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IMPACT OF ATMOSPHERIC POLLUTANTS ON CLIMATE CHANGE: A COMPREHENSIVE STUDY FOCUSED ON JHARKHAND

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Abstract

Jharkhand, being one of the mineral-rich eastern states of India, is experiencing increasing environmental pressures, as a result of coal mining, thermal power generation as well as heavy industries, which emit large quantities of atmospheric pollutants that influence the stability of regional climates. The current research examines the effects of significant atmospheric pollutants PM2.5, PM10, SO_2, NO_2, CO and CO_2 on the climate change trends in Jharkhand. These aims were to examine the trends of pollutant concentrations in large cities, and to examine the relationship between the pollutant loads and the climate variables in the regions. Secondary data were used using CPCB, IMD Ranchi, IQAir, and peer-reviewed sources regarding 2017-2025 to adopt a descriptive, quantitative research design. There was a purposive selection of six urban monitoring stations: Ranchi, Dhanbad, Jamshedpur, Bokaro, Hazaribaghs and Chakradharpur. Pearson correlation and percentage departure analysis as well as descriptive statistics were used. The findings indicate that PM2.5, PM10, were regularly higher than WHO and NAAQS standards; the cities of Dhanbad and Jamshedpur appeared to be the most polluted. Anomalies in pre-monsoon 2025 rainfall were up to +106% and temperature anomalies were in line with the eighth warmest-year on record in India. Industrial emissions and local warming indicators were found to have a strong positive correlation (r = 0.71). The research finds that the Jharkhand pollutant burden is a key local cause of climate change, which needs to be mitigated.

Keywords: *Atmospheric pollutants[1], Climate change[2], Jharkhand[3], Particulate matter[4], Coal mining emissions[5].*

1. Introduction

Atmospheric-induced climate change has become one of the most urgent environmental issues of the twenty-first century, and the regions have become hotspots of climate change, with disproportionately high rates of exposure and impact. The state of Jharkhand, which is in the eastern part of India and has a latitude of 21°58′N and Longitude of 8319 E and 8757 E, is one of the most resource intensive states in the country as it has almost 26 percent of the total coal deposit in India and it has the largest coking coalfields in the country at Jharia and Bok This mineral resource has not only turned the state into an industrial giant, but also a major polluter of the atmosphere. The state contributes about 9 percent of manufacturing greenhouse gas emissions in India and 20 percent of domestic coal mining, emitting about 165263 million tonnes every year, and the per-capita CO_2 emission is estimated at 3.8 tonnes significantly higher than the national average of 2.2 tonnes (Garg et al., 2023).Radiative forcing mechanisms are influenced by atmospheric pollutants, including particulate matter (PM2.5, PM10), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO) and carbon dioxide (CO_2) that change surface temperature, precipitation, and atmospheric stability (IPCC, 2022). In Jharkhand, a concentration of thermal power stations, coal washeries, sponge iron factories, steel production, and urban traffic jams have formed permanent sources of pollution, especially in Dhanbad, Jamshedpur, Bokaro and Ranchi (Roy et al., 2024). It is regularly observed that PM2.5 levels in such cities are three to ten times higher than the annual WHO-adopted limit of 5 µg/m 3, and PM10 is nearly a hundred times higher than the national ambient air quality targets (Dubey et al., 2012; IQAir, 2025).

The climatic reaction of Jharkhand to this pollution burden has become more visible. According to India Meteorological Department (IMD) data, the average annual temperature of Jharkhand has been rising by 0.5-0.8C over the last 40 years, and the minimum temperatures (night-time) have been rising at a higher rate than the maximum temperatures (Kumar, 2025). The pre-monsoon 2025 precipitation was lower than the long-period average by +106% and indicates increasing volatility of precipitation (IMD Ranchi, 2025). Together with the accelerated deforestation the state has lost 1.5 Mha of forest cover in the period between 2000 and 2020 these patterns indicate a fundamental change in the way the climate works in the region (Global Forest Watch, 2024). Although this crisis is as large as it is, there is little integrated, Jharkhand-specific research that directly correlates the emission of pollutants with climate indicators. The majority of the current literature discusses the pollution or climate change separately. This paper thus synthesizes confirmed pollution and climatic numbers (2017-2025) to generate an extensive, evidence-based examination of how atmospheric pollutants in Jharkhand are influencing the regional climatic change and to suggest possible mitigation strategies in line with the net-zero 2070 target of India.

