iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VIII **Month of publication:** August 2025

DOI: https://doi.org/10.22214/ijraset.2025.73625

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VIII Aug 2025- Available at www.ijraset.com

Assessment of Ambient Air Quality in Different Areas of Jaypee Cement Plant, Rewa, Madhya Pradesh, India

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Abstract: ***The term air quality means the state of the air around us. Ambient air quality refers to the quality of outdoor air in our surrounding environment. It is typically measured near ground level, away from direct source of pollution. The paper present air pollutants (such as particulate matter 10, particulate matter 2.5, sulphur dioxide SO_X, oxide of nitrogen NO_X and carbon monoxide CO) emitted from Jaypee cement plant, Rewa, Madhya Pradesh. This study was undertaken to investigate the air quality around the cement plant within 5 km radius. The air temperature, relative humidity, wind speed and predominant wind direction were studied for the sampling days. Data for all five air pollutants were collected for a study period at four different stations (Near Washing Ramp, Near Narmada Gate, Near Estate Office, Near Bhagirathi Gate). Results indicate that both particulate matter (PM_{10} and PM $_{2.5}$) and gaseous pollutants (SO_x, NO_x & CO) are within the permissible limit prescribed for industrial, residential and rural uses by CPCB, New Delhi. The average value of concentration of all the air pollutants under the permissible limits due to industry have installed air trapping devices which control air pollution and helps to minimize the dust in the surrounding area.***

Keywords: Ambient air quality, PM_{10}, PM $_{2.5}$, SO_x, NO_x & CO, cement plant pollution, Jaypee Rewa, industrial emissions.

I. INTRODUCTION

Air pollution is becoming serious because of four developments: increasing traffic, growing cities, rapid economic development and industries. Cement plants a vital role in contributing towards the progress of human society. The main environmental problems from the cement plants are PM_{10}, PM $_{2.5}$ and gaseous pollutants such as Sulphur dioxide (SO_X), oxide of nitrogen (NOx) & carbon monoxide (CO). Given this context, the assessment of ambient air quality around cement plants becomes crucial for evaluating the environmental impact of industrial activities. This study aims to systematically assess the concentration of key air pollutants in the vicinity of a cement plant and analyze their spatial and seasonal variations. The findings are compared with the National Ambient Air Quality Standards (NAAQS) prescribed by the Central Pollution Control Board (CPCB) to evaluate the level of compliance and identify areas of concern.

A. Objectives of the Study

- To assess the levels of ambient air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO) in and around the cement plant.
- To identify the spatial and seasonal variation of air quality across different locations near the cement plant.
- To compare observed pollutant concentrations with National Ambient Air Quality Standards (NAAQS) prescribed by CPCB.
- To analyze the impact of cement plant emissions on the surrounding environment, vegetation, and human health.
- To recommend appropriate air pollution control measures for sustainable plant operation and environmental protection.

Monitoring of air quality around the cement industries in India has been a subject of many recent studies (Banejee and Panday 1989; Gupta 1994; Chandrasekharan et. al, 1996, 1998; Agrawal and Khanam 1997; Shrivastava 1999) . Effect of air pollutants in human health are studied by Pope (2000a, 2000b) , HEI (1995, 2000a, 2000b) , and WHO (2000a, 2000b). Air pollution is the introduction of unwanted materials such as chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment, into the atmosphere (Chouhan et.al 2012). Air Pollutants means any solid, liquid or gaseous substance present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment (Abdullah and Iqbal 1991). The air is a composition of gases and is utilized by all the living organisms in respiration to liberate chemical energy for their survival.

