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RESEARCH ARTICLE

Design of an Integrated System for Modeling of Functional Air Quality Index Integrated with Health-GIS Using Bayesian Neural Network

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Abstract

Air pollution is a major problem, conscious both for health and surroundings. This is a novel approach for the design & development of a system for the monitoring of different air pollutants especially at remote places where it is difficult to install any conventional air quality monitoring stations as well as for the cities. In this research work, a framework of Functional air quality index which is an indicator of susceptibility to respiratory illness has been built using the Bayesian neural network to provide the random real-time data about a location through wireless communication. The monitoring system is integrated with different types of sensors to measure the level of different air pollutants or air quality parameters such as Suspended particulate matters, ($PM_{2.5}$), Nitrogen dioxide, Sulphur dioxide, Ozone which are directly associated with airways inflammatory diseases such as Asthma, Bronchitis, COPD. Each location in Map (GPS) can be updated automatically with fAQI to the user through mobile computing and satellite commutation. The user gets information about the neighborhood location with health-related information such as- whether a particular location is sensitive to respiratory diseases such as Bronchitis, asthma, COPD etc. due to suspended allergen/pollutants in the ambient air. This novel approach is designed with its' own prototype and an application of Inter of Things in Health GIS for the benefit of humanity.

Keywords Ambient air quality monitoring · Bayes network · Wireless communication · fAQI · Health GIS

Introduction

Outdoor air pollution is a serious problem especially in developing countries like India. In case of a developed nation like the USA, the ambient levels of many NAAQS (National Ambient Air Quality standard) pollutants have decreased, to a great extent as a result of public policy decisions made over the past 30 years. It is more severe in crowded urban and industrialized cities (Fig. 1 showing the temporal trends of major air pollutants for India). Economic growth and industrialization are taking place at a rapid speed as a result number of the pollution emission source are also increasing. The major consequence of air pollution on health is the risk of respiratory diseases. Air pollutants come in contact with the airways and lungs first and then the other organs of the body. Common respiratory diseases associated with the air pollution are Bronchitis, Asthma, COPD, and Emphysema. In present time above 50% of the population lives in the urban area. It is established fact that the major health effects of air pollution come out as Respiratory and cardiovascular diseases (USEPA 1999; UK Department of Health 2006; WHO 2002). Following Table 1 showing the association between major criteria pollutants (as identified in clean air act by USEPA for National Ambient Air Quality standard) which are associated with respiratory and cardiovascular diseases and their corresponding health effects (Williams et al. 2014).

Exposure to common outdoor air pollutants Air pollution has a harmful effect on human health, especially respiratory and cardiovascular system (Epa 2006, 2009). Several studies have proved the Relations between air

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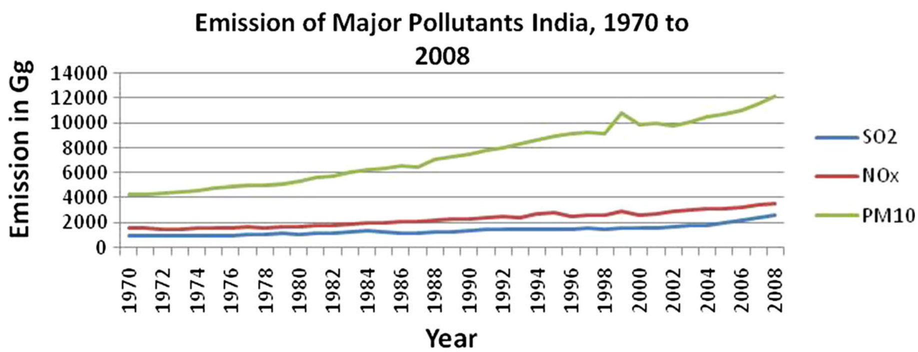

Fig. 1 Emission of major pollutants India, 1970–2008 (Reproduced with permission from European Commission 2010)

Table 1 Major criteria Pollutants and their Adverse Health affect associated with respiratory and cardiovascular disease (Williams et al. 2014)

Pollutants	Health effects
Ozone (O_3)	Breathing ozone: Chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground level ozone can also reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue
Particulate matter (PM includes $PM_{2.5}$ and PM_{10})	Breathing particulate matter: can cause premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, and increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. Long- and short-term exposures to fine particles cause premature death and adverse cardiovascular effects, including increased hospitalizations and emergency department visits for heart attacks and strokes. Fine particle exposures are also linked to respiratory effects including increased hospital admissions and emergency department visits for respiratory effects, such as asthma attacks, as well as increased respiratory symptoms such as coughing, wheezing, and shortness of breath as well as reduced lung development in children. Short-term exposures to thoracic coarse particles are linked to premature death and hospital admissions and emergency department visits for heart and lung disease
Sulphur Dioxide (SO_2)	Aggravates pre-existing respiratory disease in asthmatics leading to symptoms such as cough, wheeze, and chest tightness. Asthmatics are most at-risk, but very high levels can cause respiratory symptoms in people without lung disease. Exposures over longer time periods can result in hospital admissions and ED visits in the general population
Nitrogen Dioxide (NO_2)	Aggravates respiratory symptoms, increases hospital admissions, and ED visits, particularly in asthmatics, children, and older adults; increases susceptibility to respiratory infection
Carbon monoxide (CO)	Reduces the amount of oxygen reaching the body's organs and tissues; aggravates heart disease, leading to hospital admissions and ED visits

