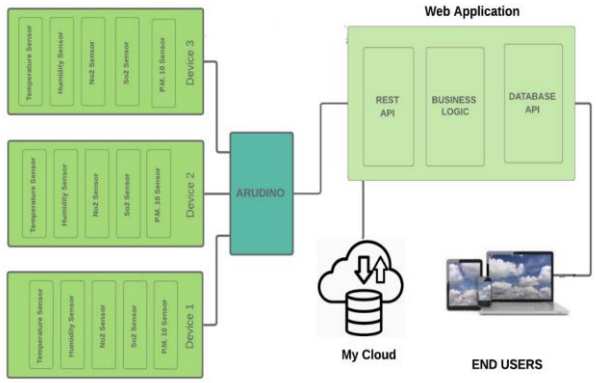

Fig. 5 System Diagram

A. Device Implementation

The system employs Arduino Uno which is an open source electronics platform compatible with easy to use hardware and software and has helped researchers, hobbyists in developing interactive projects with ease (Arduino)[51]. The sensors used are

- Pollution Sensors

1) Nox – MQ6 Gas Sensor
2) So2 – MQ6 Gas Sensor
3) P.M.10 – Dust Sensor Module: DSM501 series

- Environmental Sensors

1) Temperature – DHT 11
2) Humidity – DHT 11

B. Management Platform

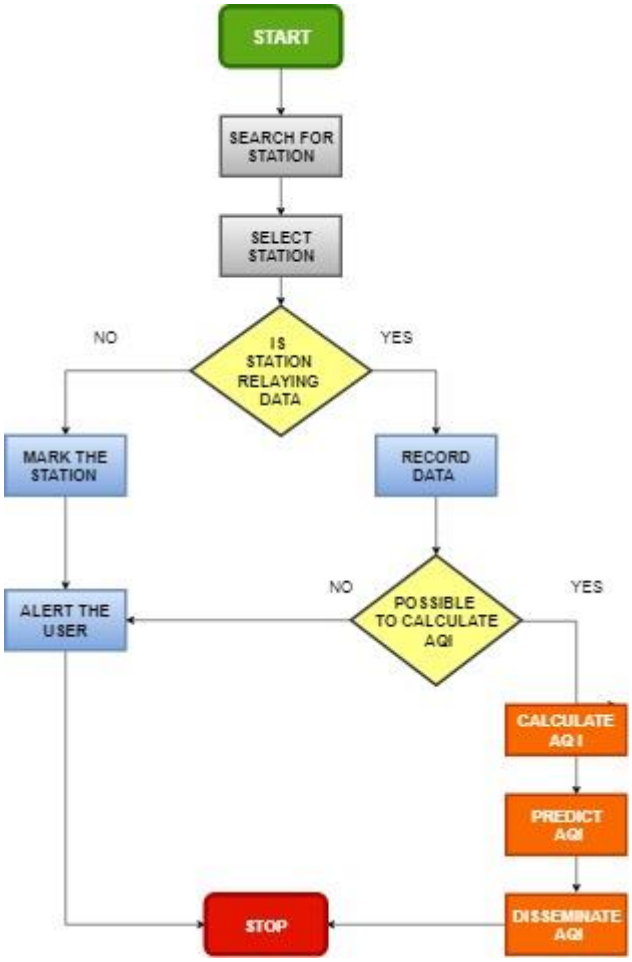

Fig 6 The working flow

In this section, we exemplify the software platform that we have worked upon to manage the sensors and the system. Management platforms is categorized as

a. Cloud Computing Service
b. Android Service
c. Data base service
d. Prediction Service

a) Cloud Computing Service

Cloud computing service involves development of functionality to manage the sensors where it would be required to coordinate between the Sensor Owner, the cloud provider and the end user. The sensor owners develop the system and develop functionality to publish the data on the cloud. The cloud providers then provide the cloud services and may charge the end user with some fee for the access. We utilize the PaaS (Platform As A Service). PaaS provides a platform for software creation. This platform is delivered over the web, and gives developers the freedom to concentrate on building the software while still not having to worry about operating systems, software updates, storage, or infrastructure. Another important factor of PaaS is that it allows business to design and create applications that are built into the PaaS with special software components. These applications, or middleware, are scalable and highly available as they take on certain cloud characteristics. [52]