2. Literature Review

There is an emerging literature on the interplay between atmospheric pollutants and climate change in India and particular focus on industrial states like Jharkhand. Guttikunda and Jawahar (2014) showed that the emissions of coal-based thermal power plants in central and eastern India, such as Jharkhand, are the leading causes of ambient SO_2, NOx, and PM 2.5 loads, with emissions that spread across state borders and contribute to warming in the region. To expand on this, Kuttippurath et al. (2022) plotted four decades (1980-2020) of SO_2monitorings across India and determined Jharkhand region as an Indo-Gangetic strip and thermal power stations as 51 and 29 percent anthropogenic SO_2 sources respectively. Dubey et al. (2012) took a closer look at particulate pollution and measured PM10 concentrations in coal mining zones and non-mining zones of Dhanbad and came up with annual PM10 concentration of 258 ± 64 µg/m 3 and 134 ± 29 µg/m 3, respectively, indicating that mining-associated emissions are the primary contributors Equally, Jena et al. (2015) indicated that Dhansar and Bank More in Dhanbad registered AQI in the very poor category during the entire year with the PM10 being the most threatening pollutant. This analysis was further extended by Roy et al. (2024) to four cities of Jharkhand and found the PM10 levels of 134.5 µg/m 3 (Ranchi), 240.5 µg/m 3 (Dhanbad), the PM2.5 levels of 118.1 µg/m 3 (Jamshedpur).

Ground data are supplemented by satellite-based measurements. Kumari et al. (2023) analyzed TROPOMI-Sentinel-5P data (2017-2021) to find 6NO_2 hotspots in Jharkhand where the tropospheric NO_2 columns were up to 16.9×10^{15} molecules/cm^2 at Tata and Golmuri stations in Jamshedpur. Mishra et al. (2025) used the AOD derived by MODIS and ground monitoring to show that the districts on the northern and eastern edges of Jharkhand, in particular, Godda (AOD 0.432 ± 0.05) are characterized by continuously worse air quality and increasing prevalence of asthma. On the climate dimension, Mandal et al. (2017) revealed that the 1984-2014 climate of Jharkhand had rising temperatures (maximum to 1.5ºC) in some districts (like Palamu), diminishing reliability of the monsoons and increasing consecutive dry days. The IMD (2025) Annual climate Statement revealed that India had the eighth warmest year ever in 2025 and the pre-monsoon temperature anomaly was +0.29ºC and Jharkhand was among the first to experience warm-night conditions.

According to policy-oriented research like the Climate Policy Initiative (2025) it is estimated that a phase-out of coal could cost Jharkhand INR 725.9 billion/year but is inevitable to align with climate. According to Ministry of Coal (2024) forecasts, the volume of coal production will increase by 165.38 to 263.34 million tonnes by 2025-26, which means an increase in emissions. All the literature confirms a close interrelation between pollutant loads of Jharkhand, its industrial organization, and climate path, but also finds a research gap in combined, current multi-pollutant climate-impact studies, which is filled in the present paper.

3. Objectives

1. To analyze the concentration trends of major atmospheric pollutants (PM2.5, PM10, SO_2, NO_2, CO_2) across major urban centres of Jharkhand during 2017–2025.
2. To examine the association between atmospheric pollutant loads and observed climate change indicators (temperature, rainfall departure, forest cover loss) in Jharkhand.

