

STUDY OF QUALITY OF AIR NEAR COASTAL AREAS DUE TO INCREASING INDUSTRIALIZATION IN INDIA

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Abstract

Fossil-fuel-based power industries play a pivotal role in India's economic liberalization and industrialization. However, their growth is accompanied by heightened air pollution, necessitating robust modeling approaches to design effective pollution control measures. This study evaluates the effectiveness of two dispersion models—Desein Dispersion Model (DDM) and the Industrial Source Complex Short-Term (ISCST3) model—in predicting Ground Level Concentrations (GLCs) of pollutants, specifically sulfur dioxide (SO2) and nitrogen oxides (NOx). Using hourly meteorological data, this research compares GLC predictions under varied seasonal conditions and highlights DDM's suitability for Indian scenarios. Results indicate that DDM, with its reflection coefficient and gravitational settling terms, provides more accurate and practical assessments for pollution management in coastal and industrial regions.

Keywords: Ground Level Concentration, Coastal Fumigation, Dispersion Modeling, Air Pollution, Indian Power Sector

1. Introduction

The rapid industrialization and privatization of India's power sector have significantly contributed to economic growth but also escalated environmental concerns, particularly air pollution. Fossil-fuel-based power plants are among the leading contributors to emissions of SO2 and NOx, which adversely affect human health, vegetation, and infrastructure. Effective air quality management requires accurate modeling of pollutant dispersion, influenced by meteorological conditions such as wind speed, temperature, stability classes, and mixing heights (Simpson, 1994).

Meteorological factors such as land-sea breezes, valley winds, and inversion layers play crucial roles in pollutant transport and deposition (Kurita et al., 1990; Savijarvi, 1995). Coastal regions, in particular, experience unique dispersion dynamics due to internal boundary layers formed over land. These conditions often result in elevated short-term GLCs, necessitating accurate modeling frameworks for impact assessments.

This study focuses on comparing two prominent dispersion models—ISCST3, developed by the U.S. EPA, and the Desein Dispersion Model (DDM)—to assess their performance in predicting

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pollutant GLCs in Mangalore, a coastal industrial region. The results aim to guide policymakers in designing effective pollution control measures tailored to Indian conditions.

2. Objectives

The primary objectives of this study are:

- To evaluate the short-term (24-hour) GLCs of SO2 and NOx emitted by existing and proposed industries in a coastal region.
- To compare the predictive accuracy of the ISCST3 and DDM models under varied meteorological conditions.
- To assess the impact of these pollutants on human settlements near the power plants and recommend suitable pollution control measures.

3. Research Gap

While extensive studies have focused on dispersion modeling in developed nations, limited research has evaluated model performance under Indian meteorological and industrial conditions. Models like ISCST3 have been widely adopted but do not account for certain region-specific factors such as gravitational settling and coastal fumigation. Additionally, the scalability and adaptability of these models to India's unique climatic and topographic conditions remain underexplored. This study addresses this gap by comparing ISCST3 with DDM, which incorporates a reflection coefficient term to better simulate pollutant behavior in Indian contexts.

4. Methodology

4.1 Study Area

The study was conducted in Mangalore, located on the Arabian Sea coast, characterized by a mix of industrial and residential zones. Meteorological data were collected for January (winter), May (summer), July (monsoon), and October (post-monsoon) of 1996.

4.2 Dispersion Models

ISCST3 Model:

Developed by the U.S. EPA, ISCST3 uses a steady-state Gaussian plume approach to calculate pollutant concentrations.

Input parameters include hourly wind speed, temperature, stability class, mixing height, and emission rates.

Limitations include the exclusion of gravitational settling and dry deposition effects for gaseous pollutants.

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Desein Dispersion Model (DDM):

DDM incorporates a reflection coefficient term to account for gravitational settling and pollutant behavior near the emission source.

This feature enhances its applicability to Indian conditions, where industrial and residential areas are often in close proximity.

4.3 Data Collection

Hourly meteorological data, including wind direction, wind speed, temperature, stability class, and mixing height, were sourced from local meteorological stations. Emission rates for SO2 and NOx were obtained from industrial records.

4.4 Model Validation

Model predictions were validated against observed GLCs at nine monitoring stations around the pollution sources. Statistical metrics, including mean bias and root mean square error (RMSE), were used for performance evaluation.

5. Results and Discussion

5.1 Seasonal Variations in GLCs

Short-term GLCs of SO2 and NOx varied significantly across seasons:

Monsoon (July): GLCs were relatively low due to enhanced dispersion from strong wind speeds and unstable atmospheric conditions.

Winter (January): Higher GLCs were observed due to stable atmospheric layers and low mixing heights, which restrict vertical dispersion.

Summer (May): Moderate GLCs were recorded, influenced by increased mixing heights and wind speeds.

Post-Monsoon (October): Elevated GLCs were noted due to transitional meteorological conditions.

5.2 Model Performance

Comparison of model-predicted and observed GLCs revealed:

ISCST3 Model: While effective in capturing general dispersion trends, ISCST3 underestimated GLCs near the source due to the exclusion of gravitational settling.

DDM Model: Predicted GLCs closely matched observed values, particularly in areas with high population density. The reflection coefficient term proved critical in accurately simulating pollutant behavior.

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5.3 Human Health and Environmental Impacts

Elevated GLCs of NOx and SO2 during winter and post-monsoon seasons pose significant risks to human health, including respiratory illnesses and reduced agricultural productivity. The findings underscore the need for stringent emission controls and stack design improvements.

6. Conclusion

This study highlights the importance of accurate dispersion modeling in managing air pollution from fossil-fuel-based power industries. The Desein Dispersion Model (DDM) outperformed the ISCST3 model in predicting short-term GLCs under Indian meteorological conditions, particularly in coastal regions. The inclusion of gravitational settling and reflection coefficient terms makes DDM a more suitable tool for policymaking and environmental impact assessments in India.

Future research should focus on integrating advanced meteorological parameters and expanding model applications to other industrial regions. Additionally, real-time monitoring and adaptive modeling frameworks can further enhance pollution management efforts.

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