J. Ind. Geophys. Union, 30(3) (2026), 194-201
https://doi.org/10.71122/JIGU.30(3)2026.0020

Interlinkages between air pollution and local weather changes in urban environment: A case study from Alwar, Northwestern India

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ABSTRACT

The air pollution challenge has become a significant environmental and public health issue in the semi-arid urban areas of India. The current study looked at the effect of meteorological factors on the ambient air quality of Alwar, which is a non-attainment city in northwestern India, by examining five years (2018-2022) data of Continuous Ambient Air Quality Monitoring Station (CAAQMS) of the Central Pollution Control Board (CPCB) in Alwar. The parameters of interest are $PM_{10,}$ $PM_{2.5}$, NO_2, SO_2, CO, and O_3. $PM_{2.5}$ concentrations ranged from an annual mean of 40.9-52.1 µg/m^3 and PM_{10} concentrations from 77.5-105.4 µg/m^3; both of which are consistently above the NAAQS. Highest concentrations of particulates were found during winter months with $PM_{2.5}$ concentrations exceeding 90 µg/m^3 under low wind speed/stable atmosphere conditions. The correlation analysis found a negative correlation between PM, NOx and CO; and positive correlation between O_3 and temperature. The drop in pollutants during the 2020 pandemic showed that humans were the dominant contributor to air pollution. Based on these findings, it is concluded that the use of meteorological conditions within air quality management strategies will contribute to improving the air quality in semi-arid urban areas.

Keywords: Urban air pollution, Meteorological parameters, Particulate matter ($PM_{2.5}$, PM_{10}), Seasonal variation, Alwar, Northwestern India

INTRODUCTION

Air is one of the most important components of the biosphere because it provides all living organisms with the ability to live on the planet, as well as sustains life itself. Unfortunately, many factors that are outside the control of nature have created an increase in the amount of contamination found in the air, resulting from the increasing levels of human activity on Earth. It has created significant air pollution, which threatens both human health and ecosystems, as well as the climate. Urbanization, industrialization, and increasing energy use, have significantly reduced air quality, especially in cities. Many of the emissions produced by business industries, automobiles, construction projects, and even the weather conditions where the air is polluted, can lead to very high levels of emission of pollutants like PM, SO_2, NO_x, CO, and hydrocarbons, which impact both the processes related to atmospheric chemistry and global warming.

India has become one of the world's highly polluted nations in the last thirty years and is particularly polluted in the western part of the country and along the Indo-Gangetic Plain. Most of the air pollution in urban India comes from large groups of industries, the number of vehicles in use, an overall lack of urban planning and the burning of both biomass and coal in the home environment. The air pollutants responsible for the majority of urban air pollution in India are found in the form of particulate matter ($PM_{2.5}$ and PM_{10}), but they also transport trace elements and heavy metals, most of which are associated with a variety of illnesses, including respiratory and cardiovascular diseases (Moghadamnia et al., 2017; Li et al., 2018; Kumar et al., 2020, 2023; Rani and Kulshrestha, 2026). In addition, $PM_{2.5}$ frequently contain more harmful metals compared to PM_{10} particles (Kulshrestha et al., 2009; Hsu et al., 2016), and there is a large number of epidemiological studies showing that there is a strong correlation between PM exposure and adverse health effects (Dockery et al., 1993; Cascio et al., 2009; Knol et al., 2009; Hoek et al., 2010; Cassee et al., 2013; Kelly and Fussell, 2015; Gupta and Elumalai 2017). In addition to health impacts, PM also results in decreased visibility, imbalance of the Earth's radiative system and the ability for global climate to remain stable (Dan et al., 2004).

The concentrations of air pollutants are affected by weather because the weather determines how much and how fast these pollutants are released, dispersed, and chemically transformed (Latini et al., 2002; Yang and Wang, 2017). The meteorological parameters that influence accumulation and transport of pollutants include solar radiation, wind speed, temperature and relative humidity; these parameters have a larger impact on semi-arid desert regions (Ma et al., 2025). Due to rapid urbanization of cities like Alwar (Rajasthan), increased vehicle emissions, dust resuspension and the climate, Alwar is becoming increasingly vulnerable to decreased air quality. Alwar has a mixed emissions profile from vehicle, industrial, residential and construction emissions and natural sources of dust due to its proximity to the Aravalli mountain range and also from the Indo-Gangetic Plain. Alwar is more representative of emerging urban centers in NW India, where studies of the relationship between meteorology and pollutant