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Sensor based real time air pollutants monitoring for an urban industrial area

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ABSTRACT

Introduction: This study used economical sensors and an Unmanned Aerial Vehicle (UAV) to examine real-time air pollution assessment for an urban industrial area.

Materials and methods: Using a DJI Phantom 3 Pro, the concentrations in the research area were measured. In the study, Carbon monoxide (CO) and Nitrogen dioxide (NO_2) were measured using metal oxide sensors, and Particulate Matter (PM_{10}) was determined using a dust smoke particle sensor. Pollutants were measured at heights of 0.8 m and 10 m for a period of one month.

Results: With an increase in elevation, a gradual drop in pollutant concentration has been seen. High traffic volumes and fuel combustion are to blame for this increase. The concentration of CO, NO_2 and PM_{10} at 0.8 m has been found to be 22.53%, 42.90% and 45.86% respectively higher when compared at 10 m. The main finding of this study is the use of an UAV integrated with sensors for vertical monitoring of the pollutant concentration.

Conclusion: The CO concentration was found to be less than the standard value but near to it, when the data were compared to the Central Pollution Control Board (CPCB) standards. While it was discovered that the measured PM_{10} concentration was higher than the CPCB standard value, the observed NO_2 concentration was determined to be lower than the standard value. Also, given that they produce satisfactory results, low-cost gas sensors can be employed to conduct concentration measurement studies.

Introduction

In both urban and rural locations currently, poor air quality is one of the major environmental problems. Numerous human breathing illnesses and other environmental problems are caused by gas emissions. The pollutants that come from industry and traffic are odourless and tasteless. As a result, it is hard for humans to detect these toxins in time to take action. Nearly all monitoring systems are static and placed in strategic locations around cities. It is crucial to gather geographically scattered concentration

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measurements in order to get an accurate depiction of the gas dispersion. As a result, from an economic and deployment standpoint, a stationary sensor network is frequently not a viable alternative. Unmanned Aerial Vehicle (UAV) may have a significant impact in this area by offering adaptable systems for the automated monitoring of various environments. Many researchers have developed wireless monitoring devices that use sensors on an electronic board to determine the concentration of air contaminants. This lessens the need for labor-intensive human labour and associated costs, enables widespread sampling, and expands the scope of sampling and monitoring.

The first study to describe data collecting with a quadcopter has been done by employing a user measuring method to keep track of pollutants and air quality. The central element of this system is a quadcopter, which is fitted with sensors to track pressure, temperature, humidity, and gases like O_2 and CO_2 both vertically and horizontally [1]. A pollution driven UAV control (PdUC) method to monitor air pollution in sites with limited accessibility results in the development of pollution maps by concentrating on locations with greater pollutant concentrations. This approach makes it possible to produce precise maps more quickly than with other approaches [2]. A Wireless Sensor Network (WSN) has been created with 44 air quality sensors and several node kinds [3]. In order to calculate the area's real-time CO levels a mobile device has been built which comprises of a wireless sensor integrated to a smartphone that acts as an terminal [4]. In order to measure the concentration of O_3, CO, NO_2, CO_2, SO_2, NH_3, and PM emissions, E-drone has been used [5]. The perpendicular profiles of $PM_{2.5}$ and black carbon has been analyzed in China, from the ground level to 500 meters above the ground using a UAV equipped with small sensors [6]. A 3D air quality monitoring system based on IoT has been developed and the observed data has been processed using method based on spatial fitting [7]. Measurement of CO, NO_2, O_3 using sensors originated from smoke produced by a controlled fire fueled by vegetation has been done without any validation [8]. Laser based Air Quality Index (AQI) detection sensor which has been fitted on drone. The particle dispersion in air was studied using a Gaussian plume model based on neural networks. The drone's battery consumption has been reduced using an adaptive control algorithm [9]. Measurement of carbon monoxide using metal oxide semiconductor gas sensor and built a three dimensional distribution map of the CO gas has been performed using kernel algorithm [10]. A device has been developed in which the sensors capable of measuring CO, CO_2, CH_2O, and $PM_{2.5}$ are connected by an electronic circuit board. Temperature and humidity are also monitored by the gadget. The device board came with the ESP-07 microcontroller, which has a Wi-Fi interface and a Bluetooth communication chip to enable the wireless connection [11]. An IoT system for monitoring air quality ahs been proposed that uses a Raspberry Pi board and a Node-MCU ESP 8266 to measure the concentration of O_2 as well as the pollutants CO_2 and $PM_{2.5}$. An electronic circuit board connects the microcontroller to all of the sensors. The data is delivered to a Raspberry that serves as a MQ telemetry transport server over Wi-Fi. The objective of this work is to measure CO, NO_2 and PM_{10} concentrations using an UAV fitted with low cost sensors [12]. The main objective of this study is to reliability of the portable gas sensors in measurement of air pollutant concentration with high accuracy.