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The composition determines the quality and is being changed in the recent past due to emission of huge amount of unwanted materials in the atmosphere by industries and automobiles. This changed quality of air has become a great threat for the survival of life, materials and ecosystem as a whole. In order to arrest the deterioration in air quality, it is necessary to assess the present and anticipated air quality through continuous air quality monitoring programs (Acosta et.al 2007; Adamson et.al 1994; Bache et.al 1991). Air pollution is a problem faced by both developing and developed countries and India is one of them. Increasing industrialization for economic development of nation to meet the specific requirements of the ever-increasing population is proving to be extremely dangerous for all living beings and ecosystems which alter their characteristics features. Air pollutants do not limit their boundaries and spread all around in the atmosphere. The complex among the natural disturbances, industrial emissions and transportation is not easily quantifiable. Cement making is an unavoidably a dusty operation as it is much concerned with hot dry powders. Various operations like crushing of stone or raw material, transport, storage and packaging in the cement factory produce fugitive dust emissions. Cement dust contains high concentrations of many metals known to have toxic effect not only on plants and animals but also on humans (Shukla et.al 1990; Hirano et.al 1995). According to the World Health Organization (WHO), air pollution is responsible for increasing regular visits of patients due to respiratory and cardiovascular diseases, hospital admissions and mortality. Present study is conducted to estimate the qualitative impairment of ambient air due to PM_{10}, PM $_{2.5}$, SO_2 , NO_2 &CO.

II. STUDY AREA

Jaypee Cement plant Rewa is situated in Rewa district, which is situated on the north eastern part of Madhya Pradesh state, central part of India. The founder of Jaypee group is Shri Jaiprakash Gaur ji. It lies between Latitude 24^0 31′ 37"*N* and Longitude 81^0 10′05.04"E. It is situated in Nabusta town Jaypee Nagar Distt. Rewa (M.P.) The Cement plant is encircled with the coal and limestone mines which gives the necessary raw material needed for the running of plant. Figure 1 Map of Jaypee Cement Plant showing study site

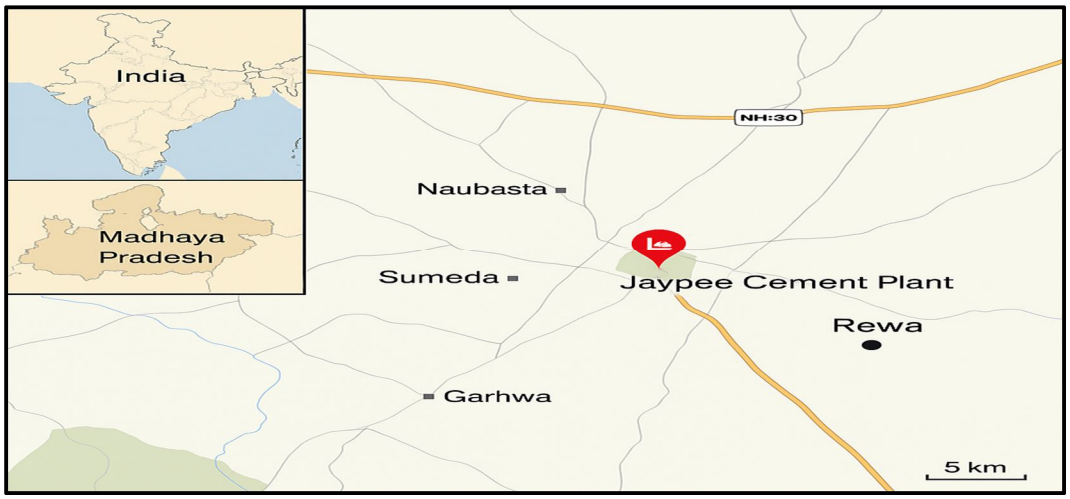

Fig. 1 Map of Jaypee Cement Plant showing study site

Study site - The present investigation on monitoring and assessment of ambient air quality at different station locations of cement plant was analyze in the laboratory. The details of the selected sampling sites are provided in Table 1.

Table 1
Station of Study Sites

S.No.	Station No.	Station	Location Near Station
1	S1	Near Washing Ramp	close to material handling area
2	S2	Near Narmada Gate	residential exposure zone
3	S3	Near Estate Office	administrative and employee housing
4	S4	Near Bhagirathi Gate	outskirts of the plant boundary

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III. MATERIALS & METHOD

A. Air Pollutants Measurement as per CPCB

The ambient air quality of any area can be measured by the methods that are prescribed by the Central pollution control board and BIS Standards. National Ambient Air Quality Standards (NAAQS, 2009) to control industrial air pollution. Table 2 air pollutants measurement method.