The "Breathe-safe" application that we developed on PaaS platform utilizes various computation algorithms and AQI calculation based on current sensors values and showing it to user on GUI using JavaScript based charts & Graph API. For PaaS platform we use Everdata cloud services for deploying our services for end users. This service relays the information on GUI and Android App.

b) Android Service

Android has turned into a highly popular operating system operating in millions of smartphones. Android scores in terms of user friendly features and services. Many companies are using android operating system for their smartphone device to provide high end features to their users. The official language for Android development is Java. The official integrated development environment (IDE) for Android platform provided by Google. The Android Studio allow us to create Application and provide easy to access API of Google. This gives developers the ability to create customized apps without the headache of implementing the core services.[53]

c) Data base service

In a well-designed application the database logic is separated from the business and presentation logic. It must be able to run independently from the business and the presentation logic. This allows the developer much better maintainability, testability, reusability and replace ability. To achieve this, we follow the DAO (Data Access Object) Pattern for implementing the data base services.[54] The DAO advantage is its separate the database functionality with the business logic and allow easy migration or changes in the database layer without effecting the business logic. The DAO's can create, read, update and delete (CRUD) the model objects in/from the datastore. The model objects are just javabeans representing real world data, such as User, Sensors, AQI, etce

- **Data Processing in Arduino Uno:** Data from sensor is relayed to web application using the GSM
- **Creation of temporary data base:** The data from sensors is buffered momentarily in flash memory of Arduino uno to prevent the data loss in case of network issues.
- **Cloud Data Analytics:** Data from different sensor is logged in the mysql data base. This data from database is utilized as input for machine learning service. Machine learning service carries on with the prediction functionality and is deployed as a web service to be used by any user as desired.
- **Data Representation:** The Web application displays the data in the form of Graphs and Tables whereas the Android App directly displays the data on the dash board .

d) Forecasting Service

We have used ANFIS combined with Substractive clustering method to achieve forecasting. ANFIS maps the inputs with the outputs based on fuzzy if-then rules along with the specified input-output data pairs. It helps to achieve inference from imprecise model so as to derive conclusion, thus bettering the human experience. Membership functions for the mapped input output training data pair with the Fuzzy If-then rules are obtained. Membership functions are attuned with the associated parameters which approach desired data sets using the neural training process [55]. Precursor membership functions are achieved using substractive clustering method. The Subtractive Clustering Method (SCM) proposed by Chiu [56], is an extension to the mountain clustering method [57].

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Chiu's SCM estimates the number and initial location of cluster centers along with the TSK (Takagi, Sugeno, and Kang) fuzzy rules from input/output data. SCM operates to identify the optimal data point defining a cluster center based on the density of neighboring data points. SCM is fast, specifically for high dimension problems with a moderate number of data points.

VI. RESULT AND DISCUSSION

Fig. 7 below shows the developed "Breathe-Safe" module which has been utilized to carry on with air pollution monitoring.

Fig.7 One Unit of "Breathe-Safe"

03 units of "Breathe- safe" were installed at three different locations to form a wireless sensor network. The nodes sense and forward the values of So2 No2, P.M. 10 , temperature and humidity to the cloud where the data management module accepts the data and displays it through the graphical user interface and is alternately published at the android application Breathe Safe. Once registered the user can access the information on the web interface as well at the Android Application. The user has a choice to observe the data from three station as per his requirement. Apart from displaying the current data the user can also go in for historical data recorded over the time. The registered users enjoy the privilege of being provided the predicted values of pollutants along with the AQI 24 hours in advance which may help him to alter is routine such that he is able to minimize his exposure to the pollutants and ease his agony in terms of trigger which may lead to an asthma attack.

