

Integrating Atmospheric Dispersion Modelling into Environmental Impact Assessment of Industrial PM₁₀ Emissions

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Abstract - Assessment of ambient air quality is a fundamental component of Environmental Impact Assessment (EIA), particularly for industrial facilities where particulate emissions may influence surrounding environmental receptors. Atmospheric dispersion modelling offers a scientifically robust approach for predicting pollutant transport and evaluating potential environmental impacts under representative meteorological conditions. This study presents an integrated framework for assessing PM₁₀ dispersion from multiple industrial emission sources using the AERMOD modelling system. To preserve confidentiality, the identity and location of the investigated industrial facility are not disclosed.

The assessment incorporated elevated process stacks, operational area sources, and transport-related fugitive emissions within a 10 km × 10 km modelling domain. Site-specific meteorological observations were processed through AERMET, while terrain characteristics were incorporated using AERMAP to simulate pollutant dispersion and estimate ground-level PM₁₀ concentrations. Model predictions were subsequently interpreted within the Environmental Impact Assessment framework to identify dominant emission sources, evaluate cumulative impacts, and examine compliance with applicable ambient air quality standards.

The results indicated that fugitive emissions associated with transportation and operational activities exerted a greater influence on local PM₁₀ concentrations than elevated stack emissions, primarily because of their ground-level release characteristics. Predicted cumulative concentrations remained within the prescribed regulatory limits, indicating acceptable ambient air quality under the evaluated operating conditions. The study demonstrates that integrating atmospheric dispersion modelling into Environmental Impact Assessment provides an effective decision-support framework for environmental planning, regulatory compliance, and development of targeted air pollution mitigation strategies for industrial facilities

Keywords - Environmental Impact Assessment, Atmospheric Dispersion Modelling, PM₁₀, Air Quality Assessment, Industrial Emissions, Fugitive Dust, AERMOD, Environmental Compliance

I. INTRODUCTION

Industrial development has played a pivotal role in economic growth; however, it has also intensified environmental concerns associated with atmospheric emissions, resource consumption, and ecological degradation. As industries expand in scale and complexity, there is an increasing need to evaluate their environmental consequences using scientifically sound assessment tools that support sustainable decision-making. EIA has therefore become an essential component of environmental governance by providing a structured framework for identifying, predicting, and

mitigating adverse environmental impacts prior to or during industrial operations [1,2].

Among the environmental components addressed in EIA, ambient air quality is one of the most sensitive because atmospheric pollutants can disperse beyond facility boundaries and affect surrounding communities, ecosystems, and infrastructure. Air quality assessments are consequently required for many industrial projects to demonstrate regulatory compliance and to identify appropriate pollution mitigation strategies. While routine monitoring provides information on existing pollutant concentrations, it cannot predict future environmental conditions or evaluate the influence of alternative operational scenarios. Predictive assessment methods are therefore indispensable for comprehensive environmental planning [3,4].

Particulate matter with an aerodynamic diameter of less than 10 µm (PM₁₀) remains a pollutant of significant environmental and public health concern because of its persistence in the atmosphere and its ability to penetrate the human respiratory tract. Industrial PM₁₀ emissions originate from a combination of elevated process stacks, raw material handling, waste management operations, transportation activities, stockpiles, and wind-induced resuspension of deposited dust. Continuous exposure to elevated particulate concentrations has been associated with respiratory diseases, cardiovascular disorders, and reduced quality of life, leading regulatory agencies worldwide to establish stringent ambient air quality standards for particulate matter [5,6].

Atmospheric dispersion modelling has emerged as a reliable predictive approach for evaluating the transport, dilution, and spatial distribution of air pollutants released from industrial sources. Unlike conventional monitoring programs, dispersion models estimate pollutant concentrations across large geographical areas by integrating emission characteristics with local meteorological and terrain information. Such predictive capability enables environmental practitioners to assess potential impacts before project implementation, evaluate cumulative effects from multiple emission sources, identify sensitive receptors, and develop evidence-based mitigation measures. Consequently, atmospheric dispersion modelling has become a standard component of Environmental Impact Assessment studies conducted for industrial facilities worldwide [3,7,8].

Among the available regulatory models, the American Meteorological Society/United States Environmental Protection Agency Regulatory Model (AERMOD) has gained

widespread acceptance because it incorporates advanced boundary-layer physics, terrain interactions, and source-specific dispersion algorithms while maintaining computational efficiency for near-field applications. Numerous studies have demonstrated its applicability for evaluating emissions from manufacturing industries, waste management facilities, transportation corridors, mining operations, and energy sectors, making it one of the most frequently adopted tools for regulatory air quality assessment [9,10].

Despite extensive application of atmospheric dispersion models, published investigations often concentrate on individual emission categories such as stack releases or fugitive dust, whereas comparatively fewer studies have evaluated the combined influence of multiple industrial emission sources within a unified Environmental Impact Assessment framework. Furthermore, many case studies primarily report predicted pollutant concentrations without adequately discussing how modelling outcomes can support environmental management, source prioritization, and pollution mitigation. Bridging this gap is important because industrial facilities typically comprise several interacting emission sources whose cumulative impacts cannot be reliably assessed using isolated source evaluations [11,12].