Table 2
Parameter to be analysis

S.No.	Pollutant	Method of Measurement
1	Particulate Matter (PM10)	Gravimetric Method
2	Particulate Matter (PM2.5)	Gravimetric Method
3	Sulphur Dioxide (SO2)	Improved west & Geake Method
4	Nitrogen Dioxide (NO2)	Jacob& Hochheiser Modified (NaoH-NaAso2) Method
5	Carbon Monoxide(CO)	NDIR (Non-Dispersive Infrared)

1) Particulate Matter -10 (PM_{10})-PM_{10} stands for Particulate Matter less than or equal to 10 micrometres in aerodynamic diameter. These are inhalable particles present in the air that are small enough to enter the nose, throat, and upper respiratory tract.

2) Particulate Matter -2.5 ($PM_{2.5}$)-The APM 550 Fine Particle Sampler consists of three sections: the air inlet and Impactor assembly, the main instrument case housing the WINS Impactor, filter holder and flow totalizer and the pump unit. During transportation the Air Inlet assembly and PM10 Impactor section is detached from the main instrument case. CPCB Guidelines / IS 5182 (Part 23).

3) Sulphur dioxide (SO_X)-The most commonly used method for measuring atmospheric $S0_2$ is based on colourimetry and is known as modified West-Gaeke method. In this method $S0_2$ from a measured quantity of air is absorbed in a solution of sodium tetrachloromercurate to form a stable and non-volatile dichlorophitomercurate complex. This is then reacted with formaldehyde and bleached pararosaniline, yielding a magenta-coloured pararosaniline sulfonic acid product.

4) Nitrogen Oxides (NO_X)-Concentration of Oxides of nitrogen are estimated in ambient air by using Jacob and Hochheiser method. Oxides of nitrogen are collected by bubbling air through a sodium hydroxide solution to form a stable solution of sodium nitrite. The nitrite produced during sampling is determined colorimetrically by reacting the exposed absorbing reagent with phosphoric acid, sulfanilamide, and NEDA (1-naphthyl ethylenediamine dihydrochloride) at 540 nm (BIS: 5182 Part-VI, 1975).

5) Carbon Monoxide (CO)-Carbon Monoxide (CO) is a colorless, odorless, and tasteless gas that is primarily emitted from incomplete combustion of carbon-containing fuels. In areas surrounding cement plants, CO emissions may arise from fuel combustion processes (e.g., coal, diesel) used in kilns, generators, and vehicular traffic. High exposure to CO can reduce the oxygen-carrying capacity of blood, leading to serious health risks including dizziness, headaches, and in extreme cases, asphyxiation. As per IS 5182 (Part 10): 1999 / CPCB Guidelines, method used Non-Dispersive Infrared Spectroscopy (NDIR) by Instrument: Continuous CO Analyzer.

Sampling Schedule - The sampling was done continuously for 24 hours for PM2.5, PM10, SOx and NOx with a frequency of twice a week.

Meteorological data analysis - Meteorological data was monitored during the period of study. It is very useful for proper interpretation of the baseline information as well as for input predication models for air quality dispersion.

IV. RESULTS & DISCUSSIONS

The present study focuses on evaluating the ambient air quality in and around the Jaypee Cement Plant located in Rewa, Madhya Pradesh. The primary objective was to measure the concentrations of key air pollutants—such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO and to assess their potential impacts on environmental and human health in the surrounding region

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A. Ambient Air Quality

In this study, air samples were collected from multiple locations strategically selected to represent different environmental settings such as industrial, residential, and background areas—within the influence zone of the cement plant. The primary pollutants monitored & discussion below;

1) Particulate Matter (PM_{10}): The PM_{10} was monitored at Jaypee Rewa plant at four stations in different directions with the help of RDS. The concentration of PM_{10} ranged from 28.99-71.89 µg/m^3. The minimum concentration was found 28.99 µg/m 3 near Estate Office and the maximum value was found near Washing Ramp 71.89 µg/m 3 within the limit prescribed by NAAQM (100µg/m^3).

