Performance & Evaluation Studies of Airborne Particulate Matter Near Bhilai Steel Plant Using Iot - Based Data Logger

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Abstract- *The present review aims to understand and get aware of the pollution, mainly to find out the level of particulate matter PM2.5, PM10 with CO (carbon monoxide) level within 15 km of range. This project is a Data survey of particulate matter and carbon monoxide levels in a range of 15 km from the Bhilai steel plant. In the present work, the data logger is used to find out the air quality and pollutants levels. Pms7003 sensor is used to evaluate the PM2.5 and PM10 While the MQ7 sensor is used to detect Carbon monoxide. Since Air pollutants show diurnal variations in their levels. During the daytime, solar heating causes maximum turbulence and the strongest vertical motions. This causes the maximum amount of momentum exchange between the various levels in the atmosphere. On clear nights with light winds, heat is radiated from the Earth's surface resulting in cooling of the ground and air adjacent to it. This results in extreme stability of the atmosphere near the Earth's surface. Under these conditions, turbulence is at a minimum. The present project work concludes some results that, in summer season mainly the pollutants have low concentration near-source while more concentration away from source due to average mixing height is more in summer. In the rainy season, rain washes down the pollutants, the result is similar to the summer season but has less concentration as compared to the summer season. In winter due to the typical average height of mixing because of this reason, the source has more concentration and after some kilometers, the pollutant concentration shows decrement. The IND AQI during the summertime was 84 to 104 and during the rainy time 82 to102 and during the winter season the IND AQI was 103 to 123.*

Keywords- Data Logger, PM10, PM2.5, PMS7003, MQ7, Air Quality Index: IND AQI.

I. INTRODUCTION

Air Pollution is defined as "the presence in the outdoor atmosphere of one or more contaminants, such as dust, fumes, gas, mist, odor, smoke or vapor in quantities, of characteristics, and of duration, such as to be injurious to human, plant, or property, or which unreasonably interferes with the comfortable enjoyment of life and property." Air pollution, as defined above, is not a recent phenomenon. Natural events always have been the direct cause of enormous amounts of air pollution. Volcanoes, for instance, spew lava onto land and emit particulates and poisonous gases containing ash, hydrogen sulfide (H_2S), and Sulphur dioxide (SO_2) into the atmosphere.

In the last few decades, air pollution became a global concern due to adverse health effects and other environmental issues such as global warming, poor visibility, etc. There are primarily two sources of air pollution in the atmosphere; (1) Natural emissions; and (2) Anthropogenic emissions. Anthropogenic emissions are produced by internal combustion (IC) engines and furnaces via combustion. IC engine has made our life more convenient; however, in return for this convenience, automobiles have caused air pollution which has led to adverse health effects.

Expanding areas of cities, rising traffic jams, higher energy consumption, rapid economic development is directly associated with air pollution. Air pollution is divided into two categories—primary and secondary air pollution. Primary pollutants are those which are emitted directly from a source like the exhaust of automobiles, industries, burning of fossil fuels. Some of them include hydrocarbons, carbon dioxide, carbon monoxide, Sulphur dioxide, nitrogen oxide, particulate matter. A secondary pollutant is a product of reaction among the primary pollutants or with water vapour and sunlight; examples are sulphuric acid, ozone, peroxy-acyl-nitrate (PAN), etc.

Study Area:

The Bhilai city (81.38º E longitudes, 21.21º N latitudes, and M.S.L. 297 meters) is situated in Mahanadi (Great River) basin in Chhattisgarh (India). Durg district is one of the urbanized industrial districts among the total 27 districts of Chhattisgarh. According to the census of 2021, it had a population of 36,98,169. The city is located 35 km. west of the capital Raipur, on the main Howrah– Mumbai rail line, and national highway 6.

The present review aims to understand and get aware of the pollution, mainly to find out the level of particulate matter $PM_{2.5}$, PM_{10} with CO (carbon monoxide) level from Bhilai Steel Plant to Minimata Square covering 15 km range and recording values in excel data format and converting the data and observing it in the form of graphs.