Materials and methods

Study area

Raipur, the state capital of Chhattisgarh, is situated on the Mahanadi River's western bank. Raipur is located at 21° 11’22” N, 21° 20’02” N, and 81°32’20” E, 81°41’50” E, respectively. The city's elevated landscape varies between 219 and 322 meters. It features a level surface with a few high areas that have a general northwest slope. Raipur has a tropical climate with both wet and dry seasons. The average yearly temperature is around 27°C. In April and May, temperatures may exceed 45°C. The annual precipitation averages around 1330 mm. Fig. 1 shows the study area. Siltara area of Raipur city has been considered as study area which is an industrial region. Fig. 1 shows sensors fitted on UAV for pollutant measurement. Pollutants has been measured at two different elevations i.e.at 0.8 m and 10 m above ground level for one month time period. The elevation of 0.8 m has been chosen because as per guidelines of United States Environment Protection Agency (USEPA), the minimum height of taking observation of gaseous pollutants is around 0.9 m. The reason for taking the highest elevation of 10 m is due to the limitation of flying UAV up to mentioned height has been imposed by local authority. The measurements were done for a period of 10 min. The time interval of 10 min has been considered for each elevation because the UAV have the maximum endurance of 10 min. The observed values has been compared with the standard values defined by CPCB.

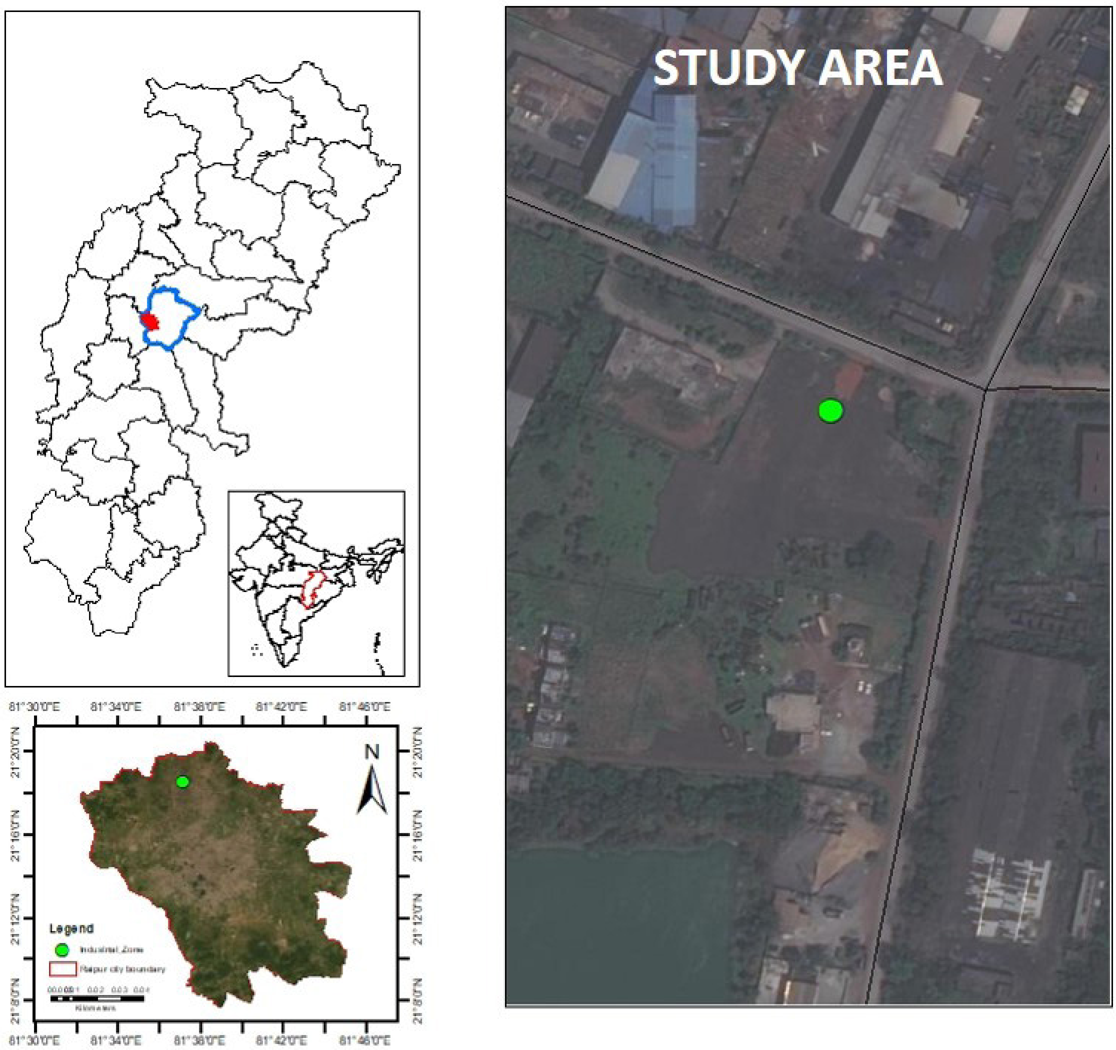