pollution, asthma, and mortality (Schwartz 1994; Pope et al. 1992). Air pollution and health-related studies are an important issue in the present time especially the association between exposure to particulate matter and ozone and Hospital admission and mortality (Brunekreef and Holgate 2002).

It can be hypothesized that major cause of systematic inflammation and cardiovascular disorders is the oxidative stress imposed by Reactive Oxygen species induced by exogenous pathway like many airborne particles and oxidants (Srikanth and John 2015). Disastrous Industrial Haze took place at Donora, PA in 1948 and The Great smog (last for 5 days) of London in 1952 killed 12,000 people of within 3 months, which initially driven the attention to the epidemiological study and air pollution (Hunt et al. 2003; Bell and Davis 2001).

The key pollutants that are notably related to respiratory failure include NO_x, SO_2, particulate matter (PM) and CO (Stieb et al. 2002). It is a fact that urban or traffic-related air pollutants provokes acute exacerbations and worsening symptoms in patients suffering from various degrees of COPD (Sunyer 2001). High concentration of NO_2 and black smoke is recorded during the air pollution episode took place in 1991 in London caused increased hospital admission of elderly patients suffering from COPD (Anderson et al. 1995). Although Due to advancement in medical facilities death rate caused by respiratory diseases has decreased throughout the time still the amount is high especially for Srilanka, Nepal & India among South Asian country (Figs. 2, 3) comparing to other diseases and majority of risk for respiratory illness comes from environmental factor (Fig. 4).

Nation wise air quality monitoring systems are generally operated by official Authorities of any particular Nation E.g. in India The Central Pollution Control Board (CPCB) a statutory organisation under the Ministry of Environment,

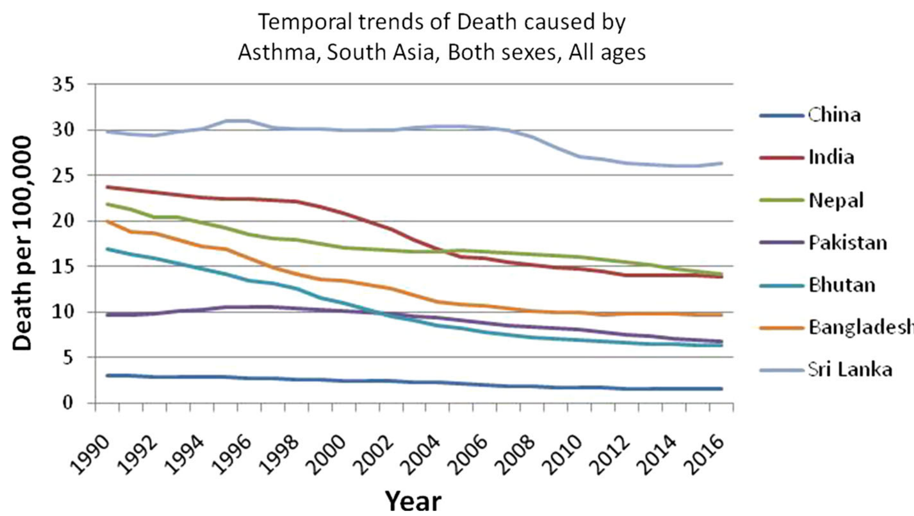

Fig. 2 Temporal trends of Death caused by Asthma, South Asia, 1970–2008 (Reproduced with permission from European Commission Institute for Health Metrics and Evaluation 2017)

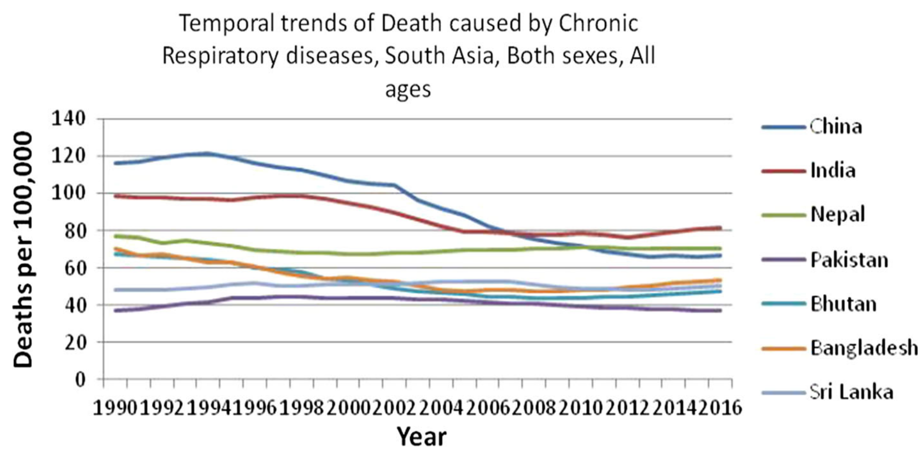

Fig. 3 Temporal trends of Death caused by Asthma, South Asia, 1970–2008 (Reproduced with permission from European Commission Institute for Health Metrics and Evaluation 2017)

