

Designing of Urban Air Pollution Monitoring System and Notify Traffic Police to their Personal Exposure in Urban Air Pollution

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Abstract— Urban air pollution has significant effects in living beings and nature. Automobile exhaust emissions are the main cause of air pollution. Moreover, the major contribution of Air pollution is by static vehicle traffic over a long period when vehicles stop at a traffic crossing. This article purposed a framework for managing traffic police duty hours based on the recommended time exposure to the pollutants. Air Pollution Monitoring System measures concentration value of harmful gases like CO, CO₂, NO₂, SO₂ and particulate matters in real-time and send these value wirelessly to ThingSpeak IoT cloud through ESP8266 Wi-Fi module. An analysis of personal exposure to pollution of traffic police individually and total Air Quality Index (AQI) calculated in MATLAB environment. An alert email has been sent to traffic police control room about apprise duty hour of traffic police to aware less affected exposure time of urban air pollution for that particular crossing.

Keywords— static vehicle traffic, Urban Air Pollution, CO, CO₂, NO₂, SO₂, Particulate Matters, Real-Time, ThingSpeak, personal exposure, MATLAB analysis, Alert email, traffic police control room

I. INTRODUCTION

India is a rapidly growing country in Asia. The growth linked huge traffic emission and extensive Air pollution in urban areas. Urban Air pollution involves particulate matters (PM_{2.5}, PM₁₀), sulfur oxides (SO₂), carbon monoxide (CO) and excessive level of carbon dioxides (CO₂). Automobile exhaust emissions are main cause of air pollution. Lung Diseases, heart problem, weak respiratory system and premature death could be caused by Air pollution [1]. Human inhales 10,000 liter air approximately in a day, since we spent more time outdoor, so it is required to monitor its pollutant and its effect in human life [2]. Good air quality is basic requirement for human beings. Air is mixture of gases needed and harmful gases which is detrimental to human. When harmful gases reached above its minimum level, it will disrupt the human for carrying out their life activity. Just because these gases are harmful in nature so it is categorized as pollutant. Main cause of Air pollution in urban area is industries, technologies and heavy traffic. Moreover, the

highest contribution of Urban Air pollution is by static vehicle traffic over a long period when vehicles stop at the traffic circle. Iasmina Gruicin et al. [3] presented monitoring air quality in urban area focused on the micro scale monitoring or in personal level of air quality associated with activities, health symptoms and behavior, this research present a system and implement application known as Airify scenario to use the application. Swati Dhingra et al. [4] present an IOT kit using gas sensors and arduino to detect air pollution the route and can physical places anywhere to detect AQI and IOT-Mobair mobile application helps the user to predict AQI. Md. Mohiuddin Ahmed et al. [5] proposed a systems for gas leaked incidence, a real time air quality monitoring and alert user about air quality. Himanshu Nigam et al. [6] proposed an IOT based indoor air AQI monitoring and notification system which send an email notification of CO₂ and CO concentration. Vijay et al. [7] proposed a system which uses cloud services thingspeak and send email notification through IFTTT services. Fig. 1 shows the health consequences of urban air pollution over respiratory system, nervous system, heart and other body organs [8][9][10].

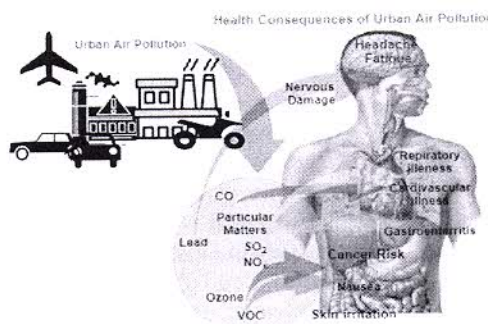


Fig. 1. Health consequences due to urban air pollution

Francesca Borghi et al. [11] present a study of sensors whether versatile, precise, enhancement to personal exposure and their performance. Housseem Eddine Fathallah et al. [12] described the Time-Weighted Average Individual Exposure E_{TWAi} for calculating personal exposure of a person spent in different microenvironment. E_{TWAi} values Compared with E_{TWAi} Limit

guidelines values for regulation, in this process $C_i(tn)$ is individual air pollutant concentration and $c_j(tn)$ is the new received pollutant concentration and time spent in microenvironment is $T_i = T_m - T_{last}$ where T_m is new air quality measurement time and T_{last} is last event trigger time, by solving E_{TWAi} values we can get individual exposure limit and triggers proper action and alert message.

$$ETWAi = \frac{\sum_{n=1}^k c_i(tn) * T_i}{\text{Period of exposure}} \quad (1)$$