Fig. 1. Study area

Methodology

This study used a quadcoptor UAV to assess CO, NO_2 and PM_{10} concentrations at various elevations. Electrochemical sensors has been used in the study for meaurement of CO (SPEC Sensor) and NO_2 (Alphasense NO_2-B43F sensor) while laser particle counter sensor (Plantower PMS7003) has been used for PM_{10}. The pollution monitoring system has been integrated with the UAV which transmits the monitored data to Ground Control Station (GCS). The monitoring system uses a GSM module to transmit real-time data to the ground station. The data is sent via Message Queuing Telemetry Transport (MQTT) protocol. The GCS includes the remote control device to manage the UAV at different elevations and cell phone device with data card for receiving and saving the real time pollution data from monitoring system. The monitoring time for this study is between 9:00 am to 12:00 Noon in the morning session and 4:00 pm to 6:00 pm in the evening session. UAV used in the current study is DJI Phantom 3 Professional. The height of the UAV from the ground level has been set as a parameter flight control/fly path in the software before operation. The same flying height is being observed through the display of the UAV's remote control. All the monitoring has been done in the normal climatic conditions i.e., in very low to low wind speed conditions in which there will not be much effect/negligible effect of wind speed. Fig. 2 shows the methodology used for the study. Fig. 3 shows the UAV integrated with sensors.