2) Particulate Matter ($PM_{2.5}$): The $PM_{2.5}$ was measured at Jaypee Rewa plant at the four stations in different directions with the help of FDS (Fine Dust Sampler). $PM_{2.5}$ Concentration ranged from 15.50-43.67 µg/m^3. The minimum concentration was found near Estate Office and the maximum concentration was found near Washing Ramp within the limit prescribed by NAAQM (60 µg/m^3).

3) Sulfur Dioxide (SO_2): Its concentration was monitored at four stations in Jaypee Rewa Cement plant with the help of RDS. The concentration of SO_2 ranged from 4.67-9.56 µg/m^3. The minimum concentration was found near Estate Office and the maximum concentration was found near Washing Ramp, within the limit prescribed by NAAQM (80µg/m^3).

4) Nitrogen Dioxide (NO_2): Its concentration was monitored at four stations in Jaypee Rewa plant with the help of RDS. The concentration of NO_2 ranged from 8.21-17.32µg µg/m^3. The minimum concentration was found near Washing Ramp and the maximum concentration also was found near Washing Ramp, within the limit prescribed by the NAAQM (80 µg/m^3)

5) Carbon Monoxide (CO): Its concentration was monitored at four stations in Jaypee Rewa plant with the help of RDS. The concentration of CO ranged from 57.51-113.98 µg/m^3. The minimum concentration was found near Narmada Gate and the maximum concentration was found near Washing Ramp, within the limit prescribed by the NAAQM (2000 µg/m^3)

From the above data of all the different parameters with station. We calculated the average ambient air quality of Jaypee Rewa plant which is summarized below in the table 3 & average ambient air quality show in figure 2

S.NO.	Parameter	Name of Stations			
		Washing Ramp	Narmada Gate	Estate Office	Bhagirathi Gate
1.	PM_{10} (µg/m³)	50.80	41.24	41.38	40.82
2.	$PM_{2.5}$ (µg/m³)	29.21	26.10	20.76	22.68
3.	SO_x (µg/m³)	7.22	7.19	7.10	6.53
4.	NO_x (µg/m³)	10.63	11.29	10.33	10.89
5.	CO (µg/m³)	87.06	87.68	87.24	87.59

Table 3. Average ambient air quality at various sampling stations

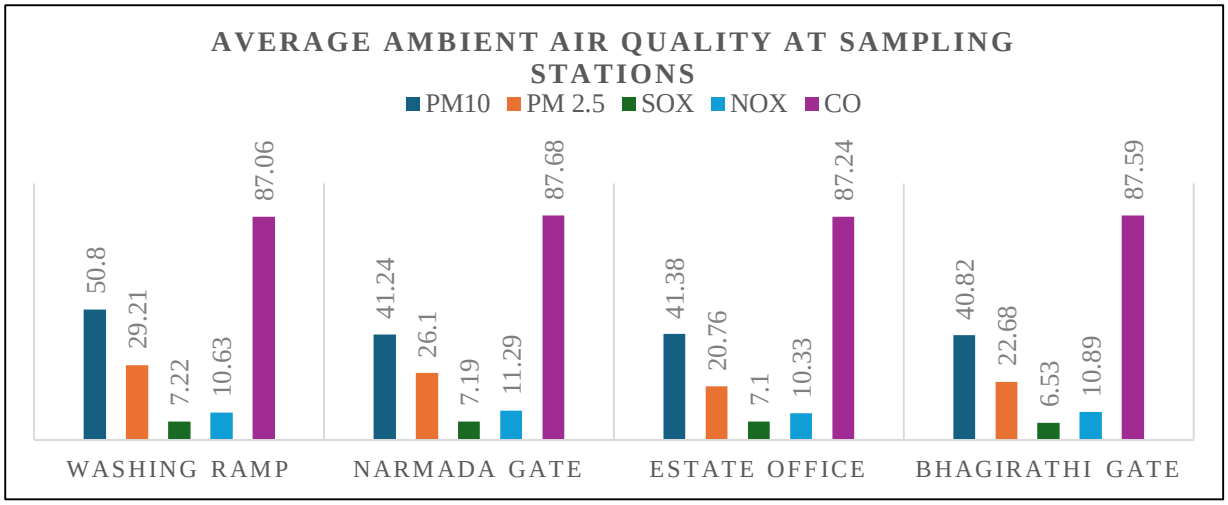

Fig. 2 Average Ambient Air Quality at Different Stations

B. Standards of National ambient air quality as per NAAQI

These standards specify the permissible concentration limits of key air pollutants in ambient air for both 24-hour average and annual average, depending on the pollutant. Table 4 Standards of National ambient air quality as per NAAQI

