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STUDY ON INDUSTRIAL STACK EMMISSION FROM INTEGRATED STEEL PLANT AND AMBIENT AIR QUALITY OF KUTCH, GUJRAT

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Abstract: **Industrial activities are among the major contributors to air pollution, particularly in resource-intensive sectors such as the iron and steel industry. Continuous monitoring of stack emissions and ambient air quality is therefore essential for regulatory compliance and environmental management. The present study assesses industrial stack emissions and their influence on ambient air quality in an integrated steel plant using data from Online Continuous Emission Monitoring Systems (OCEMS) and Continuous Ambient Air Quality Monitoring Systems (CAAQMS).**

Stack emission data for particulate matter (PM), sulphur dioxide (SO_2), and oxides of nitrogen (NO_x) were collected from multiple emission sources. Simultaneously, ambient air quality data for $PM_{2.5}$, PM_{10}, SO_2, and NO_2 were analyzed. Daily and monthly variations, maximum–minimum concentrations were evaluated.

The results indicate insignificant variation in both stack emissions and ambient pollutant concentrations, with certain units contributing higher particulate emissions during specific operational periods. Ambient air quality showed occasional elevations in $PM_{2.5}$ and PM_{10} levels, indicating the influence of industrial emissions combined with local meteorological and operational factors. Overall, all the parameters remained within prescribed regulatory limits, highlighting the role of pollution control systems and continuous monitoring.

The study demonstrates the importance of integrating OCEMS and CAAQMS data for effective environmental compliance assessment and provides insights for improving emission control strategies in large-scale industrial operations.

Keywords: **Stack Emission monitoring, Ambient air quality monitoring, Particulate matter, steel industry.**

I. INTRODUCTION

Rapid industrialization has significantly contributed to economic growth in developing countries; however, it has also led to increased environmental challenges, particularly air pollution. Among various industrial sectors, the **steel industry** is recognized as one of the major sources of atmospheric emissions due to high energy consumption, complex production processes, and the use of fossil fuels and raw materials. Emissions from steel plants, especially **particulate matter (PM), sulphur dioxide (SO_2), and oxides of nitrogen (NO_x)**, pose serious risks to ambient air quality and public health if not effectively controlled.

The integrated steel plant comprises multiple emission-intensive units such as **blast furnaces, sinter plants, rotary kilns, boilers, and induction furnaces**, each contributing differently to the overall emission load. Variations in operational conditions, raw material quality, fuel usage, and pollution control system performance can result in temporal fluctuations in stack emissions. These fluctuations may subsequently influence ambient air quality in and around the plant, especially in nearby residential or sensitive areas.

Previous studies on industrial air pollution have primarily focused either on **stack emission characterization** or **ambient air quality assessment** as independent components. However, studies integrating **continuous stack emission data with ambient air quality measurements** for compliance evaluation and impact assessment are comparatively scarce, particularly for large-scale steel industries in India. Such integrated assessments are crucial for understanding the effectiveness of pollution control measures and for strengthening evidence-based environmental management and policy decisions.

In this context, the present study aims to **assess industrial stack emissions and their influence on ambient air quality** in an integrated steel plant using OCEMS and CAAQMS data collected over a three-month period

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(October– December 2025). The objectives of the study are to analyze temporal variations in stack emissions from major sources, evaluate ambient air quality status in relation to National Ambient Air Quality Standards (NAAQS), and examine the potential relationship between industrial emissions and ambient pollutant levels. The findings of this study are expected to provide valuable insights into continuous emission monitoring, regulatory compliance, and sustainable environmental management in the iron and steel sector.

II. STUDY AREA

The present study was conducted in the **eastern part of Kutch (Kachchh) district, Gujarat, India**, a region known for its rapid industrial development and strategic importance in the country's mineral- and energy-based industries. Kutch district is located in the westernmost part of India between **22°44′ to 24°41′ N latitude and 68°09′ to 71°54′ E longitude**, and is characterized by a semi-arid to arid climate.

The **East Kutch region** has emerged as a major industrial hub due to the presence of large-scale **steel, power, cement, and mining-related industries**, supported by proximity to ports, availability of land, and favorable industrial policies. The integrated steel plant selected for this study is situated within this industrial belt and operates continuously, contributing significantly to local economic activity.

Climatically, the region experiences **hot summers, mild winters, and low annual rainfall**, with precipitation largely confined to the monsoon months. High wind speeds and frequent dust events are common features of the area, which can influence the dispersion and transport of air pollutants. The terrain is predominantly flat with sparse vegetation, further affecting ambient particulate matter concentrations.