Fig. 8 Data recieved from the sensors and its subsequents diplay along with the AQI

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DOI: 10.35940/ijitee.J9992.0881019
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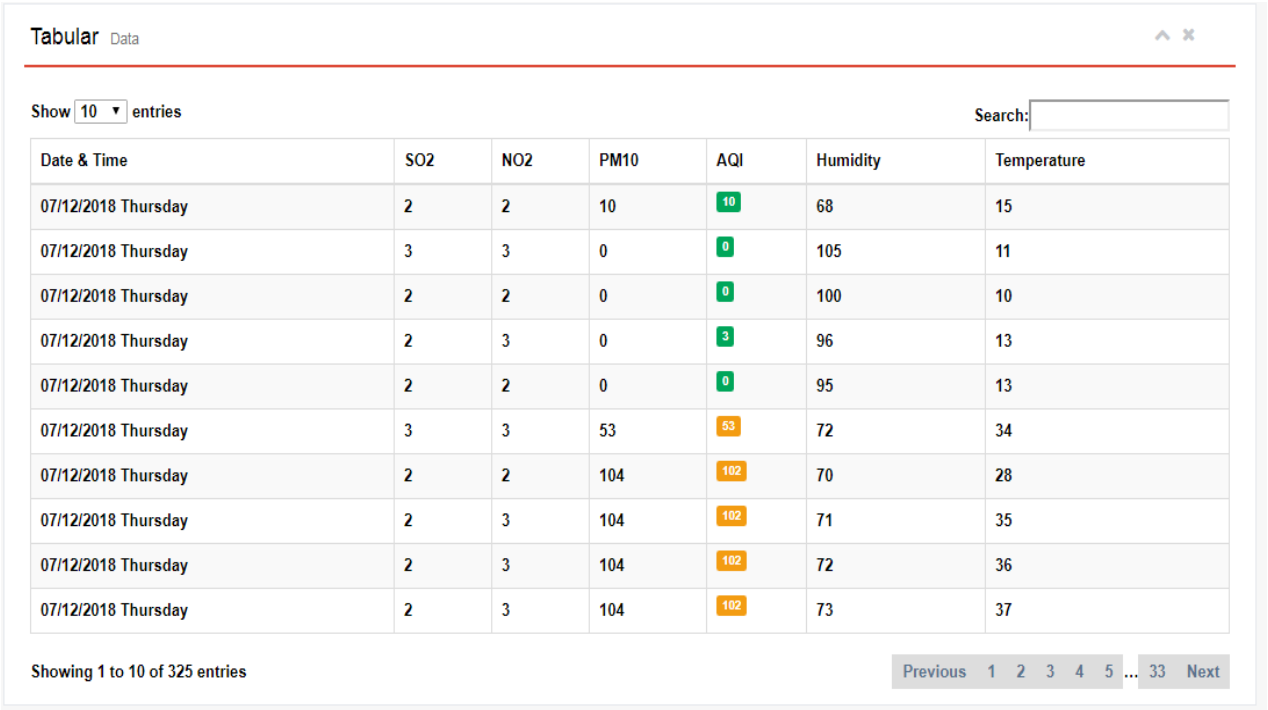