Several research papers have been published in an Air pollution monitoring system using wireless connectivity, these research papers have not included a time-weighted average (TWA). In

this research article, the architecture of the system defines personal exposure assessment of CO_2 , SO_2 , NO_2 , CO , and particulate matters (PM_{10} , $PM_{2.5}$) urban air pollutants. When the monitor data of traffic circle increases from guidelines value, traffic police Management has been notified as an awareness of traffic police exposure in surrounding atmosphere. Hence, negative impact of exposure can be decrease by reducing the duty hours of traffic police or regulating the pollution in highly polluted area. In this work, a sensor node (microcontroller interfaced with sensors and Wi-Fi module) implemented for sending real time data of urban air pollutants, temperature and Humidity data to IOT cloud platform for storing and analysis purpose. Once the pollutants data start collecting at cloud, the personal exposure duration start calculating of Traffic police person assigned on duty at that region.

II. SYSTEM FRAMEWORK

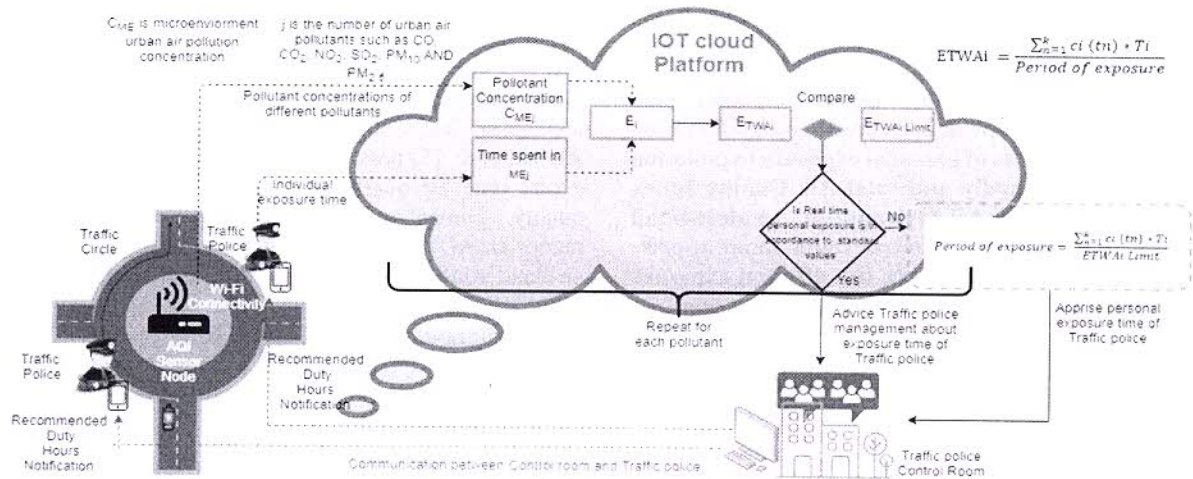


Fig. 2. System Framework of Urban Air Pollution Monitoring System

In this section, we discuss the System Framework of Urban Air Pollution Monitoring System. An AQI sensor node has been deploy in Traffic circle to enumerate Air Quality Index of urban air pollutants and determine personal exposure of traffic police on the duty. AQI sensor has Wi-Fi connectivity to send its air pollutants concentration to IOT cloud platform for plotting and storing. After plotting and storing data on IOT cloud platform urban air pollutant concentration analyzing has been emerge. On IOT cloud platform, C_{MEj} pollutants concentration and ME_j time spent in that microenvironment is merge into E_i where E_i is individual exposure in environment and ME is microenvironment and j is number of air pollutants. Time weighted average values of different urban air pollutants are compared with defined guidelines value.

Generally, traffic police have an average of duty for 8 hours. In this framework we observed the urban air pollutants total AQI for last 8 hours and determine personal exposure of traffic police on an interval of 1 hour and notify the traffic police management that this person (traffic police) have less negative

health impact and if individual exposure in environment is greater than guidelines values then suggest traffic police management to reduce the duty hours of traffic police in that particular traffic circle.

III. METHODOLOGY

The whole system methodology is divided into two sections I. Sensor node for capturing the pollutants value from the environment II. IoT cloud, where sensor data aggregated and analyzed for targeted objective and producing results.