The surrounding environment includes **industrial installations, transportation corridors, and scattered rural settlements**, making air quality management a critical concern for both regulatory authorities and local communities. Given these characteristics, East Kutch represents a suitable location for assessing the interaction between **industrial stack emissions and ambient air quality** under challenging meteorological and environmental conditions.

The **Continuous Ambient Air Quality Monitoring Station (CAAQMS)** considered in this study is located near the plant boundary, strategically positioned to capture the combined influence of industrial emissions and local background conditions. The study area thus provides a representative setting to evaluate the effectiveness of pollution control measures and regulatory monitoring frameworks in an industrialized, arid-region context.

Figure 1. Location Map of the Study Area

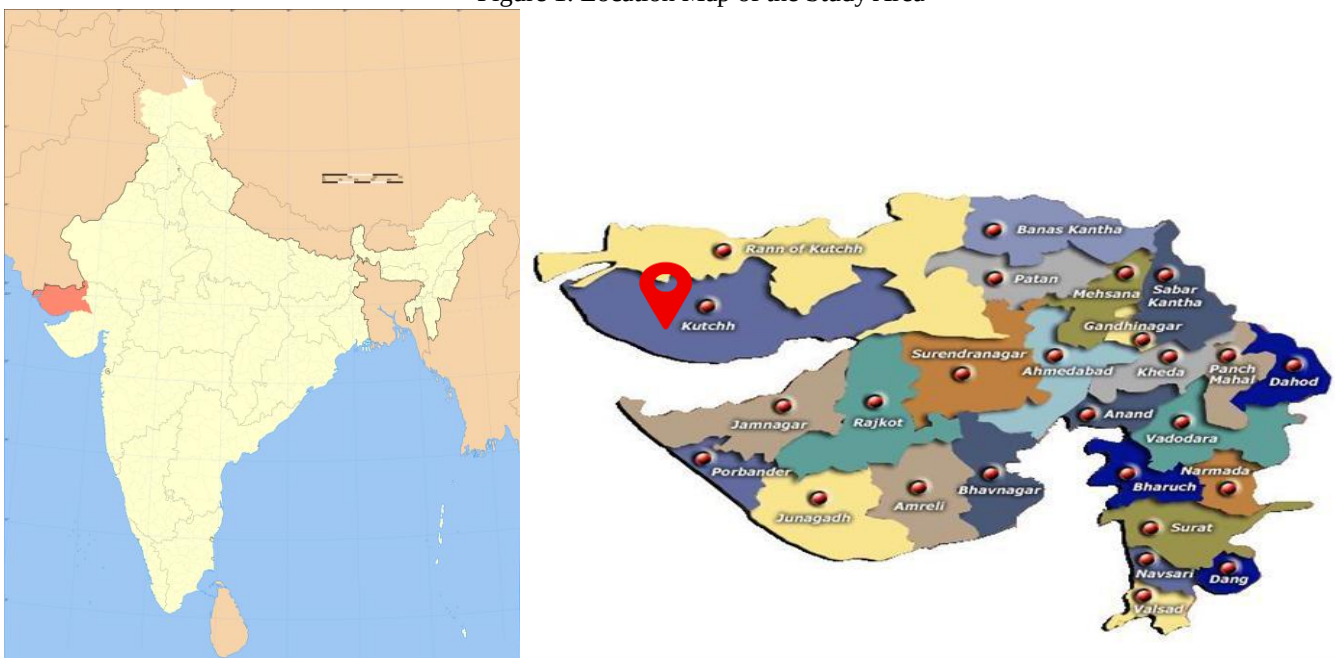

Figure 1 illustrates the geographical location of the **integrated iron and steel plant** situated in the **East Kutch (Kachchh) district of Gujarat, India**. The map shows the position of the study area within Gujarat state and highlights the **industrial zone of East Kutch**, which hosts several large-scale metal, power, and mineral-based industries.

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III. MATERIALS AND METHODS

The present study was conducted at an **integrated steel plant** located in India, comprising multiple emission-intensive units including **blast furnaces, sinter plant units, rotary kilns, boilers, and induction furnaces**. These units operate continuously and are equipped with air pollution control devices such as **electrostatic precipitators (ESPs), bag filters, and scrubbers**, as per regulatory requirements. A **Continuous Ambient Air Quality Monitoring Station (CAAQMS)** is installed near the main gate of the plant to assess the impact of industrial emissions on the surrounding environment.

Stack emission data were obtained from **Online Continuous Emission Monitoring Systems (OCEMS)** installed on major emission sources of the steel plant. The monitored parameters included **particulate matter (PM)**, **sulphur dioxide (SO_2)**, and **oxides of nitrogen (NO_x)**. Data were collected on a **daily basis** for the period **October–December 2025**.