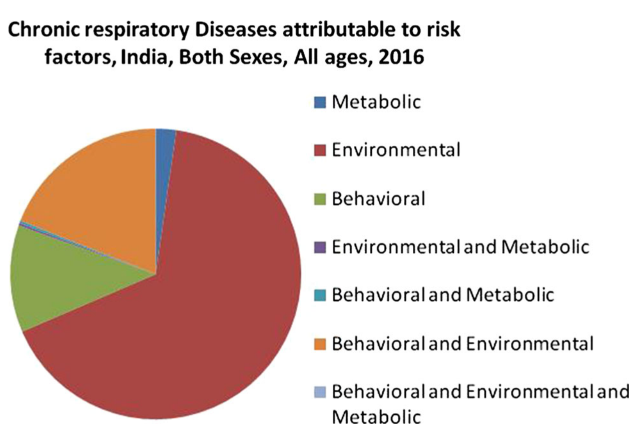

Fig. 4 Chronic respiratory Diseases attributable to risk factors, India, Both Sexes, All ages, 2016, South Asia, 1970–2008 (Reproduced with permission from European Commission Institute for Health Metrics and Evaluation 2017)

Forest and Climate Change s executing a nation-wide programme of ambient air quality monitoring known as National Air Quality Monitoring Programme (NAMP). The network consists of three hundred and forty-two (342) operating stations covering one hundred and twenty-seven (127) cities/towns in twenty-six (26) states and four (4) Union Territories of the country. Those conventional air quality monitoring stations by govt. agencies are stationary and they monitor air quality using spectrometry, Gravimetric, spectrophotometry, NDIR (non-dispersive infrared), Chemiluminescence methods for analysis which are precise but expensive and time-consuming, they are also difficult to transport being cumbersome (Table 2 is showing the methodological guidelines of National Air Quality Monitoring Programme (NAMP) for ambient air quality monitoring). A large number of expensive equipment's, expert personals are requiring for the establishment of stations, sampling and chemical analysis. Such stationary conventional stations are very difficult to install in mountains, hilly inaccessible area due uneven topography high altitude and remoteness. Urban air pollution pattern is very complex in nature indeed. Diffusion and dispersion dynamics of pollutants are complex in nature in cities and urban area due to the complex road network and building orientation. In such areas instead of the presence of high

Table 2 Methodological guidelines by Central Pollution control board for the National Air Quality Monitoring Programme (NAMP)

Pollutants	Methods for automatic stations	Methods for manually operated stations	Averaging time
So_2	Ultraviolet fluorescence	Improved west and geake method	24 h & annually
No_2	Chemiluminescence	Modified Jacob Honchheiser method	24 h
O_3	UB-Photometric, Chemiluminescence	Chemical (Buffered KI) method	8 & 1 h
$PM_{2.5}$	TEOM, Beta attenuation	Gravimetric method	24 h & annually
PM_{10}	TEOM, Beta attenuation	Gravimetric method	24 h & annually

concentration of pollutants, sometimes nearby stations can report low concentration of pollutants due to the street canyon effects (Vardoulakis et al. 2003).

Recent advancement in Arduino Based Multi-Gas Sensors with micro-controller for air quality monitoring can solve this problem of a limited number of high dimensions and high costs monitoring stations. In last couple of years many works came out proposing the new Arduino Based Multi-Gas Sensors as an alternative tool for air quality monitoring due to its low cost, easy installation and user-friendliness (Croxford et al. 1996; Kamionka et al. 2006; Tsujita et al. 2005) Nanotechnology has been proved very useful for many industrial and domestic applications such as detecting gas leak in factories, detecting alcohol in breath, detecting toxic gases and fire. In reality, these solid-state gas sensors proffer a wonderful prospect for application in environmental monitoring due to light weight, small size, robustness, low cost and also as they can be installed anywhere to collect data covering extensive areas (Pummakarnchana et al. 2005). Many authors have studied the efficiency of those sensors and presented comparative analysis with the traditional air quality monitoring system. Al-Haija et al. (2013) monitored concentration of Carbon monoxide and LPG using Wireless sensor network based Arduino Microcontroller for micro-region level (at King Faisal University). Few of Authors e.g.(Pummakarnchana et al. 2005) integrated those real-time data with GIS through wireless communications to produce an information service to the public for awareness and enhanced public participation (Pummakarnchana et al. 2005). Völgyesi et al. 2008 developed a Mobile Air Quality Monitoring Network using a number of car-mounted sensor nodes measuring different pollutants in the air. They formed a sensor map portal where they can upload processed data uploaded from periodically collected from onboard GPS tagged Data points. Tsujita et al. 2005 conducted a study to assess the accuracy of such models along with the implementation and auto calibration through the network by comparing with nearby sensors and governmental monitoring stations. However, calibration of those data is necessary due to the intrinsic long-term stability and selectivity issues that affect the solid-state sensors they rely on can rigorously limit their reliability when compared with traditional spectrometers based stations (Vito et al. 2009). Vito et al. (2009) proposed multivariate calibration estimated using 2 weeks long on-field data recording and neural regression systems.