1.1 Various Pollutants Causing Air Pollution:

The atmospheric air may contain hundreds of air pollutants from natural or anthropogenic (manmade) sources. The following five primary pollutants contribute to about90% of global air pollution. The Important Primary air pollutants are:

S. No.	Pollutant	Characteristics	Source	Health Effects
1.	Suspended particulate matter	Solid particles like dust, smoke and	Dust storm; cigarette	Effects on breathing and
2.	Sulphur dioxide (SO_2)	Colourless gas; taste threshold at	Combustion of oil and coal in	Effects on breathing,
3.	Nitrogen dioxide (NO_2)	NO is a reddish brown highly	High temperature	NO plays a major role in

1.2 Data Logger

A data logger (data logger or data recorder) is an electronic device that records data over time or concerning position via built-in sensors or external devices and sensors. It's not perfect, but it's 2 gradually based on digital processors (or computers) (DDL digital data loggers). Generally small, battery-powered, portable, equipped with a microprocessor, internal memory, and sensors for data storage.

PMS7003 - Laser PM2.5 Digital Universal Particle Concentration Sensor

PMS7003 is a kind of digital and universal particle concentration sensor, which can be used to obtain the number of suspended particles in the air, i.e., the concentration of particles, and output them in the form of a digital interface. This sensor can be inserted into variable instruments related to the concentration of suspended particles in the air or other environmental improvement equipment to provide correct concentration data in time.

MQ-7 Carbon Monoxide Sensor

The sensitive material of the MQ-7 gas sensor is SnO2, which with lower conductivity in clean air. It makes detection by method of cycle high and low temperature,and detect CO at low temperature (heated by 1.5V). The sensor's conductivity gets higher along with the CO gas concentration rising. At high temperature (heated by 5.0V).

1.3 Air Quality Index (AQI)

An air quality index is defined as an overall scheme that transforms the weighed values of individual air pollution-related parameters (for example, pollutant concentrations) into a single number or set of numbers (Ott, 1978). The result is a set of rules (i.e., a set of equations) that translateparameter values into a simpler form by 3 means of numerical manipulation. If actual concentrations are reported in µg/m3 or ppm (parts per million) along with standards, then it cannot be considered as an index. At the very last step, an index in any system is to group-specific concentration ranges into air quality descriptor categories.

Indian Air Quality Index (IND-AQI)

Air quality standards are the basic foundation that provides a legal framework for air pollution control. An air quality standard is a description of a level of air quality that is adopted by a regulatory authority as enforceable. The basis of the development of standards is to provide a rationale for protecting public health from adverse effects of air pollutants, to eliminate or reduce exposure to hazardous air pollutants, and to guide national/local authorities for pollution control decisions. With these objectives, CPCB notified (http://www.cpcb.nic.in) a new set of Indian National Air Quality Standards (INAQS) for 12 parameters [carbon monoxide (CO) nitrogen dioxide (NO_2), Sulphur dioxide (SO_2), particulate matter (PM) of less than 2.5 microns size ($PM_{2.5}$), PM of less than 10microns size (PM_{10}), Ozone (O_3), Lead (Pb), Ammonia (NH), Benzo(a)Pyrene (BaP),

Benzene(C_6H_6), Arsenic (As), and Nickel (Ni)]. The first eight parameters have short-term (1/8/24hrs) and annual standards (except for CO and O_3) and the rest four parameters have only annual standards.