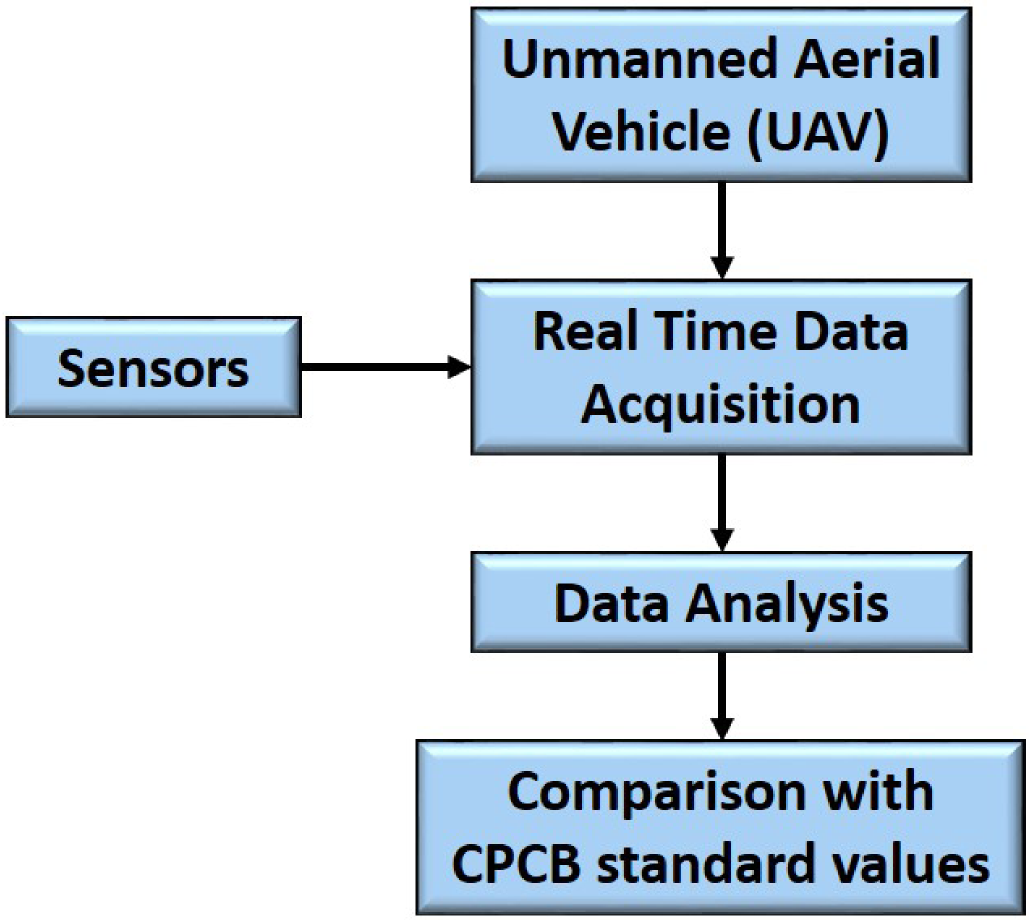
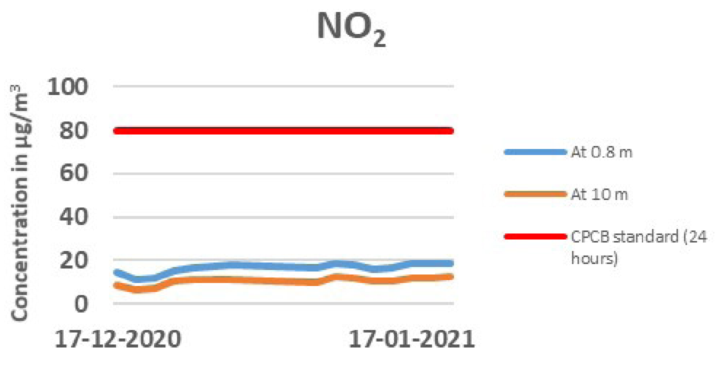


Fig. 2. Methodology

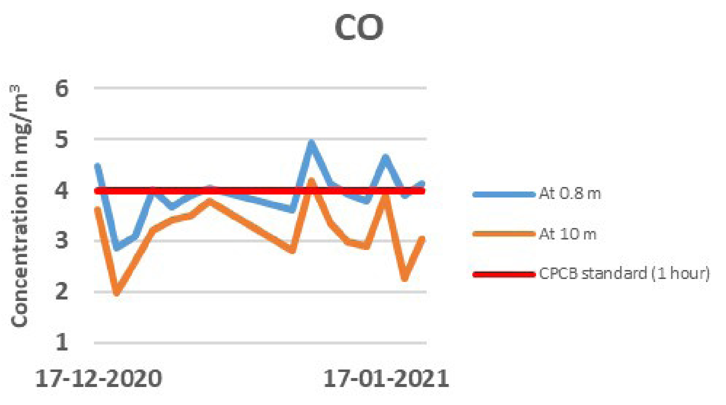
Fig. 3. UAV with sensor based air quality monitoring systems