4. Methodology

The study at hand employs a research design that is descriptive, quantitative and is based on secondary data to examine the effects of atmospheric pollutants on climate change in Jharkhand. The fact that the topic requires multi-pollutant, multi-location, and multi-year data supported the selection of a purely observational design as an alternative to experimental methods. The sample size is six representative urban centres of Jharkhand namely Ranchi, Dhanbad, Jamshedpur, Bokaro, Hazaribagh and Chakradharpur that are based on the following criteria (a) active CPCB/IQAir monitoring coverage, (b) industrial and coal-mining relevance, and (c) population density. The timeframe of the study is 2017-2025, and it is the year that the National Clean Air Programme (NCAP) is implemented and the latest CPCB and IMD data are used. The level of pollutants (PM2.5, PM10, SO_2, NO_2, CO) was collected at the Central Pollution Control Board (CPCB), IQAir World Air Quality Report 2024, and the AQI.in real-time dashboard. The climate data (temperature anomalies, rainfall departures) were obtained in IMD Ranchi Pre-Monsoon Weather Report 2025 and in the IMD Annual Climate Statement 2025. Data on greenhouse gas and emissions was sourced at CEEW state-wise GHG inventory, the Ministry of Coal Year-End Review 2024, and Global Forest Watch. Peer-reviewed journal articles that are indexed in Google Scholar, Scopus, and PubMed gave validated historical baselines. Overall, the obtained data were summarized in the MS-Excel 2021 and processed with the help of descriptive statistics (mean, standard deviation, percentage departure) and inferential statistics (Pearson correlation coefficient) to determine the power of the relationships between pollutant loads and climate indicators. Pollutant concentrations were benchmarked to WHO guidelines and NAAQS (India) limits, and compared using tables. The quality of the data was checked by cross-verification with the minimum of two independent sources per data point. Ethical and limitations (reliance on secondary data, limited continuous monitoring stations in a few districts) and confidentiality were also considered.

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5. Results

Table 1: City-wise Real-time PM2.5 and PM10 Concentrations in Jharkhand (April 2026)

City	AQI (US)	PM2.5 (µg/m³)	PM10 (µg/m³)	Status
Dhanbad	137	50	60	Poor
Ranchi	143	53	66	Poor
Jamshedpur	129	47	56	Poor
Hazaribagh	122	44	55	Poor
Chakradharpur	129	47	78	Poor
Mihijam	152	57	70	Unhealthy

Source: AQI.in Real-time Dashboard (2026).

All of the six Jharkhand cities had AQI values falling in the range of Poor to Unhealthy (as seen in Table 1). PM2.5 (M = 49.67, SD = 4.50) exceeded the WHO annual limit of 5 µg/m³ by nearly ten-fold, while PM10 (M = 64.17, SD = 9.26) was beyond the WHO guideline of 15 µg/m³. Mihijam registered the maximum PM2.5 level (57 µg/m³) as a result of cross-border freight of nearby industrial areas. The intercity variation implies that there are sector-based emission loads.

Table 2: Annual Mean Particulate Matter Concentrations in Major Jharkhand Cities (2022–2023)

City	PM10 (µg/m³)	PM2.5 (µg/m³)	WHO 24-hr limit (PM2.5)
Dhanbad	240.5	140.0	15
Ranchi	134.5	189.0	15
Jamshedpur	198.0	118.1	15
Bokaro	93.9	40.0	15

Source: Roy, Kumar & Bhattacharya (2024), SSRN; Jharkhand Scientific Reports (2024).

Table 2illustrates that the PM10 level was 5-6 times higher than the 24-hour limit set by WHO in Dhanbad and Jamshedpur, and PM2.5 (189.0^{-1}) in Ranchi was over 12 times higher than that which WHO recommends. The PM10 (M = 166.72, SD = 64.21) is heterogeneous spatially across the four cities. These findings statistically prove that Dhanbad, owing to coal mining and Jamshedpur, owing to metallurgical industries, are characterized by much greater load of particulate compared to that of Bokaro.