Indian National Air Quality Standards (units: µg/m^3 unless mentioned otherwise)

Pollutant	SO_2	NO2	$PM_{2.5}$	PM_{10}	O_3		CO		Pb	NH3
Averaging time	24	24	24	24	1	8	1	8	24	24
Standard	80	80	60	100	180	100	4	2	1	400

B(a)P, C6H6, As, and Ni have annual standards

IND-AQI Category and Range

AQI category	AQI Range
Good	0-50
Satisfactory	51-100
Moderate	101-200
Poor	201-300
Very poor	301-400
Severe	401-500

Breakpoints for AQI Scale 0-500 (units: µg/m^3 unless mentioned otherwise)

AQI	PM10	PM2.5	NO2	O3	CO	SO2	NH3	Pb 24-
Good	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory	51-100	31-60	41-80	51-	1.1-2.0	41-80	201-400	0.6 –1.0
Moderate	101-	61-90	81-	101-	2.1- 10	81-380	401-800	1.1-2.0
Poor	251-	91-	181-	169-	10.1-17	381-	801-	2.1-3.0
Very poor	351-	121-	281-	209-	17.1-34	801-	1201-	3.1-3.5
Severe	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

Health Statements for AQI Categories

AQI	Associated Health Impacts
Good	Minimal Impact
Satisfactory	May cause minor breathing discomfort to sensitive people
Moderate	May cause breathing discomfort to the people with lung disease
Poor	May cause breathing discomfort to people on prolonged exposure
Very Poor	May cause respiratory illness to the people on prolonged exposure.
Severe	May cause respiratory effects even on healthy people and serious

Interpretation of Air quality using IND-AQI

The sub-index (Ip) for a given pollutant concentration (Cp), as based on 'linear segmented principle' is calculated as:

Ip= [{(IHI - ILO)/ (BHI -BLO)} * (Cp-BLO)] +ILO

BHI= Breakpoint concentration greater or equal to a given concentration
BLO= Breakpoint concentration smaller or equal to a given concentration
IHI = AQI value corresponding to BHI
ILO = AQI value corresponding to BLO; subtract one from ILO, if ILO is greater than 50
Finally;
AQI = Max (Ip)
where; p= 1,2,...,n; denotes n pollutants

II. LITERATURE REVIEW

This review addresses air pollutants, an instrument used to determine pollutants (PM10, PM2.5, CO), Calculation of IND AQI, and gather the seasonal variation in summer, winter, and rainy seasons. Era Upadhyay et al. (2016), Studied Air Quality Status of Lucknow City-A Case Study, In This Study. The researcher determines the air quality of Lucknow city during (2013-2015). Data of air pollutants (NO_2, SO_2, and PM_{10}) has been analyzed from five monitoring sites of the city which includes residential, industrial, and commercial areas. The annual average concentration of PM_{10} for 2013-2015 ranges approximately from 60 ug/m_3 to 200 ug/m^3 exceeding the National Ambient Air Quality Standards for Industrial, Commercial and Residential areas. The annual average values range around 8 ug/m^3 for SO_2 concentration and are in the order of 30 ug/m^3 for NO_2 concentration. however, NO_2 and SO_2 are under permissible limits. The paper also investigates the count of exceedances of Nation Ambient Air Quality Standard and briefly compared the data from Delhi to understand the comparative status of air quality in Lucknow.

III. MATERIAL AND METHODOLOGY

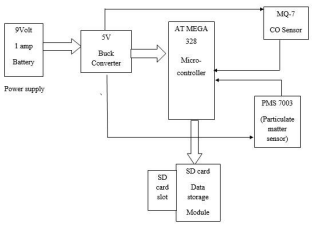
System Design

This project "Real-Time Data Logging System using Serial Peripheral Interface or SPI communication protocol" mainly projects on both the hardware and embedded software. The hardware implementation is done using the ARDUINO microcontroller, switches, and SPI communication protocol and the software implementation is done using ARDUINO IDE software and it is simulated, uploaded to the flash memory in the ARDUINO controller.

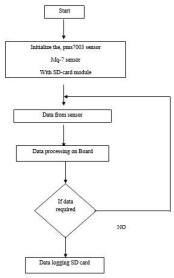
Working Principle

This project "Real-Time Data Logging System using SPI" as the various hardware components such as the Microcontroller, Memory storage data logging module (i.e.,

SD card module), Particulate Matter sensor, CO sensor. The block diagram of the proposed system is shown in Fig.