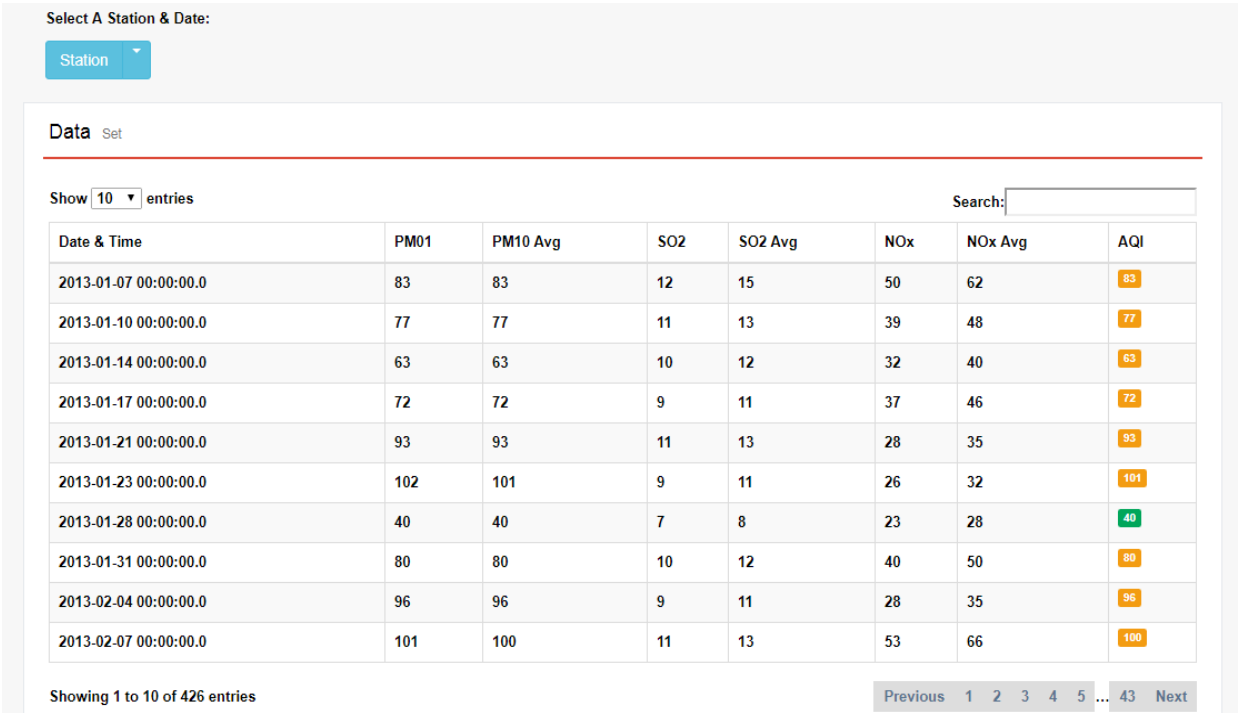
Tabular Data

Show 10 entries Search:

Date & Time	SO2	NO2	PM10	AQI	Humidity	Temperature
07/12/2018 Thursday	2	2	10	10	68	15
07/12/2018 Thursday	3	3	0	0	105	11
07/12/2018 Thursday	2	2	0	0	100	10
07/12/2018 Thursday	2	3	0	3	96	13
07/12/2018 Thursday	2	2	0	0	95	13
07/12/2018 Thursday	3	3	53	53	72	34
07/12/2018 Thursday	2	2	104	102	70	28
07/12/2018 Thursday	2	3	104	102	71	35
07/12/2018 Thursday	2	3	104	102	72	36
07/12/2018 Thursday	2	3	104	102	73	37

Showing 1 to 10 of 325 entries Previous 1 2 3 4 5 ... 33 Next

Fig.9 Data recieved from the sensors and its subsequents display along with the AQI in Tabular structure



Select A Station & Date:

Station

Data Set

Show 10 entries Search:

Date & Time	PM01	PM10 Avg	SO2	SO2 Avg	NOx	NOx Avg	AQI
2013-01-07 00:00:00.0	83	83	12	15	50	62	83
2013-01-10 00:00:00.0	77	77	11	13	39	48	77
2013-01-14 00:00:00.0	63	63	10	12	32	40	63
2013-01-17 00:00:00.0	72	72	9	11	37	46	72
2013-01-21 00:00:00.0	93	93	11	13	28	35	93
2013-01-23 00:00:00.0	102	101	9	11	26	32	101
2013-01-28 00:00:00.0	40	40	7	8	23	28	40
2013-01-31 00:00:00.0	80	80	10	12	40	50	80
2013-02-04 00:00:00.0	96	96	9	11	28	35	96
2013-02-07 00:00:00.0	101	100	11	13	53	66	100