A sensor node consists Arduino Mega 2560 microcontroller, which is connected to CO Sensor, CO_2 Sensor, SO_2 Sensor, NO_2 Sensor, $PM_{2.5}$ and PM_{10} Sensors, Temperature and Humidity sensors. Microcontroller also interfaced with ESP8266 Wi-Fi module for Wi-Fi connectivity. This Wi-Fi module send data to router which is connected to IOT cloud. Thingspeak IOT cloud used for receiving data. Channel with 8 fields on ThingSpeak for plotting and storing data of CO , CO_2 ,

NO₂, SO₂, PM_{2.5} and PM₁₀ concentration and temperature and humidity data. After collecting, plotting and analyze the data on MATLAB analysis for personal exposure, an email alert sent to traffic police control room and control room internally communicates with traffic police.

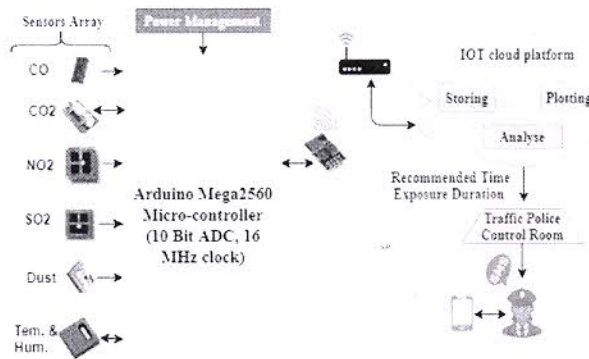


Fig. 3. Block Diagram of Urban Air Pollution System

For Calculating AQI values CPCB presented AQI mathematical statement to determine the air quality index using concentration value, and breakpoint for the pollutants. Mathematically AQI formula: [13]

$$IP = (Cp - Bplow) * \frac{Ihigh - Ilow}{(Bphigh - Bplow)} + Ilow \quad (2)$$

Where:

IP = The Index for pollutant, CP = The rounded concentration of pollutant, BPhigh = The breakpoint that is greater than or equal to CP, BPlow = The breakpoint that is less than or equal to CP, Ihigh = The AQI value corresponding to BPhigh, Ilow = The AQI value corresponding to BPlow. Table 1 shows the threshold value for different pollutants for Air Quality Index break points.

TABLE I. ENVIRONMENT PROTECTION AGENCY (EPA) AIR QUALITY INDEX CATEGORY [3] [13] [14]

AQI	PM _{2.5} (µg/m ³) (24- hours)	PM ₁₀ (µg/m ³) (24- hours)	CO (ppm) (8- hour)	NO ₂ (ppb) (1- hour)	SO ₂ (ppb) (1- hour)	SO ₂ (ppb) (24- hour)	CO ₂
0-50	0.0- 12.0	0-54	0.0- 4.4	0-53	0-35	-	
51- 100	12.1- 35.4	55-154	4.5- 9.4	54- 100	36-75	-	
101- 150	35.5- 55.5	155- 254	9.5- 12.4	101- 360	76- 185	-	
151- 200	55.5- 150.4	255- 354	12.5- 15.4	361- 649	186- 304	-	
201- 300	150.5- 250.4	355- 424	15.5- 30.4	650- 1249	-	305- 604	
301- 400	250.5- 350.4	425- 504	30.5- 40.4	1250- 1649	-	605- 804	
400- 500	350.5- 500.4	505- 604	40.4- 50.4	1650- 2049	-	805- 1004	

IV. SYSTEM IMPLEMENTATION

A. Hardware description

In this section, we describe the hardware components of sensor node for Urban Air Pollution Monitoring System. This sensor node uses multiple sensors which consists of gas sensor (CO, CO₂, NO₂, SO₂), environmental sensor (Temperature/humidity), and dust sensor (PM_{2.5}, PM₁₀), interfaced with microcontroller along with Wi-Fi module. Individual sensor is described further.

SHT20 Sensor: This sensor measures the temperature and humidity parameter, and operating voltage of this sensor is 3.3V. It works on I2C communication protocol having 0X40 I2C address, 0XF5 is humidity measurement command, and 0XF3 is temperature, measurement command.

TGS5342 Sensor: - TGS5342 is a low power, selective electrochemical carbon monoxide sensor, which operates on 0-5V input supply voltage and 0-10,000 ppm is the maximum detection range for CO. It has 0.7-1.4nA/ppm sensitivity for carbon monoxide. The output current generated by the electrochemical sensor is directly proposal to the CO gas concentration level. The calculation for concentration value of CO is

$$co \text{ concentration} = \frac{\text{sensor current}}{\text{output current in co}} \quad (3)$$

MH-Z14A CO₂ Module: It detects the carbon dioxide (CO₂) level in atmosphere using Non-dispersive infrared (NDIR) principle. This sensor module produces the output in the form of PWM, digital, and analog. It requires 0-5V input supply voltage, detection range of CO₂ is 0-10,000 ppm, preheating timing is very less just 3min, and response time less than 120s. This module is highly sensitive for target gas.