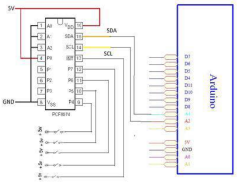
Block diagram of the proposed system



Flow diagram of the proposed system

Data Logger

A data logger (data logger or data recorder) is an electronic device that records data over time or about the position via built-in sensors or external devices and sensors. It's not perfect, but it's 8 gradually based on digital processors (or computers) (DDL digital data loggers). Generally small, battery-powered, portable, equipped with a microprocessor, internal memory, and sensors for data storage.



Circuit for Microcontroller interfacing with I2C Bus

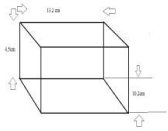
The data logger used in this experiment can detect the following parameters: -

1) Particulate matter 2.5
2) Particulate matter 10
3) Carbon Monoxide

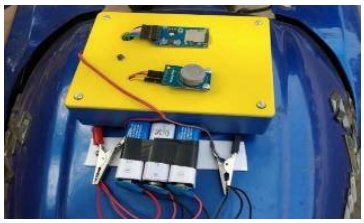
Data logger making process

Specification about the Data Logger Used in this experiment: -

The data logger used in this experiment is a PVC (Polyvinyl Chloride) container measuring 13.2 x 10.2 x 4.5 cm, 0.3 mm thick for easy cutting and drilling. Its top cover is secured with screws for further modification if needed. All hardware components used in this data logger were purchased from Quartz Components (online electronic components shopping app).



Data Logger enclose dimension



Data logger used experiment

Arduino Uno R3 ATmega328P Arduino Compatible - DIP (without cable)

The Arduino Uno R3 is an ATmega328P microcontroller-based development board. Arduino isn't a microcontroller nor a microprocessor: It's a simple and easy-to-use development board that is relying on a microcontroller in it. Generally, the board provides complete access to functions of a microcontroller or microprocessor like programming the controller, to using the input/output pins, to communicate. Some of the Arduino boards are Arduino Mega, Arduino Uno, Arduino Due, etc. Arduino UNO supports AT mega 328 microcontrollers which are developed by Atmel. This is widely popular in Embedded electronics because of the available resources and eases to use by everybody's features. With 14 digital input/output pins where 6 can be configured and used as PWM outputs, 6 as analogy inputs are a great addition for I/O related operations.

A2A development board with a microcontroller

ATmega328P Microcontroller with Arduino Bootloader

The ATMEGA328 (microcontroller) has 14 I/O lines, serial communication, and 6 ADC (Analog to Digital Converter) (A0 to A5) converters. The device operates in 5v. SD card and SPI protocol are interfaced with microcontroller chips. ATmega328P Microcontroller is the most widely used standalone AT mega IC for electronics projects. It can be connected to an Arduino UNO board as it comes with an Arduino bootloader. It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture.

Atmega328p Microcontroller with Arduino Bootloader

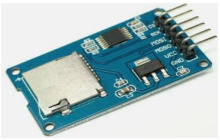
Micro SD Card

This Micro SD Card is used for transferring data to and from a standard SD card. The pinout is directly compatible with Arduino and also can be used with other microcontrollers. It allows us to add mass storage and data logging to our project. It is the tiniest memory card that will be bought; at fifteen-millimeter x eleven millimeters (about the scale of a fingernail).

Micro SD card

Micro SD Card Module

SD cards are often used along with microcontrollers to store and retrieve a huge amount of data, mostly in data logging or visualization applications. This SD card module will help us to easily interface an SD card with Microcontrollers.



micro-SD card module

micro-SD card module interface

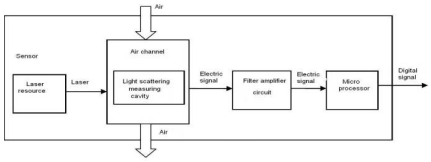
Particulate Matter Sensor -PMS7003

We are using the PMS7003 sensor for measuring particulate matter in the air with diameters of around 1.0, 2.5, and 10 microns. Particulates are the most harmful form of air pollution because they can penetrate deep into the lungs, bloodstreams, and brain causing many health problems

PMS7003 7th generation sensor with connector to monitor $PM_{2.5}$, PM_{10}

Working principle: -

The laser scattering principle is used for such a sensor, i.e., produce scattering by using a laser to radiate suspending particles in the air, then collect scattering light to a certain degree, and finally obtain the curve of scattering light change with time.