IV. RESULTS AND DISCUSSION

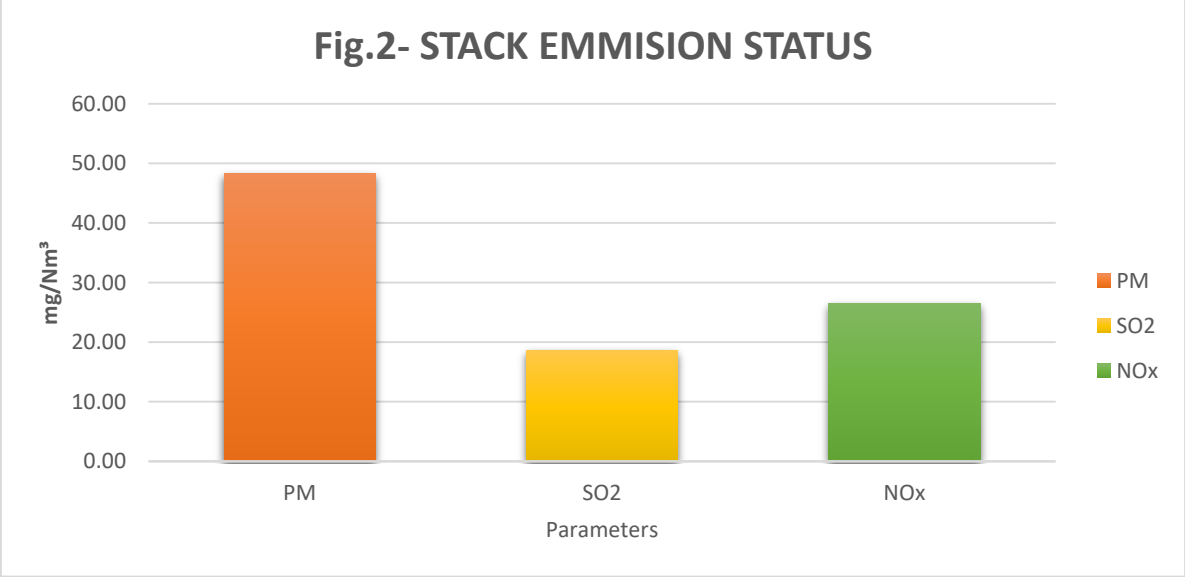
Stack Emission Characteristics

Monthly average stack emission data for **particulate matter (PM), sulphur dioxide (SO_2), and oxides of nitrogen (NO_x)** were analyzed for the period **October–December 2025**. The results indicate relatively stable emission levels across the monitoring period, with insignificant month-to-month variation.

Table 1- Showing data of Stack Monitoring

Stack Emission Status			
Month	**PM**	**SO2**	**NOx**
Oct-25	48.32	18.36	26.22
Nov-25	47.57	19.58	27.38
Dec-25	49.01	17.89	26.01
Average	**48.30**	**18.61**	**26.54**
Maximum	49.01	19.58	27.38
Minimum	47.57	17.89	26.01
Std. Div.	0.72	0.87	0.74

The average PM concentration recorded from stack emissions was **48.30 mg/Nm³**, with a maximum of **49.01 mg/Nm³** observed in December 2025 and a minimum of **47.57 mg/Nm³** in November 2025. The standard deviation for PM was **0.72 mg/Nm³**, indicating low variability in particulate emissions over the study period (fig-2).



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Similarly, SO_2 concentrations showed an average value of **18.61 mg/Nm³**, ranging between **17.89 mg/Nm³** (December 2025) and **19.58 mg/Nm³** (November 2025). The standard deviation of **0.87 mg/Nm³** reflects minor fluctuations in sulphur dioxide emissions. NO_x concentrations exhibited an average of **26.54 mg/Nm³**, with a maximum of **27.38 mg/Nm³** in November 2025 and a minimum of **26.01 mg/Nm³** in December 2025. The observed standard deviation (**0.74 mg/Nm³**) indicates consistent emission control across the months.

Overall, stack emission parameters demonstrated **low temporal variability**, suggesting stable operational conditions and effective performance of air pollution control systems.