Table 4
Standards of National ambient air quality as per NAAQI

S.NO.	Parameters	Standards(µg/m³)
1.	Particulate Matter (PM10)	100
2.	Particulate Matter (PM2.5)	60
3.	Sulphur Dioxide (SO2)	80
4.	Nitrogen Dioxide (NO2)	80
5.	Carbon Monoxide (CO)	2000

C. Pearson Correlation Heat map

The scatter plots provide a visual representation of the relationship between two specific variables. Each point on the plot represents an observation with its corresponding values for the two selected pollutants/locations. The heatmap visually represents the Pearson correlation coefficients between different air pollutant levels at various locations. Figure 3 show the Pearson Correlation Heat map -

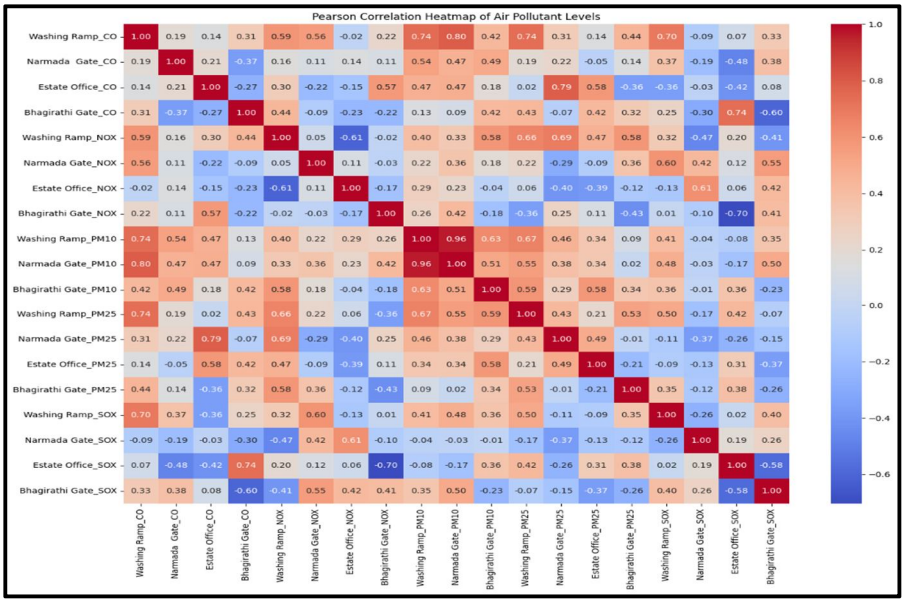

Fig 3 Pearson Correlation Heat map

1) Steps for Creating the Pearson Correlation Heatmap

Assuming you have ambient air quality data (e.g., for pollutants PM_{10}, $PM_{2.5}$, NO_x, SO_2 & CO) measured at: Near Washing Ramp, Near Narmada Gate, Near Estate Office, Near Bhagirathi Gate. Following steps for creating the Pearson Correlation Heatmap-

Step 1. Organize data in tabular form (e.g., daily averages of each pollutant at each station).

Step 2. Calculate Pearson correlation coefficients (values range from -1 to +1):

+1: Strong positive linear correlation

0: No linear correlation

-1: Strong negative linear correlation

Step 3. Generate heatmap (color-coded correlation matrix).

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2) Scatter Plot Interpretation

For strong positive correlations (bright red) to identify pollutants and locations that tend to increase or decrease together. This could suggest common sources or similar environmental factors affecting those pollutants in those areas.