Showing 1 to 10 of 426 entries Previous 1 2 3 4 5 ... 43 Next

Fig. 10 Display of historical data made available in the system[58]

Select A Station:

Station

Predicted 1 Year

Show 10 entries Search:

Date & Time	PM10	SO2	NOx	AQI
2018-07-01 00:00:00.0	4	3	8	10
2018-07-02 00:00:00.0	1	2	3	3
2018-07-03 00:00:00.0	2	9	9	0
2018-07-04 00:00:00.0	1	4	4	0
2018-07-05 00:00:00.0	2	11	1	13
2018-07-06 00:00:00.0	3	7	1	8
2018-07-07 00:00:00.0	0	2	4	5
2018-07-08 00:00:00.0	1	5	2	6
2018-07-09 00:00:00.0	2	7	0	8
2018-07-10 00:00:00.0	3	5	2	6

Showing 1 to 10 of 406 entries Previous 1 2 3 4 5 ... 41 Next

Fig. 11 Forecasted data along with AQI in Tabular structure

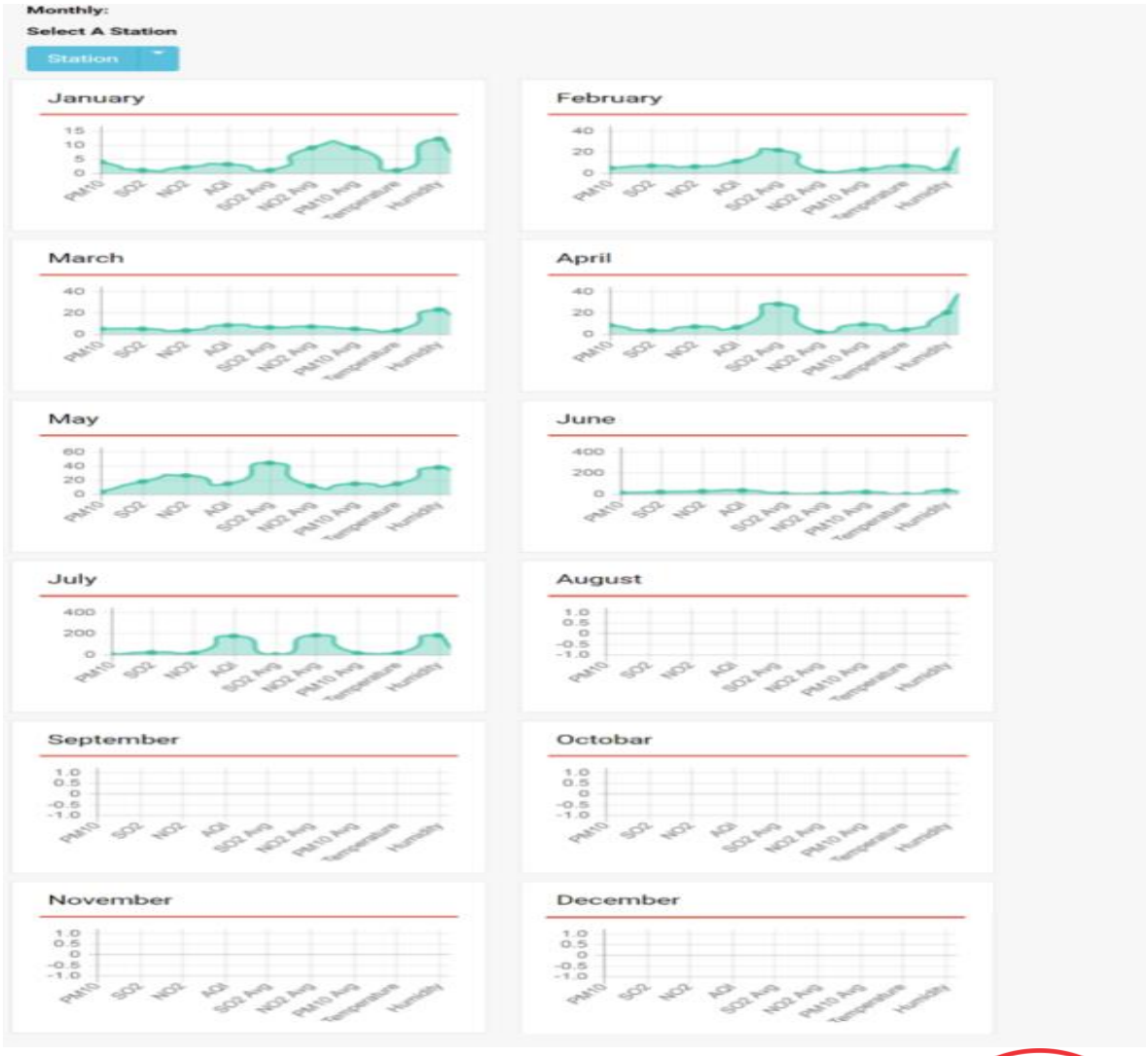
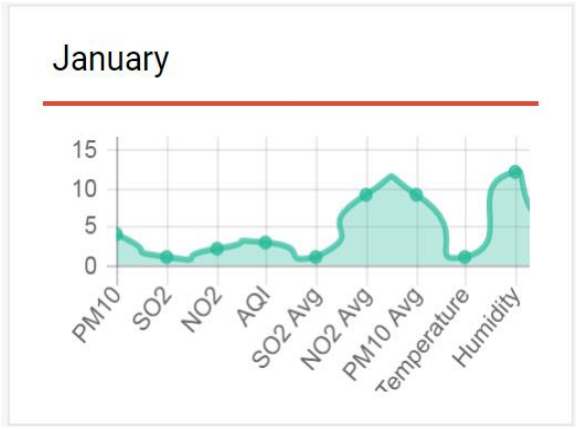