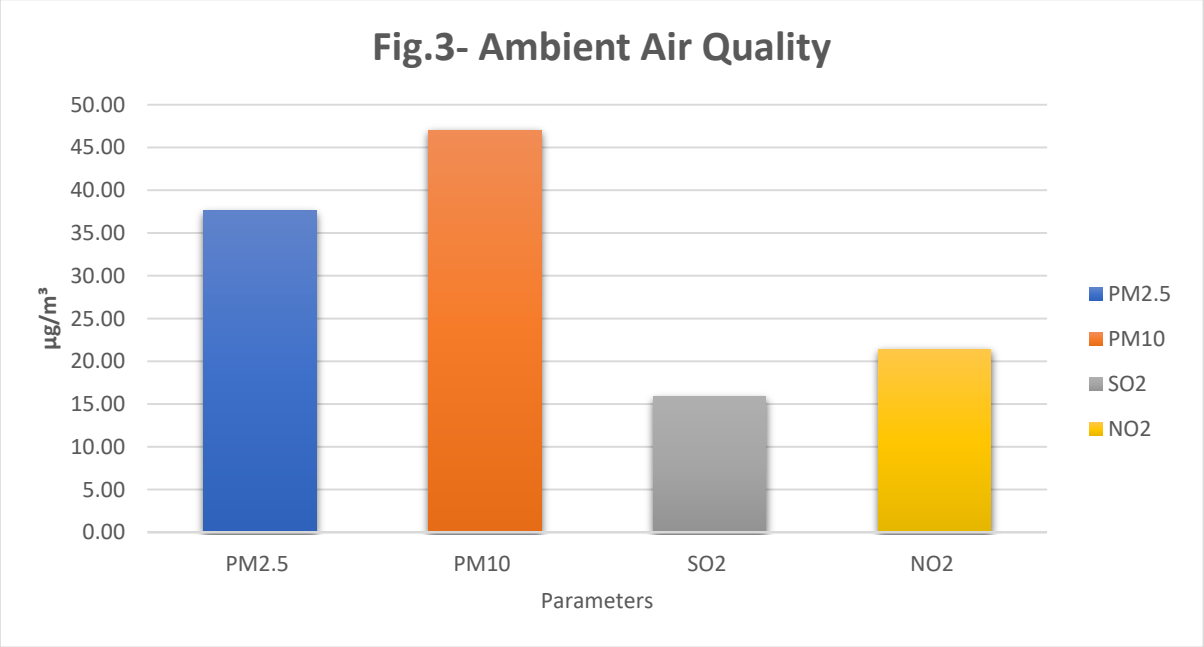
Ambient Air Quality Status

Ambient air quality data for **$PM_{2.5}$, PM_{10}, SO_2, and NO_2** were evaluated for the same monitoring period (October–December 2025). The average ambient concentrations of $PM_{2.5}$ and PM_{10} were **37.67 µg/m³** and **47.04 µg/m³**, respectively. $PM_{2.5}$ concentrations ranged from **36.34 µg/m³** in December 2025 to **38.79 µg/m³** in November 2025, while PM_{10} values varied between **45.31 µg/m³** and **49.70 µg/m³(fig-3)**.

Table 2- showing data of ambient air quality monitoring

Ambient Air Quality				
Month	**$PM_{2.5}$**	**PM_{10}**	**SO_2**	**NO_2**
Oct-25	37.88	45.31	15.50	21.40
Nov-25	38.79	49.70	17.17	22.42
Dec-25	36.34	46.11	14.91	20.47
Average	**37.67**	**47.04**	**15.86**	**21.43**
Maximum	38.79	49.70	17.17	22.42
Minimum	36.34	45.31	14.91	20.47
Std. Div.	1.24	2.34	1.17	0.97

The standard deviation values of **1.24 µg/m³** for $PM_{2.5}$ and **2.34 µg/m³** for PM_{10} indicate moderate variability in ambient particulate concentrations, potentially influenced by operational activity and local environmental conditions.



Ambient gaseous pollutants showed relatively stable trends. The average SO_2 concentration was **15.86 µg/m³**, with values ranging from **14.91 µg/m³** to **17.17 µg/m³**, while NO_2 concentrations averaged **21.43 µg/m³**, with a minimum of **20.47 µg/m³** and a maximum of **22.42 µg/m³**. The low standard deviations for SO_2 (**1.17 µg/m³**) and NO_2 (**0.97 µg/m³**) indicate minimal temporal fluctuation.

Both stack emission concentrations and ambient air pollutant levels remained within the prescribed regulatory limits during the monitoring period, indicating effective emission control and within environmental standards.

The present study provides an integrated assessment of **stack emissions and ambient air quality** over a three-month period (October–December 2025), offering insights into emission stability, ambient air conditions, and regulatory compliance in an industrial setting. The observed results indicate a **consistent emission profile** with limited temporal variability, reflecting stable operational conditions and effective pollution control mechanisms.

V. CONCLUSIONS

This study presents an integrated assessment of **stack emissions and ambient air quality** over a three-month monitoring period (October–December 2025) using continuous monitoring data. The analysis indicates that **stack emissions of particulate matter (PM), sulphur dioxide (SO_2), and oxides of nitrogen (NO_x)** remained stable throughout the study period, with low temporal variability and consistent monthly averages. These findings reflect effective operational control and satisfactory performance of air pollution control systems.

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