Therefore, it is necessary to develop a monitoring system which can monitor rapidly, regularly with dense monitoring network and can provide real-time information to the public through GIS interference and wireless communication. In the present study, the emphasis has been given for developing Index which indicates the susceptibility for respiratory or airways inflammation caused by $PM_{2.5}$, Ozone, NO_2, and SO_2.

Methods and Equipment

In this series of research work, the data acquisition system has been implemented and it has worked satisfactorily in outdoor environments to measure the ambient air pollutants specifically which are responsible for the acute exacerbation of respiratory inflammation. This application on the next part of this research work will integrate ArcGIS by developing its software application and hence customize with the new features of Health GIS.

Defining fAQI

In the present study, the fAQI Functional Air Quality Index indicates the susceptibility of any genetically polymorphic or nonpolymorphic person for triggering or exacerbation of acute respiratory inflammation (Asthma, Bronchitis, and COPD).

Averaging Time

Selecting averaging time is an important aspect for Air quality Index estimation (Wai et al. 2012). Any air quality Index deals with the acute symptoms associated with short-term exposure to the air pollutants; hence for the calculation of AQI generally shorter averaging is considered (Wai

Table 3 Sampling stations

Sampling stations	Types of stations	UTM		Co-ordinates geographical lat-long
		X (Easting)	Y (Northing)	
1. Victoria	Type A: downtown pedestrian exposure station	638,047.5	2,493,742.2	22°32′41″N 88°20′33″E
2. Rabindra Bharati University	Type A: downtown pedestrian exposure station	641,848.4	2,502,881	22°37′37″N 88°22′49″E
3. Parivesh Bhawan	Type A: downtown pedestrian exposure station	644,797	2,495,732.9	22°33′43.7″N 88°24′29.9″E
4. Behala Chowrasta	Type A: downtown pedestrian exposure station	635,104	2,487,331.1	22°29′13.4″N 88°18′48.0″E

et al. 2012). Averaging time of specific pollutants depends upon pollutant's exposure–response (health) relationship, which is different for each pollutant (Cairncross and John 2004; Cairncross et al. 2007). Any AQI is also guided by a specific standard threshold value above which exacerbation of symptoms occurs. Therefore it is necessary to select the same averaging time as it is used in the standard threshold value e.g. 25 μg/m^3 24-h mean for $PM_{2.5}$, 50 μg/m^3 24-h mean for PM_{10}, 100 μg/m^3 8-h mean O_3 and 200 μg/m^3 1-h mean No_2 by WHO [20].

Study Area

The study was carried out in Kolkata Municipal Corporation located at 22°30′ North and 88°30′ East on the east bank of river Hooghly elevation of approximate 9 m (Shuttle Radar Topography Mission, National Aeronautics and Space Administration, February 2000) and covers an area of 200.71 km^2. Kolkata is one of the worst polluted cities in Asia, according to the Centre for Science and Environment (CSE) pollution live in Kolkata is much higher than the permissible limit and Kolkata should start acting on emergency pollution control measures like Delhi. Four well-distributed Sampling stations have been selected (Table 3). The Sampling Season has been chosen as the onset of winter as the season change trigger and worsens the airways inflammation.

Sampling Season

Sampling season has been chosen here as the onset of winter i.e. October 2016 as during this time concentration of most of the airborne pollutants increase rapidly due to several factors (Karar et al. 2006) such as (1) inverse relation between the concentration of pollutants and the metrological factors such as precipitation, wind, temperature and relative humidity (Spiroska et al. 2011). During winter due to less wind circulation wind becomes stagnant which helps particulate matter to stay near the ground. Lack of moisture and precipitation decreases the amount of wet deposition and wash out of atmospheric substance to the earth surface (Gupta et al. 2008). The same scenario can be seen for Kolkata (Spiroska et al. 2011). (2) Major festivals of India contributing to air pollution and hastening the concentration of pollutants during this time. Another reason behind the selection of onset of winter is respiratory illness reaches a peak during this time (Singhi et al. 2004; Barnes et al. 2013).