Results and discussion

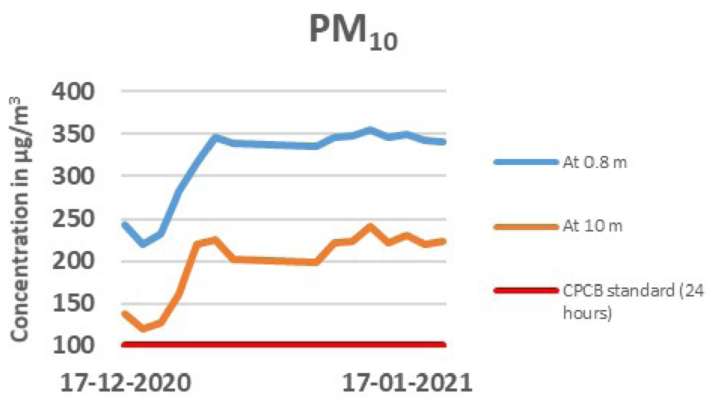
For the study area, the high value of concentration has been found at 0.8 m when compared with pollutant concentration at 10m. The concentration of CO has been found to be higher by 22.53% at 0.8 m above ground than at 10 m above ground level. Similarly concentration of NO_2 and PM_{10} has been found to be 42.90%, and 45.86% higher at 0.8 m above ground when compared to 10 m above ground respectively. The high concentration is due to combustion of fuel and heavy traffic. NO_2 has been observed to be highest on 27th December 2020, 9th and 19th January 2021 during afternoon. Table 1 shows the maximum value of NO_2 at 0.8 m and 10 m. Similarly for CO, highest concentration has been observed on 23th December 2020, 9th and on 19th January 2021 during afternoon hours as shown in Table 2. Also PM_{10} has been observed on higher side on 25th December 2020, 9th, 15th and 19th January 2021 during afternoon hours as given in Table 3. The CO concentration was found to be lower but near to the standard value when these data were compared to the CPCB standards. The observed NO_2 concentration was determined to be below the accepted value, however the observed PM_{10} concentration was found to be greater than the CPCB-recommended standard value. Fig. 4a shows the concentration of CO in the industrial area and its comparison with CPCB standards. Fig. 4b and Fig. 4c shows the concentration of NO_2 and PM_{10} in the industrial area and their comparison with CPCB standards respectively.



(a)



(b)



(c)

Fig. 4. Air pollutants concentration in industrial area

Table 1. NO_2 concentration

NO_2 Concentration (µg/m^3)		
Date	At 0.8 m	At 10 m
27-12-2020	17.5	10.9
09-01-2021	18.7	12.2
19-01-2021	18.5	13.6

Table 2. CO concentration

CO Concentration (mg/m^3)		
Date	At 0.8 m	At 10 m
23-12-2020	4.02	3.2
09-01-2021	4.96	4.3
19-01-2021	4.14	3.01

Table 3. PM_{10} concentration

PM_{10} Concentration (µg/m^3)		
Date	At 0.8 m	At 10 m
25-12-2020	315.1	220.56
09-01-2021	346.83	220.83
15-01-2021	346.43	220.89
19-01-2021	342.59	219.87

Conclusion

Throughout a month, air pollution measurements have been made in an industrial region at different elevations. The acquired results were compared to the CPCB standard values. It has been observed that, the high value of concentration has been observed at 0.8m level than 10 m above ground level. The concentration of CO, NO_2 and PM_{10} at 0.8 m has been found to be 22.53%, 42.90% and 45.86% respectively higher when compared at 10 m. The CO concentration was found to be less than the standard value but near to it when the data were compared to the CPCB standards. While it was discovered that the measured PM_{10} concentration was higher than the CPCB standard value, the observed NO_2 concentration was determined to be lower than the standard value. Also, given that they produce satisfactory results, low-cost gas sensors can be employed to conduct concentration measurement studies. The main limitation of this study has been found to be the lesser endurance of UAV and regulation imposed by the local authority for flying of an UAV.

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Competing interests
Author declares no conflict of interest.

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Ethical considerations
The authors declare that ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed

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