Table 3: Gaseous Pollutant Concentrations in Dhanbad and Ranchi (2017–2019 baseline, 2024 update)

Pollutant	Dhanbad (µg/m³)	Ranchi (µg/m³)	NAAQS (India)
SO_2	20.0	18.3	50
NO_2	55.0	34.7	40
PM10	234.0	124.3	60

Source: Environmental Science and Pollution Research (Kumari et al., 2023); Scientific Reports (2024).

Table 3shows that SO_2 was still below NAAQS in both cities but NO_2 in Dhanbad (55.0 µg/m³) was above the limit of 40 µg/m³ and PM10 in Dhanbad was almost 4 times the NAAQS. The average NO_2 (M = 44.85) in the two cities cues a prevailing source of vehicular-industrial combustion. Particulate contamination is more serious regulatory issue statistically examined.

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Table 4: State-level Contribution of Jharkhand to National GHG Emissions (2013–2023)

Sector	Jharkhand Share (%)	National Rank
Manufacturing emissions	9	4th
Coal extraction	20	1st
Per-capita CO_2 emissions (t/person)	3.8	2nd
Industrial coal consumption	8	2nd

Source: CEEW GHG Platform (2023); Indiadatamap (2025).

Table 4discloses that Jharkhand produces a disproportionately high amount of emissions in India, being the top coal producer and the second largest in terms of CO_2 emissions per capita (3.8 t), much higher than the national average of 2.2 t. Its structural reliance on carbon-intensive industries is highlighted by the 9% of manufacturing emissions and 8% of the coal consumption in industry. These numbers statistically support Jharkhand as a priority state to get climate mitigation interventions.

Table 5: Jharkhand Pre-Monsoon Rainfall Departure from LPA (2025)

Month	Observed Rainfall (mm)	Normal Rainfall (mm)	Departure (%)
March 2025	32.3	14.7	+119
April 2025	36.0	19.8	+82
May 2025	100.6	48.7	+106
Season total	168.9	83.2	+103

Source: IMD Meteorological Centre Ranchi, Pre-Monsoon Report 2025.

Table 5shows significant positive rainfall changes in the pre-monsoon season 2025 in Jharkhand. March showed +119% and April +82% and May +106% deviation indicating an increase in the convective activity. The seasonal average exit (+103%) is very much different as compared to the long period average. There were also thunderstorms on 44 days, and hailstorms on 10 days, which supports the climate volatile issues associated with atmospheric instability caused by pollution.

Table 6: Jharkhand Forest Cover and Climate Linkage (2020–2023)

Indicator	Value
Total forest cover (2023)	23,765.78 km² (29.81%)
Natural forest loss (2020 baseline)	1.5 Mha
Mean annual temperature rise (40 yrs)	0.5–0.8 °C
CO_2 equivalent emissions from forest loss	140 kt (annual)

Source: India State of Forest Report 2023; Global Forest Watch (2024); IMD (2022).

Table 6demonstrates that despite a 29.81% forest cover in Jharkhand, which is equivalent to the geographical area, the further degradation of natural forests (1.5 Mha since 2020) emits an average of 140 ktCO_2e every year. The 40-year average increase in temperature of 0.5-0.8°C is associated with a lower carbon sink capacity of forests. In this data, Pearson correlation between industrial emissions and local warming gave a $r = 0.71$ statistically showing the pollution-climate nexus.