The proposed model in hardware part uses a micro-controller Atmel 2560 based platform (Arduino Mega) and the pollutants are measured using different solid state sensors such as MQ 135, MQ 2, MQ 7, MQ 131, MQ 136, and $PM_{2.5}$ (Fig. 6a, b). Other sensors can be integrated in future according to the need of the study. These data are dynamic variable in nature and changes in meteorological parameters such as Temperature, Barometric Pressure, and Humidity. Thus, we have taken BMP 180, ADXL 335 and DHT 11 to measure the meteorological data such as Air pressure, altitude, and variation of air acceleration, temperature, and humidity.

In the training phase of our model, we took data From Four Sampling Stations (Table 3) proximal to the stations of central pollution control board (CPCB). Thus, we can access the accuracy of our acquisition by comparing our data with those data which we get from CPCB data at the same time. This particular work is in its research phase, thus need to integrate medical statistics (Hospital Admission or No. of Affected persons) on further development of the model of those areas for more accurate prediction of the upcoming disease profile using artificial intelligence. We have used the Bayesian Neural Network which studies the present probability of occurring some disease given certain pollutants and predict the probability of occurring the Diseases in Future.

The block diagram of the proposed model is given in Fig. 5 and the actual model is shown in Fig. 6.

Algorithm 1: fAQUI implementation

1. Take T = Temperature, P = Pressure, H = Humidity, A = Altitude = 9.1 for Kolkata, T, P, H, A are dynamic, vary with time, are observed in real time, Connect the sensors to Arduino input output ports as follows: PPM = PM 2.5, MQ 2.5 Output, A1 = MQ 2 output 1 (CH4), A2 = MQ 2 Output 2 (CO2), A3 = MQ131 output (Ozone), A4 = MQ135 output (NH3), A5 = MQ 136 output (H2S), A6 = MQ7 Output (CO).
2. Study PM 2.5, A0 to A6 from sensor datasheet and the characteristics curves for concentration versus Ro/Rs Plot. Finding the relation between the sensor outputs to the concentration of the gas using regression methods.
3. Define P, T, H, A as independent variable; Define PM 2.5 and A0 to A6 as dependent variable.
4. Take Real-time data after software and hardware set up and take the data.
5. Plot the PM 2.5 and A0 to A6 concentration profile as changing with P, T, H, A and with time.
6. Map to a particular disease in relation with the profile of the pollutants.
7. Defining fAQUI as per the mathematical model.
8. For online estimation, go to step 4.
9. End.

To know the sensor characteristics, sensitivity, calibration and pin description one may follow data sheet (https://www.pololu.com/file/0J309/MQ2.pdf. http://www.ti.com/lit/ug/tidub65c/tidub65c.pdf, http://www.sensorsportal.com/DOWNLOADS/MQ131.pdf, https://www.olimex.com/Products/Components/Sensors/SNS-MQ135/resources/SNS-MQ135.pdf, http://www.sensorica.ru/pdf/MQ-136.pdf, https://www.sparkfun.com/datasheets/Sensors/Biometric/MQ-7.pdf). This is because it is very important to keep input voltage of the sensor optimum to work properly.

Mathematical Modelling of Bayesian Neural Network

From basic concept of conditional probability that an event A occurs when B already occurred is P(A|B), given by the of Bayes theorem as follows

$$P(A|B) = \frac{P(B|A) * P(A)}{P(B)}$$

here, P(B|A) is trained from the system. And P(A|B) is the next state of the system. The probability of the occurrence of a particular disease for given set of pollutants is a conditional random process. The rate at which the diseases may occur also varies with person to person as they have different immune response pattern and allergic sensitivity corresponds to the ambient pollutants activities due the abnormality in their inherited genes.

Thus the entire process cannot be a realistic model, rather it has to be a stochastic process. Thus, we take a set of pollutants Z = {A0, A1, A2, A3 …}. And the most probable diseases are represented by Y = {D1, D2, D3…}. The conditional probability of a particular disease D1 is defined by

$$P(Y = D1|Z = \tau) = \frac{P(Z = \tau|Y = D1) * P(Y = D1)}{P(Z = \tau)}$$

Here, τ = Functional Air quality index (fAQUI) which is a set of threshold values of particular air pollutants above which the chance of occurrence is maximum. For simplicity, we can define τ statically from observed data and standard values given by specialized agency or Authority. But more precisely we approach to have this fAQUI to stochastic unlike a static variable, it varies from disease to disease, even person to person also. Since for a Specific value of $\boldsymbol{\tau}$1, Disease D1 may occur and Disease D2 may not occur. Thus, when the map is customized, the user gets a probabilistic value of fAQUI in the map which changes with time, temperature, air pressure etc. If we consider that $\tau = \{\tau 1, \tau 2, \tau 3, \tau 4, \tau 5 \ldots\}$ are distributed within a Markov process, then we can find using $P(Z = \tau|Y = D1)$ and hence estimate future value of the discrete model of observation.