For strong negative correlations (bright blue) to identify pollutants and locations that have an inverse relationship. This might be less common for air pollutants but could indicate complex atmospheric interactions or different dominant sources.

Interpretation of scatter plots from ambient air quality monitoring around the Jaypee Cement Plant, Rewa, at the following four locations are near Washing Ramp, near Narmada Gate, near Estate Office & near Bhagirathi Gate

Following scatter plots are between key pollutants (e.g., PM_{10}, $PM_{2.5}$, SO_2,NO_x & CO) and possibly paired pollutants, we'll interpret station wise trends based on general air quality behavior around Jaypee Cement Plant, Rewa.

- Scatter Plot of Bhagirathi Gate CO between Bhagirathi Gate PM $_{2.5}$. The CO values range approximately from 71 to 100 units. & the corresponding $PM_{2.5}$ values range from around 20 to 27 µg/m³.
- Scatter Plot of Narmada Gate PM_{10} between Narmada Gate $PM_{2.5}$. The PM_{10} values range approximately from 30 to 65 units. & the corresponding $PM_{2.5}$ values range from around 22 to 34µg/m³.
- Scatter Plot of Washing Ramp PM_{10} between Bhagirathi Gate SO_X. The PM_{10} values range approximately from 35 to 70 units. & the corresponding SO_X values range from around 5.5 to 8.5 µg/m³.
- Scatter Plot of Washing Ramp PM_{10} between Estate Office PM_{10}. The PM_{10} values range approximately from 35 to 70 units. & the corresponding PM_{10} values range from around 30 to 65 µg/m^3
- Scatter Plot of Washing Ramp PM_{10} between Bhagirathi Gate PM_{10}. The PM_{10} values range approximately from 35 to 70 units. & the corresponding PM_{10} values range from around 35 to 55 µg/m^3

V. CONCLUSIONS & FUTURE SCOPE OF THE WORK

A. Conclusions

The analysis of pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, and CO provides insights into the current status of air quality in the industrial and residential areas surrounding the plant. Based on these findings, this section presents a concise conclusion that reflects the environmental condition of the area and proposes actionable strategies and future research avenues for improving air quality management and sustainability. The assessment of ambient air quality in the vicinity of the Jaypee Cement Plant, Rewa, reveals significant environmental concerns, particularly with respect to particulate matter (PM_{10} and $PM_{2.5}$). gaseous pollutants near various station.

- PM_{10} & $PM_{2.5}$ concentrations within the National Ambient Air Quality Standards (NAAQS) at multiple locations, especially within the industrial zone and nearby residential areas.
- Gaseous pollutants such as SO_2, NO_2, and CO were found to be within permissible limits, indicating that combustion processes may be relatively well-controlled.
- All the station shows the average concentration value below the permissible limits (CPCB) standards value of all parameters i.e. PM_{10}, PM $_{2.5}$ SO_2, NO_2 & CO.
- On the basis of result the study station 1 (near Washing Ramp) was found to be most affected having PM_{10} ranges from 28.99 µg/m^3 to 71.89 µg/m^3, $PM_{2.5}$ ranges from 15.50 µg/m^3 to 43.67 µg/m^3, SO_2 ranges from 4.67µg/m^3 to 9.56 µg/m^3 , NO_2 ranges from 8.21 µg/m^3 to 17.32 µg/m^3 and CO ranges from 57.51 µg/m^3 to 113.98 µg/m^3.
- Among all four station the quality of air follows as- station 3> station 4> station 2> station 1.

B. Future Scope of the work

This section outlines the future scope of the study, focusing on the need for continuous monitoring, advanced pollutant source identification, health impact correlation, and the development of sustainable air pollution control strategies. By addressing these aspects, future research can contribute significantly to improving environmental quality, regulatory compliance, and public health protection in and around the cement plant area.

- Establish a continuous air quality monitoring system to track pollutant trends over different seasons (summer, monsoon, winter) and assess long-term environmental impact.
- Implement a source apportionment study to accurately identify and quantify individual contributors (plant operations, vehicular traffic, regional dust, etc.) to PM levels.