The calculation of the concentration level of CO₂ in atmosphere using Universal Asynchronous Receiver Transmitter (UART) communication protocol is

$$Gas \text{ concentration} = High \text{ level} * 256 + low \text{ level} \quad (4)$$

Spec SO₂ Sensor: This sensor is highly sensitive for Sulfur dioxide (SO₂) gas based on electrochemical principle. This type of sensor is perfect for atmosphere, industry, housing monitoring because its offer the low price, high performance, and compact size. Measurement range is 0 to 20 ppm, and resolution is less than 20ppb, less than 15 seconds is response timing.

Spec NO₂ Sensor: It measures the Nitrogen dioxide (NO₂) gas concentration level which detection range is 0 – 5 ppm and lower detection limit is less than 20ppb, and the resolution is <20ppb. Although identical reliable and correct, this gas sensor is mainly for residential relative gas sensing application.

GP2Y1010AU0F Sensor: - This is optical dust sensor, which detects the particulate matter PM_{2.5} and PM₁₀. Basic principle of this device, a phototransistor and an infrared emitting diode are arranged in diagonally, and detects the reflected light of particle in air. Particularly this sensor senses a very fine particle such as smoke. This sensor can operate at 5V supply voltage, and sensitivity is 0.35 to 0.65 mg/m³.

All sensors and Wi-Fi module are interfaced with Arduino Mega2560 microcontroller board because it has enough I/O pins, communication protocol, A/D (Analog to Digital converter) converter, etc. It contains 54 GPIO (General Purpose Input-Output) pins, 16 analog channels, and 15 channels for PWM (Pulse-Width Modulation) signal, 10-bit ADC, SRAM 8kb, and 256 kb for flash memory. It uses 16MHz external oscillator clock. This microcontroller is fulfilled in our requirement. Lastly these sensor data send to the cloud using ESP-01 Wi-Fi Module. This Wi-Fi module sends the data in 300 MBPS data rate, operating frequency-is 2.4GHz, and covers the connectivity range 190 meter in line of sight. The complete developed sensor node is shown in Fig. 4.

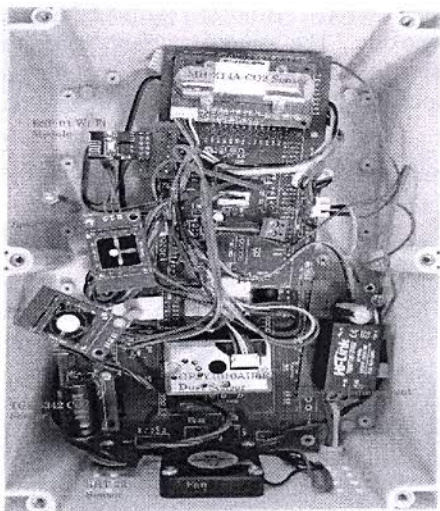


Fig. 4. Developed sensor node for pollution monitoring.

B. Software and Cloud Services

Software: Arduino IDE platform was used for writing, compiling and uploading the firmware into microcontroller. Thingspeak is a cloud services in local area network or Internet, an open source application, an API and application of Internet of Things, to retrieve and store data. IFTTT services is an abbreviation of “if this then that” where “this” is called trigger and “that” is called action.

Cloud Services: Data send by device visuals instantly to ThingSpeak, online analysis is done in ThingSpeak with MATLAB code. ThingSpeak uses REST API approach to communicate between IOT device and cloud. The key element of this platform is the channel, which stores and retrieve data generated from sensors via REST API. The Air Quality Index value has been calculated from average value of urban air pollutant and personal exposure of urban air pollutant has been determined.

IFTTT Services: “Webhooks” is used as a trigger IFTTT Webhooks services is generally for allowing other services on IFTTT and “Email” is action. Using IFTTT services creates an IFTTT URL which is mentioned in MATLAB analysis code along with ThingSpeak URL to send an Email alert to notify traffic police management.

V. RESULTS

Demonstration of Urban Air Pollution System has been done and could effectively calculate the value of Air pollutants. These air pollutants value successfully sent wirelessly to ThingSpeak channel. Fig. 5 and Fig. 6 has shown concentration of Urban Air Pollutants CO, CO₂, SO₂, NO₂ in ppm and PM₁₀ and PM_{2.5} in $\mu\text{g}/\text{m}^3$ received from sensor node.