For realistic τ, the value is a fixed number given in the literature. Standard Guideline values of PM, O_3, So_2, No_2 by WHO [20].

We consider for a respiratory immune disease say D the standards values are given in Table 4. Say for the disease D, $PM_{2.5}$is responsible 30%, PM_{10} is 40%, O_3 is 10% and NO_2 is responsible 20%. We normalize the guidelines threshold values as

$$\tau 1 = 0.3 * (25/(25 + 50 + 100 + 200)) = 0.02$$

$$\tau 2 = 0.4 * (50/(25 + 50 + 100 + 200)) = 0.05$$

$$\tau 3 = 0.1 * (100/(25 + 50 + 100 + 200)) = 0.02$$

$$\tau 4 = 0.2 * (200/(25 + 50 + 100 + 200)) = 0.10$$

$$\text{Thus for fAQUI for D is} = \tau 1 + \tau 2 + \tau 3 + \tau 4 = 0.19$$

Thus from an experiment, if we get database that we get $\tau' = 0.13(say)$. And if for the experiment $P(Y = D) = \tau' = 0.13(say)$.

Then $P(D|\tau') = \dfrac{P(Z = \tau|Y = D) * P(Y = D)}{P(Z = \tau)}$ $0.19 * 0.13/\ (0.19 + 0.13) = 0.077)$.

This is the posterior probability calculated using Bayes theorem. Now for a city with huge traffic networks, this probability value differs in different locations as network node value (Fig. 7). A user is to define his path with less fAQUI value if he has genetic polymorphism or susceptible to environmental pollution.