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- Involve the local community and environmental authorities in periodic review meetings and awareness programs to ensure transparent environmental governance.
- Future studies can link pollutant levels with AQI values and publicly display daily AQI ratings to enhance community awareness.

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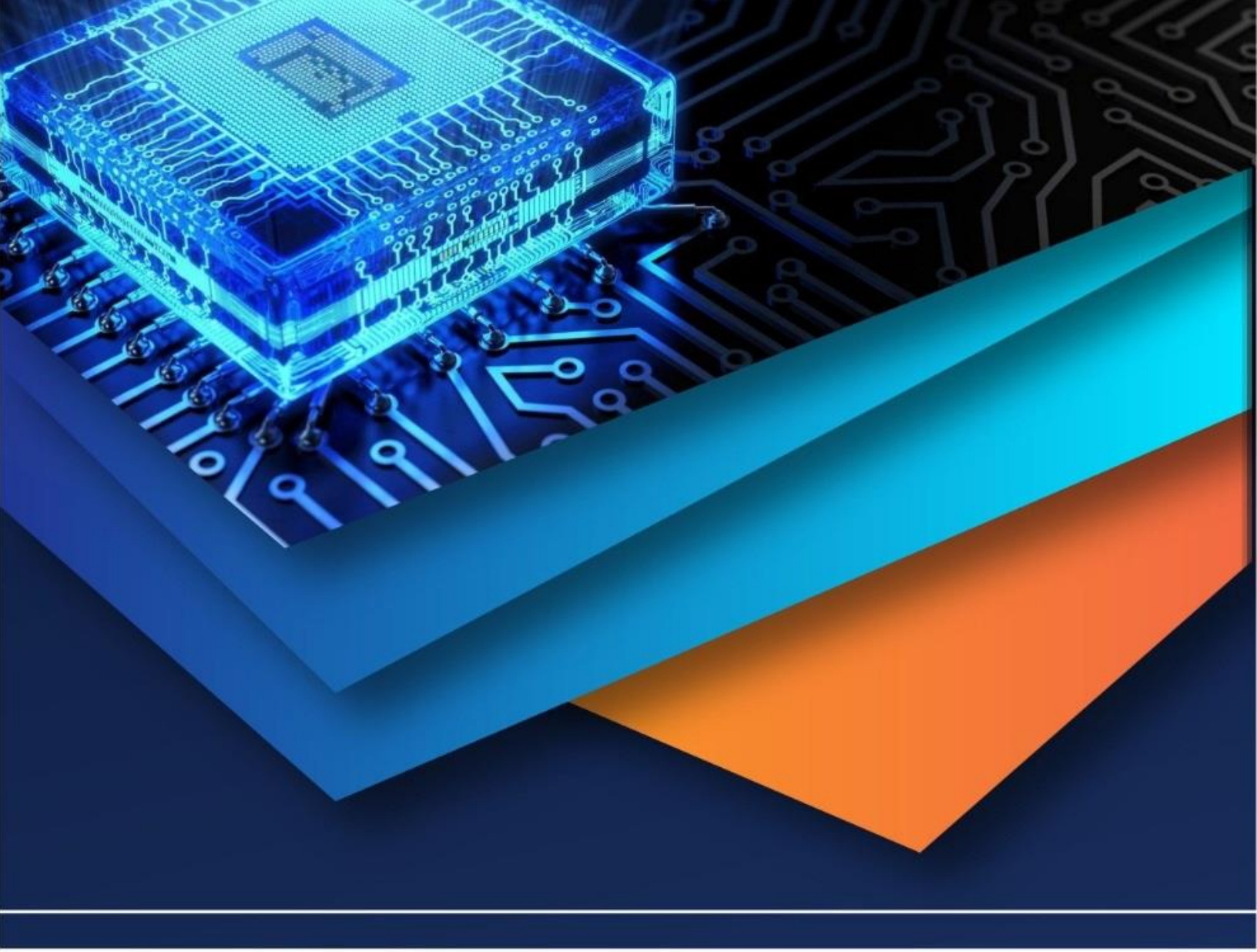

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