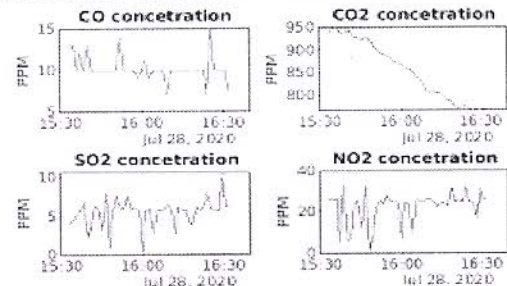


Fig. 5. Concentration of CO, CO₂, SO₂, NO₂ (ppm)

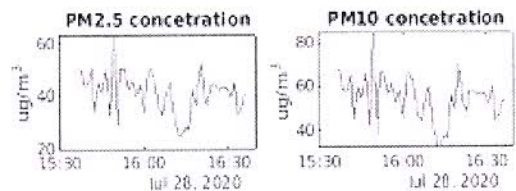


Fig. 6. Concentration of PM10 and PM2.5 ($\mu\text{g}/\text{m}^3$)

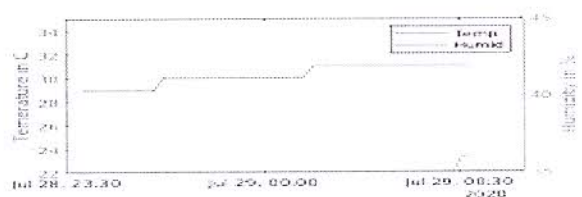


Fig. 7. Temperature and Humidity plot

After uploading and plotting the data, determined total AQI of the Urban Air Pollution System in MATLAB visualization. AQI has been categorized in good range (0-50), satisfactory range (51-100), unhealthy range for sensitive people (100-150), unhealthy range (151-200), very unhealthy range (200-300), and hazardous range 301-500 with respected colors ‘green’, ‘yellow’, ‘orange’, ‘red’ and ‘maroon’. Calculated and plotted AQI is shown in Fig. 8 with respect to its color code.

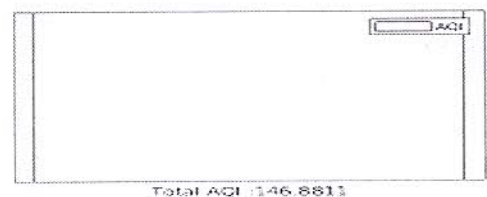


Fig. 8. Maseasured AQI at installed node location with colour code

Once the pollutants data start accumulating with respect to time period. The personal exposure calculation takes place for collected pollutants data for estimating recommended left time duration of duty hours for traffic police person, where AQI

sensor node is installed. This task has been done in MATLAB analysis and alert email has been send to traffic police control room via IFTTT services. Fig. 9, Fig. 10 and Fig. 11 shows alert messages for personal exposure and action to be taken for managing duty hours of traffic police person.



Fig. 9. Received Alert message in healthy condition

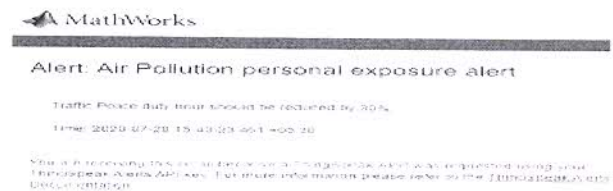


Fig. 10. Received Alert message in unhealthy condition to sensitive people condition

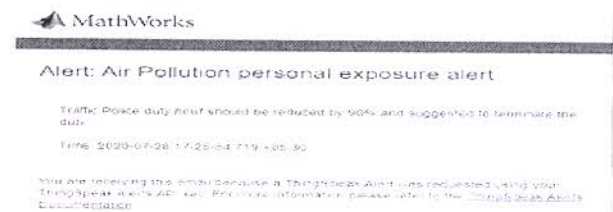


Fig. 11. Received Alert message in hazardous condition

VI. CONCLUSION & FUTURE WORK

The proposed framework is implemented for single node of outdoor pollutants exposure to human life. The designed system is capable of capturing CO₂, CO, SO₂, NO₂, PM2.5, PM10, Temperature and Humidity parameters in outdoor environment. These captured data sent to ThingSpeak IoT cloud for further analysis and calculating pollutants exposure and Notify Traffic Police control room to manage duty hours of Traffic Police man at that location. This work helps in making decision of duty hour or personal exposure hours with regard to urban air pollutants and total AQI. This system also helps in minimize negative health effect of urban air pollution on long term basis. In future, this frame work can be implemented in highly polluted urban area for context aware information sharing to residential of that locality as well as in traffic management to avoid traffic jam in a city.

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