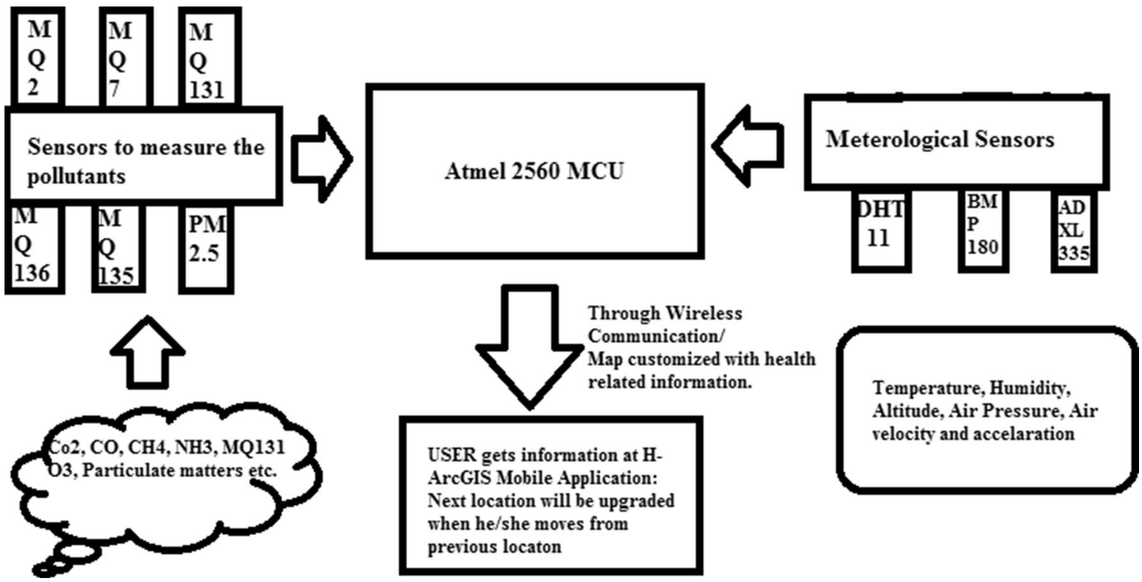

Fig. 5 Block diagram of the overall system

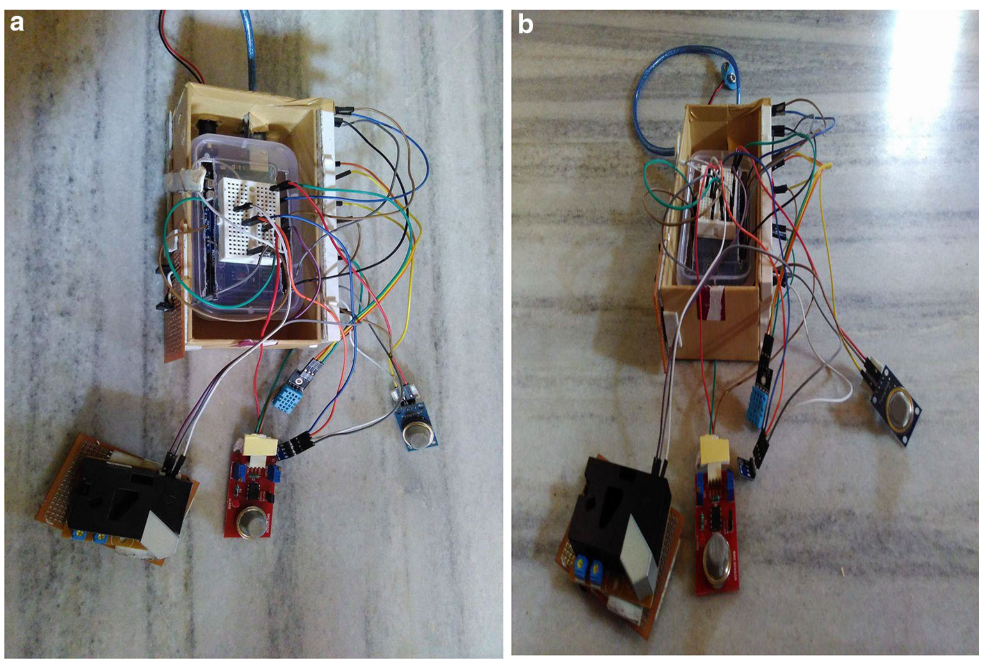

Fig. 6 **a** Actual model (top view), **b** Actual Model (side view)

Results and Discussions

We can clearly see that the majority of the pollutants especially PM & NO_x have increased at the end of the month due to two major factors (1) onset of cold season associated with the change in several meteorological parameters such as temperature, humidity and wind circulation and (2) Contribution of major Festivals such as Durgapuja (7th to 11th October, 2016), Kalipuja (29th October, 2016), Diwali (30th October, 2016). Therefore a plenty of variation (almost 300% for PM & NO_2) from the mean concentration can be seen throughout the period.

$PM_{2.5}$

Particulate matter with diameter 2.5 µm or less tends to increase with the onset of winter season or with decreasing temperature and moisture throughout the Study area. Highest Concentration found at sampling station 4 Behala Chowrasta which is a characterized with the Congested

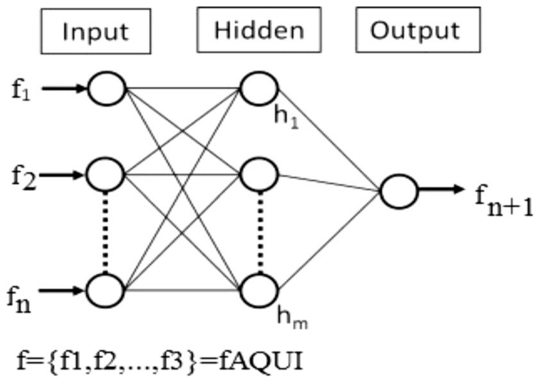

Fig. 7 A Bayesian Neural Network with fAQUI Illustration with an example

road, busy intersection, traffic, exhaust fumes and pollution and the Lowest Concentration found at the northern and eastern part of the city (Table 5).

Ozone

Concentration of Ground Level Ozone Found highest at station 4 Behala Chowrasta and lowest at station 3 Parivesh Bhawan on 5th October (Table 6).

Nitrogen Dioxide

Concentration of Nitrogen dioxide tends to increase with approaching winter season and with decreasing temperature and moisture. Highest concentration found at Station 4 Behala Chowrasta and the lowest concentration found at the northern part of the city (Table 7).

Sulphur Dioxide

Although the Temporal pattern is arbitrary in case of SO_2 Concentration but tends to increase with the onset of winter and found the highest concentration at Station 1 Rabindra Bharati university that is the northern part of the city and lowest concentration found at Station 2 Victoria memorial that is the central part of the city (Table 8).

Correlation with CPCB Data

To Access the Accuracy of the present methodology of data acquisition we have compared the acquired data with CPCB installed Data (Table 9). We have compared the data of sampling Station 4 Behala Chowrasta which is found to be the most polluted station with the data of CPCB

Table 4 Standard guideline values of PM, O_3, So_2, No_2

Pollutants	Guidelines by WHO (2006)	Guidelines by CPCB (2011)	
		Industrial, residential, rural and other areas	Ecologically sensitive area (notified by Central Government)
$PM_{2.5}$	10 μg/m^3 annual mean	Annual 40 μg/m^3	Annual 40 μg/m3
	25 μg/m^3 24-h mean	24 h 60 μg/m^3	24 h 60 μg/m^3
PM_{10}	20 μg/m^3 annual mean	Annual 60 μg/m^3	Annual 60 μg/m^3
	50 μg/m^3 24-h mean	24 h 100 μg/m^3	24 h 100 μg/m^3
O_3	100 μg/m^3 8-h mean	8 h 100 μg/m^3	8 h 100 μg/m^3
		1 h 180 μg/m^3	1 h 180 μg/m^3
NO_2	40 μg/m^3 annual mean	Annual 40 μg/m^3	Annual 30 μg/m^3
	200 μg/m^3 1-h mean	24 h 80 μg/m^3	24 h 80 μg/m^3
SO_2	20 μg/m^3 24-h mean	Annual 50 μg/m^3	Annual 20 μg/m^3
	500 μg/m^3 10-min mean	24 h 80 μg/m^3	24 h 80 μg/m^3