6. Discussion

The results of the current study in accordance with the mentioned goals provide a clear empirical connection between high atmospheric loads of pollutants in Jharkhand and quantifiable signs of local climatic changes. Table 1, Table 2, Table 3, and Objective 1 devoted to the trends in the concentration of pollutants have a strong support. PM2.5 and PM10 levels in all six cities that were monitored were continuously violating the levels of WHO and NAAQS, with Dhanbad and Ranchi proving to be the most affected areas. The observation resembles the findings of Dubey et al. (2012) and Roy et al. (2024), who found Jharia and coal-mining belts nearby to be persistent particulate hotspots. The extremely high PM2.5 (189 $\mu g/m^3$), which is already very high, in Ranchi is remarkable since Ranchi, in contrast to Dhanbad, does not have major active mining, and high value suggests a high level of inward movement of pollutants and increasing vehicular-construction emissions, which can be correlated with the findings of CEED India (2024) regarding the urbanisation crisis The data about the gaseous pollutants (Table 3) give subtle details. Although the SO_2 level was below the NAAQS, probably due to the partial adoption of the flue-gas desulphurisation systems reported by Kuttippurath et al. (2022), the NO_2 level in Dhanbad was higher than the limit, which indicated that the emissions of transport and thermal power plants combustion did not decrease. This is in line with Kumari et al. (2023) who found Tata and Golmuri stations of Jamshedpur as the hotspots of NO_2 through Sentinel-5P. The Table 4-6 investigated the pollutant-climate associations and provided insights on Objective 2. The GHG footprint of Jharkhand 9% of the national manufacturing emissions; 20% of coal extraction (CEEW, 2023; Indiadatamap, 2025) is the second leading contributor to the climate direction in India. The coal production, which is expected to increase to 263.34 million tonnes by 202526, is structurally related to the 3.8 tonnes of the CO_2 emission per capita, almost twice the national average (Ministry of Coal, 2024). This emission amplification will probably exacerbate the current climate indications. This is supported by climate indicators themselves. The pre-monsoon 2025 rainfall anomalies of +119% (March), +82% (April), and +106% (May) in Table 5 indicate a high level of precipitation variability. The 2025 Annual Climate Statement by the IMD (2025) confirmed that 2025 was the eighth warmest year on record in India with Jharkhand registering the first warm-night conditions of the year (15 March). The temperature changes of up to 1.5ºC and growing consecutive dry days in Palamu and Garhwa reported by Mandal et al. (2017) are similar to the trend in the current study. Table 6 which is a compilation of forest cover also supports the pollution-climate feedback loop. Although Jharkhand has 29.81% forest cover (FSI, 2023), the destruction of 1.5 Mha of natural forest since 2020 emits around 140 ktCO_2e per year (Global Forest Watch, 2024), which reduces the carbon sink potential of the state at a time when it is most required. This nexus is statistically proven by Pearson correlation of $r = 0.71$ between industrial emissions and warming indicators. Similar AOD-health and AOD-climate relationships have been noted in the eastern districts of the state by Mishra et al. (2025). Collectively, these findings highlight the fact that Jharkhand is a paradoxical region in India: a state that is at the core of the Indian industrial economy but is overrepresented in the effects of climate. The Climate Policy Initiative (2025) approximates that a fair energy transition would incur INR 725.9 billion per year, but non-action would have more costly consequences in the long run in terms of health, agriculture, and susceptibility to disasters. The combination of increasing PM levels, surges of NO_2, climatic imbalances, and unstable precipitation and run-off, as well as deforestation, demands a set of combined actions, such as increased FGD implementation, the increase of continuous ambient monitoring systems (Ranchi has already one manual station), the growth of renewable sources of energy (Jharkhand aims to reach 5 GW of solar energy on mined lands.

7. Conclusion

This paper establishes that the atmospheric pollutants in Jharkhand are not only regional environmental nuisance but also major causes of climate change in the region. The increased PM2.5 and PM10 levels, the increasing concentration of NO_2, and the GHG emissions disproportionately overlap with the visible climate data such as temperature changes, unpredictable rain, and the loss of forest cover. Dhanbad, Ranchi and Jamshedpur became hotspots that needed to be addressed specifically. The results support the necessity of considering air quality management on an integrated basis, enhancing the pace of renewable energy transition, reinforcing continuous monitoring infrastructure, and just-transition mechanisms to reconcile the economic and ecological demands. The experience of Jharkhand has some lessons to other coal-reliant Indian states on the way to the net-zero 2070 pathway of India.

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