Functional block diagram of the sensor

Carbon Monoxide Sensor- MQ7

We are using MQ-7 which is a simple-to-use Carbon Monoxide (CO) sensor, suitable for sensing CO concentrations in the air. It can detect CO-gas concentrations anywhere and it's a low-cost sensor having a long life. This sensor has high sensitivity and a fast response time. The sensor's output is an analog resistance. This sensor comes in a package similar to our MQ-3 alcohol sensor and can be used with the breakout board below.

MQ7 CO SENSOR

Working principle:

This sensor contains a sensing element, mainly aluminum-oxide-based ceramic, coated with Tin dioxide (SnO2), enclosed in a stainless-steel mesh. Whenever CO gas comes into contact with the sensing element, the resistivity of the element changes. The change is then measured to get the concentration of the gases present.

Nine Volt Battery

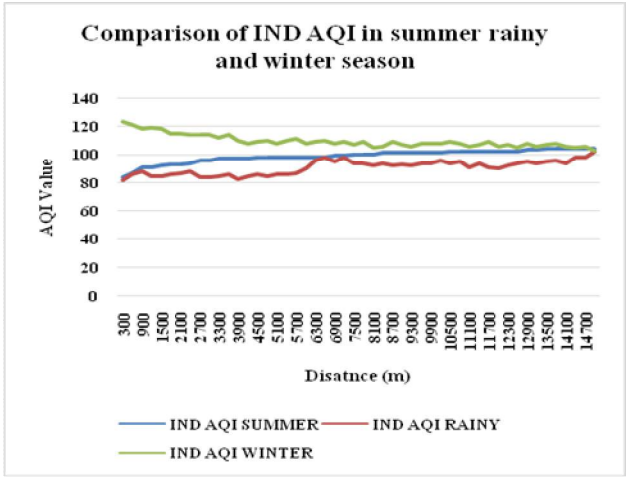
This is a General-purpose 9V Original HW marked Non-Rechargeable Battery. The 9-volt battery is a common-size battery that was introduced for early transistor radios. The battery used here has a dimension is 13 x 4.8 x 3.5 Centimeters of HIW, HIWAOTE Brand, and is a 6F22 size 9V carbon battery. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top. This type is commonly used in smoke detectors, gas detectors, clocks, etc.

9V HW High-Quality Battery

Batteries Clip Connector

IV. RESULT AND DISCUSSION

In This Result and Discussion, pollutants IND AQIwas analyzed from Bhilai Steel Plant Main Gate to Minimata Square, Tables and graphs were made for the summer season (1st March – 30th June 2021), Rainy Season (1st July – 30th Sept 2021), and Winter Season (1st Oct – 15th Feb 2022) in which Air Pollutants and Different AQI were placed such as (PM_{10}, $PM_{2.5}$, CO) and calculated (IND AQI) respectively. And also, a Comparison of the PM_{10} concentration of the data logger and the manually monitored system was made. From Graph, a discussion is extracted for better understanding.