Table 5 $PM_{2.5}$ 24 h Mean concentration (μg/m^3) month of October for 4 Sampling Stations

Stations date	Rabindra Bharati University (N)	Victoria (C)	Parivesh Bhawan (E)	Behala Chowrasta (SW)
$PM_{2.5}$ 24 h Mean concentration (μg/m^3)				
5th October	45	110.6	50.08	47.53
10th October	46.302	108.3	47	70.21
15th October	48.204	136.66	89.3	52.02
20th October	80.25	152.01	136.19	153.66
25th October	90.63	156.59	144.012	178.36
30th October	156.32	143.21	125.3	180.25

Table 6 O_3 8 h Mean concentration (μg/m^3) month of October for 4 sampling stations

Stations date	Rabindra Bharati University (N)	Victoria (C)	Parivesh Bhawan (E)	Behala Chowrasta (SW)
O_3 8 h Mean concentration (μg/m^3)				
5th October	43.5	6.9286	3.63	37.03
10th October	48.25	7.77	7.8	40.2
15th October	45.14	9.86	8.63	32.25
20th October	46.21	11	9.69	33.69
25th October	23.2	11.65	18.53	33.25
30th October	15.62	5.87	35.46	72.88

Table 7 NO_2 1 h Mean concentration (μg/m^3) month of October for 4 Sampling Stations

Stations Dates	Rabindra Bharati University (Northern)	Victoria (Central)	Parivesh Bhawan (Eastern)	Behala Chowrasta (SW)
NO_2 1 h Mean concentration (μg/m^3)				
5th October	18.53	40.12	32.15	38.25
10th October	14.52	23.521	57.25	78.35
15th October	15.63	42.99	50.36	39.46
20th October	18.23	48	42.2	42.82
25th October	29.56	45.98	44.85	45.63
30th October	55.24	29.31	56.63	69.32

Table 8 SO_2 10 Min Mean concentration (μg/m^3) month of October for 4 Sampling Stations

Stations date	Rabindra Bharati University (N)	Victoria (C)	Parivesh Bhawan (E)	Behala Chowrasta (SW)
SO_2 10 Min Mean concentration (μg/m^3)				
5th October	14.89	5.23	3.02	3.69
10th October	14.25	5.66	8.52	12.36
15th October	19.32	4.5	5.36	6.98
20th October	25.3	6.21	4.63	5.89
25th October	29.36	5.5	8.056	6.57
30th October	18.5	5.89	13.52	20.15

Table 9 Comparing Acquired data with CPCB data For Sampling Station 4 at Behala Chowrasta

Date	Acquired value $PM_{2.5}$	CPCB value	Acquired value O_3	CPCB value	Acquired value NO_2	CPCB value	Acquired value SO_2	CPCB value
Behala Chourasta								
30th oct	180.25	172	72.88	82.13	69.32	67.83	20.15	20.5
15th Oct	52.02	49	30.58	32.25	38.33	39.46	6.98	6
5th Oct	47.53	47	37.03	35.08	38.25	37.17	3.69	3.33

station located at Behala Chowrasta and Found satisfactory results with Pearson's Correlation coefficient of r = 0.999874768, 0.995820093, 0.997897373, 0.998987613 for $PM_{2.5}$, Ozone, SO_2 and NO_2 respectively.

The motivation of this research is very intuitive and new. We have produced an idea and there is a need to verify that idea. The idea is broad which includes hardware implementation, mathematical integration, area selection and online estimation of different parameters, calibration and finally user-friendly inference generation. So it is time-consuming as well as costly procedure. In this paper, we have presented the hardware part broadly what we have implemented for four stations. Same copies of hardware can be easily set up. The analysis section is a part of the ongoing research. It is important to measure the data for a long time for analysis purpose. We have measured data for 1 month in order to verify that the hardware set up is working or not. The period we have chosen has a wide fluctuation of parameters values which is more than other time of the years due to festival and occasions. We have also checked the functionality of the sensors working well in other time of the year. The latter part (analysis and inference from statistical observations) is required for a long run study which is not an objective of this present work. The intuition for this research is an online estimation of pollution parameters and an integration with the related diseases. We have tried a new approach to do such an estimation.

Conclusion

This novel work is a series of research work in health GIS. In this paper, the hardware model and algorithm has been shown. A set of results has been shown which are acquired to test the model and compared with CPCB data. The profile of pollutants of a location for some period of time has been shown graphically and also compared with the health standard given by WHO. The future work may include the use the Bayesian model extensively as presented here, to train the model and hence predict stochastically the status of a location in terms of health specifically with particular diseases caused by the proportion of different pollutants. The number of stations may be increased for more traffic planning. Use of satellite communication, sensor network and software application based map will enhance the applicability.

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