Fig.12 Annual data report of any particular station at a glance



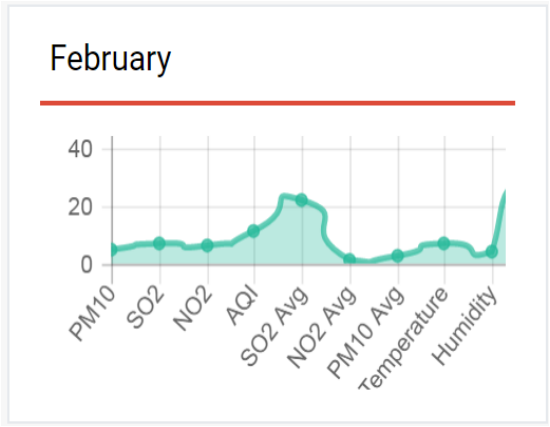


Fig.13 Monthly data report of any particular station

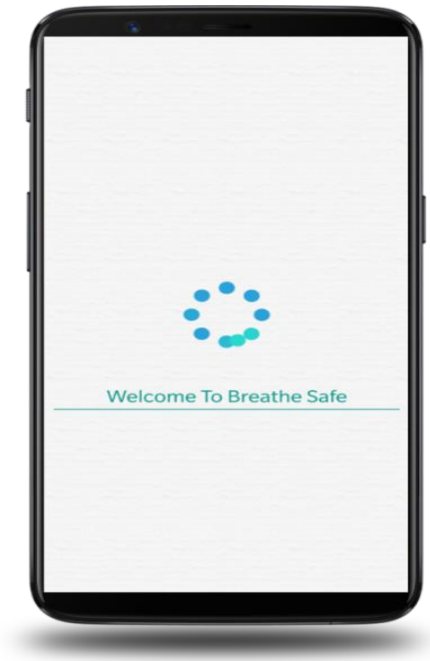


Fig.14 The welcome screen

Fig.15 Prompt for Signup

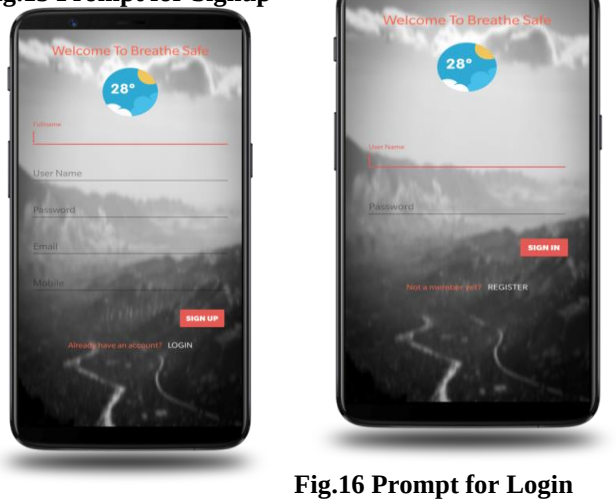


Fig.16 Prompt for Login

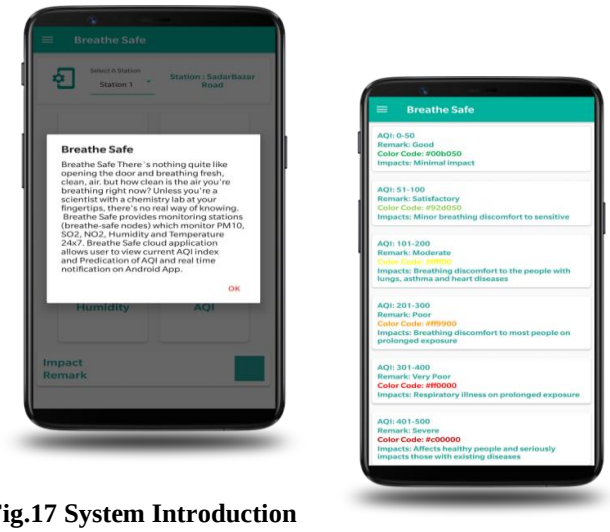


Fig.17 System Introduction **Fig.18 AQI Levels**

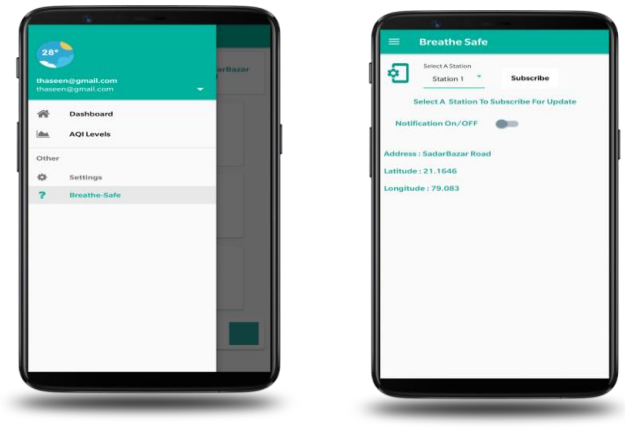


Fig.19 The Dashboard Prompt **Fig.20 Subscricption**

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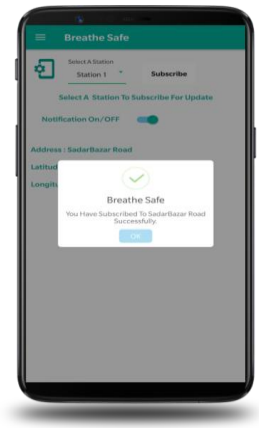

