

# 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, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub> 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, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>, 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<sub>2.5</sub>, PM<sub>10</sub>), sulfur oxides (SO<sub>2</sub>), carbon monoxide (CO) and excessive level of carbon dioxides (CO<sub>2</sub>). 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 CO<sub>2</sub> 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].

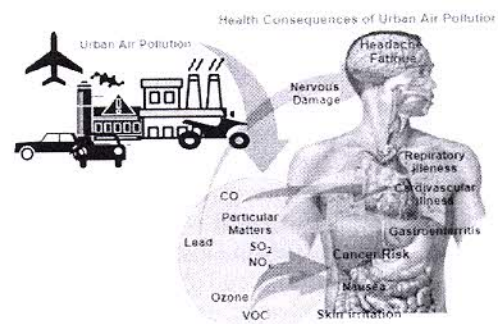


Fig. 1. Health consequences due to urban air pollution

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

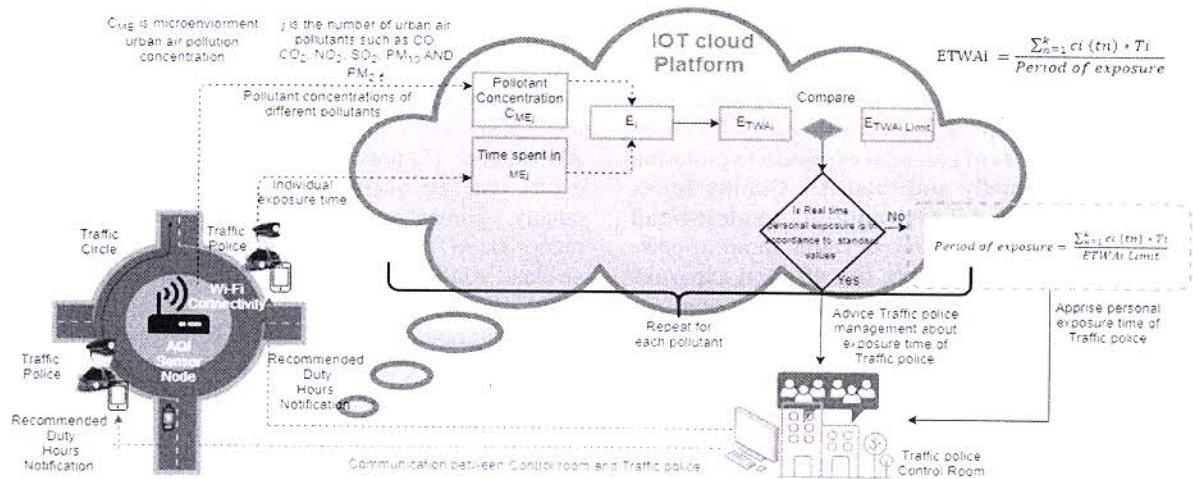


Fig. 2. System Framework of Urban Air Pollution Monitoring System

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  $CO$ ,  $CO_2$ ,



NO<sub>2</sub>, SO<sub>2</sub>, PM<sub>2.5</sub> and PM<sub>10</sub> 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.

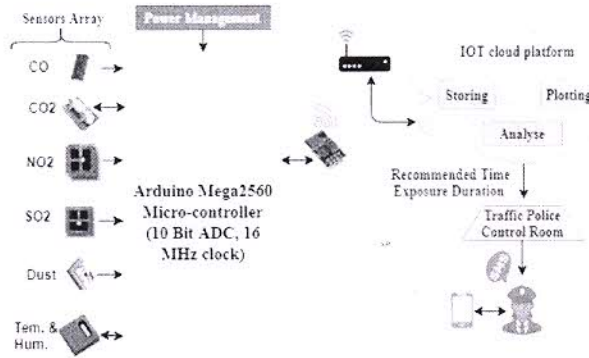


Fig. 3. Block Diagram of Urban Air Pollution System

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 <sub>2.5</sub> (µg/m <sup>3</sup> ) (24- hours)	PM <sub>10</sub> (µg/m <sup>3</sup> ) (24- hours)	CO (ppm) (8- hour)	NO <sub>2</sub> (ppb) (1- hour)	SO <sub>2</sub> (ppb) (1- hour)	SO <sub>2</sub> (ppb) (24- hour)	CO <sub>2</sub>
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, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>), environmental sensor (Temperature/humidity), and dust sensor (PM<sub>2.5</sub>, PM<sub>10</sub>), 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 CO<sub>2</sub> Module:** It detects the carbon dioxide (CO<sub>2</sub>) 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 CO<sub>2</sub> 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 CO<sub>2</sub> in atmosphere using Universal Asynchronous Receiver Transmitter (UART) communication protocol is

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

**Spec SO<sub>2</sub> Sensor:** This sensor is highly sensitive for Sulfur dioxide (SO<sub>2</sub>) 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 NO<sub>2</sub> Sensor:** It measures the Nitrogen dioxide (NO<sub>2</sub>) 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<sub>2.5</sub> and PM<sub>10</sub>. 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/m<sup>3</sup>.