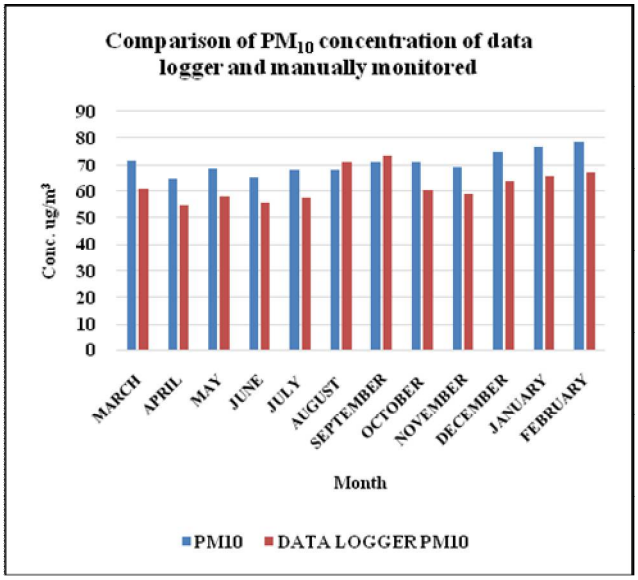


The above graph is plotted between IND AQI and Distance. In the summer season, the source has a low concentration and after some kilometers, the concentration is high because of average height mixing. In the rainy season, the source has a low concentration while after some kilometers the IND AQI shows increment this is because in the rainy season the rain washes down the pollutant concentration. The winter season has more concentration in source this is because in the winter average mixing height is typical and because of this, the IND AQI is more in winter as compared to rainy and summer seasons.

Comparing the data logger and Manually Monitored (CSIDC)

The data logger data and manually monitored data of CSIDC were compared concerning $PM_{10}$and $PM_{2.5}$. CSIDC lies in the route of Bhilai steel plant main gate and Minimata square. The distance 11400m data i.e., PM_{10} and $PM_{2.5}$ concentration were only observed to compare with CSIDC data. And to check how precisely the data logger is working concerning the manually monitored.

PM_{10} concentration



The graph is plotted between the concentration of PM_{10} and the Months for comparing the data logger and manually. As we can see in the graph the data logger shows the same behavior as manually performed data but it shows approx. 80-85% accuracy rate as compared to manually evaluated data. The Summer and Rainy months show gradually increment concentration while in winter months the concentration was more as compared to summer and rainy season both for data logger and manually evaluated.

V. CONCLUSION

In the summer season the IND AQI shows an increment but if we notice in the source area the IND AQI is low as compared to away from the source is because of Average mixing height of pollutants concentration is typically high in the source that's why the source has lower IND AQI value and as the distance increases the IND AQI value also increases.

In the rainy season, IND AQI, due to a large amount of precipitation and washes down the pollutant concentration that's why the IND AQI shows less value in source as compared to away from the source. We conclude that in the rainy season as the distance increases from the source the IND AQI value also increases.

In the winter season IND AQI was more in source and some extent to the area because the average mixing height of pollutant concentration was low and due to this reason, the IND AQI is more as compared to away from the source. We conclude that from the source as the distance increases in the winter season IND AQI shows a downfall.

The data logger is approx. 85 % efficient as compared to a manually monitored system as we compare the data of PM10 and PM2.5 data.

Based on the observation obtained from the statutory bodies such as (CECB) during this field study and the corresponding data there should be some restrictions periodically followed:

- An odd-even policy should be implemented by the state government.
- Avoid excessive idling of automobiles.
- Refuel your car in the evening when it's cooler.
- Look for the ENERGY STAR label when buying a home or office equipment.
- Use filters for chimneys

VI. FUTURE SCOPE

- Data logger can be used to determine other various pollutants such as Oxides of Sulphur (Sox), Oxides of Nitrogen (NOx), Lead (Pb), and Ammonia (NH3).
- Using SBC (Single Board Computer) we can calculate the IND AQI.
- With the help of a drone, we can also calculate the various pollutants and AQI in different altitudes.
- We can also calculate r2 and Root mean square error of the data logger.
- We can also compare the data of pollutant concentration manually, continuous ambient air monitoring system, and data logger to know the efficiency of the data logger concerning manually monitored and automatic monitored.
- Since there are many ways to calculate AQI we can merge them in such a way that, with the help of SBC we can compare the different AQI data.
- The data acquired may be used to predict pollution in similar zones depending on the location and vicinity of the type of industry in that location. This is expected to reduce the cost of pollution monitoring as well as helps people to choose their residential area depending on the associated health hazard.

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