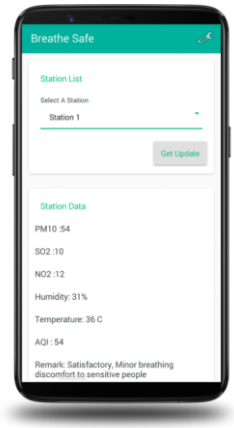

Fig.21Confirmation Prompt **Fig. 22 Data received**

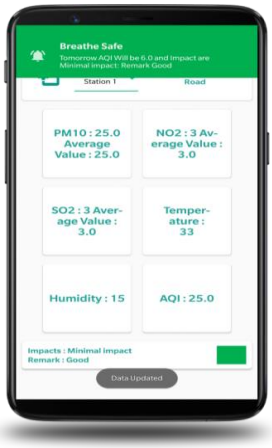

Fig.23 Data received from station 1

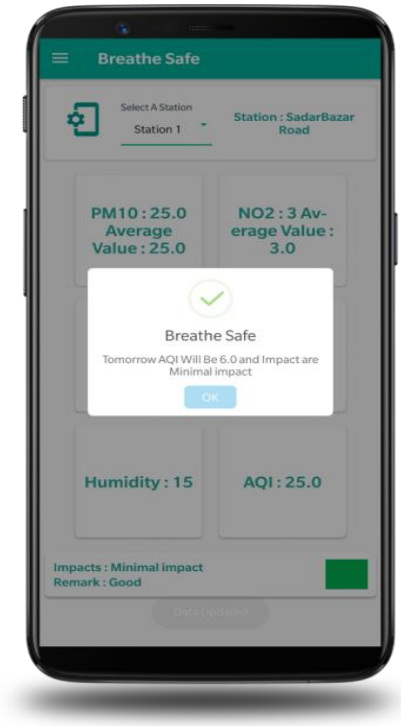

Fig. 21 The forecasted Alarm Notification

The Android app starts with a splash screen and prompts for signup and login option.First time user needs to register on the application by inputting some basic credentials in order to view and receive updates regarding the air quality

Registerd user on login is presented with the dashboard which disseminates the information about sensors and the air quality. User can select any station from the available list and view the information .The user can navigate to various tabs available which include the AQI level settings , AQI color coding[58], and the settings tab. The setting tab provides option to the user to subscribe for the prediction updates and can turn ON & OFF the notification message as per their choice.

With a system which can be easily installed and commissioned at any desired location, has the capacity to record data of locations which were not mapped and will provide a better idea of source of pollution and suitable data analytics employed by the authorities will help them to refine the guidelines proactively. This system has the capacity to develop into a dense network of sensors disseminating information about air quality on the smart phones of the users and may harbinger a positive trend where in the population turns out to be more sensitive towards air pollution and acts proactively as and when required.

With data from such a dense system on every smart phone, the system has the capacity to change the way air pollution is perceived and handled by the lay man, the stake holders and the authorities.

With the help of the forecasting capability the system can be utilized by the authorities to provide a futuristic assessment of the pollution scenario in case if a power plant or an industry is to be set up in a particular area. The authorities can impose conditions for regulatory mechanism on the industrialist right at the time of giving permission to setup the plant or an industry thus making them liable to ensure that they undo the damage which would take place.

With establishment of a dense sensor network there could be problems associated with storage and data analytics and would give rise to a need to search for viable options in direction of improved algorithm for data mining or WSN management techniques.

VII. CONCLUSION

With air pollution getting severe with every passing day, it presents a difficult preposition to the general public and specifically the persons who are suffering from respiratory disorders. There is a need of system which not only monitors the air quality but also provides an alarm in terms of an estimate of air quality in advance through notification. We conclude that we have been able to design a system which has the capability to sense the values of the air pollutants and transmit these values to the cloud and record it. On the basis of the data recorded the system is able to carry on prediction and give out the predicted values of the level of pollutants and the AQI on the website as well on the Android Application , which can be easily downloaded on the smartphone ,thus allowing the stake holders to avoid the impending pollution and limit their exposure to it.

Retrieval Number: J99920881019/19©BEIESP
DOI: 10.35940/ijitee.J9992.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

"Breathe-Safe" gives an opportunity for the people suffering from respiratory disorders, specifically those inflicted with asthma with a preventive tool, because for such patients prevention is better than cure and system exactly helps them in doing this. The developed system is cost effective and simple in operation hence addresses the limitation of government owned system and has potential to be installed at large scale thus being able to map those areas which were not mapped earlier, like a small scale industry etc.

The system can be improved further by including more number of sensors. Improved data analytics will be able to forecast the levels of pollutants more accurately.

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