In view of these considerations, the present study integrates atmospheric dispersion modelling into an Environmental Impact Assessment framework to evaluate PM₁₀ emissions from multiple industrial sources under representative ambient meteorological conditions. The investigation assesses the contribution of point, area, and transport-related emission sources to ambient particulate concentrations, evaluates cumulative environmental impacts using the US EPA AERMOD modelling system, and interprets the modelling outcomes in the context of regulatory compliance and environmental management. The proposed approach provides a practical methodology for supporting evidence-based decision-making in industrial air quality assessment while contributing to sustainable environmental planning.

II. LITERATURE REVIEW

A. Environmental impact assessment and air quality management

EIA has evolved from a regulatory compliance exercise into a comprehensive decision-support framework for sustainable development. Modern EIA practices seek not only to identify potential environmental impacts but also to evaluate their significance, recommend mitigation measures, and support environmentally informed planning. Among the various environmental components assessed during EIA, air quality occupies a central position because atmospheric pollutants can be transported over considerable distances, thereby affecting populations and ecosystems beyond the immediate project boundary [1,2].

The increasing complexity of industrial activities has further reinforced the need for predictive air quality assessment tools. Traditional monitoring programs provide valuable information regarding existing environmental conditions but are inherently limited in their ability to forecast future impacts or evaluate hypothetical operating scenarios. Consequently, atmospheric modelling techniques have become an integral

component of air quality impact assessment within EIA studies worldwide [4].

B. Industrial sources of PM₁₀ and their environmental significance

Particulate matter remains one of the most extensively studied air pollutants because of its adverse effects on human health and environmental quality. PM₁₀ emissions generated by industrial facilities originate from diverse sources, including combustion processes, material handling operations, transportation activities, waste management practices, stockpile disturbances, and wind-driven dust resuspension [5].

The environmental significance of PM₁₀ is influenced not only by the magnitude of emissions but also by source characteristics and release mechanisms. Elevated stack emissions generally experience substantial atmospheric dilution before reaching ground level, whereas fugitive emissions released near the surface often result in higher localized concentrations due to limited plume rise and reduced dispersion. Consequently, recent environmental assessments increasingly emphasize source-specific characterization rather than relying solely on aggregate emission estimates [9].

Several studies have demonstrated that transportation-related dust emissions and operational area sources can contribute significantly to ambient particulate concentrations within industrial premises. Effective environmental management therefore requires comprehensive evaluation of all emission categories rather than focusing exclusively on regulated stack releases [12].

C. Atmospheric dispersion modelling as a predictive assessment tool

Atmospheric dispersion models are designed to simulate the transport, diffusion, transformation, and deposition of pollutants released into the atmosphere. These models combine information related to emission sources, meteorological conditions, terrain characteristics, and receptor locations to estimate pollutant concentrations at specified points within the modelling domain [13].

The adoption of dispersion modelling within environmental assessment has increased considerably over the past two decades because of advancements in computational methods and regulatory requirements. Dispersion models enable prediction of pollutant behavior under various operating conditions and provide a scientific basis for assessing environmental impacts before they occur. Such predictive capability is particularly valuable during project planning, environmental clearance, facility expansion, and compliance evaluation [3].

Different modelling approaches are available for air quality assessment, including Gaussian plume models, puff models, Eulerian grid models, and Computational Fluid Dynamics (CFD) simulations. The selection of an appropriate model depends on study objectives, geographical scale, pollutant characteristics, and regulatory requirements. For near-field industrial applications, Gaussian-based regulatory models remain the most widely adopted because of their balance between computational efficiency and predictive reliability [9].

D. Applications of AERMOD in industrial environmental assessment

The American Meteorological Society/United States Environmental Protection Agency Regulatory Model (AERMOD) is currently one of the most widely accepted atmospheric dispersion models for industrial air quality assessment. Developed through collaboration between regulatory agencies and atmospheric scientists, AERMOD incorporates boundary layer parameterization, terrain adjustments, atmospheric stability classifications, and multiple source representations to improve prediction accuracy [7,8].

Numerous investigations have applied AERMOD to evaluate emissions from power plants, cement industries, mining operations, petrochemical facilities, transportation infrastructure, waste management systems, and industrial estates. These studies have demonstrated that the model can effectively predict ground-level pollutant concentrations when supported by representative emission inventories and site-specific meteorological observations [10].

Recent developments have further expanded the application of AERMOD through integration with satellite-derived datasets, advanced meteorological modelling, geographic information systems, and health risk assessment methodologies. Such integrations have enhanced the utility of dispersion modelling as a comprehensive environmental management tool rather than merely a regulatory compliance requirement [11].

E. Research Gap and study rationale

A review of the available literature indicates that substantial progress has been made in the application of atmospheric dispersion modelling for industrial air quality assessment. Nevertheless, many published studies continue to focus on individual emission sources or specific industrial processes. Comparatively fewer investigations have evaluated the cumulative influence of multiple industrial emission categories including point sources, operational area sources, and transportation-related fugitive emissions within a unified Environmental Impact Assessment framework.

In addition, limited attention has been given to translating model predictions into practical environmental management strategies capable of supporting pollution prevention and operational decision-making. Since industrial facilities often comprise numerous interacting emission sources, evaluation of isolated sources may underestimate cumulative environmental impacts and lead to ineffective mitigation prioritization.

The present study addresses these limitations by integrating atmospheric dispersion modelling into a structured Environmental Impact Assessment framework capable of evaluating the combined influence of multiple industrial PM₁₀ emission sources. The approach provides a practical basis for source prioritization, environmental compliance assessment, and development of targeted air quality management strategies within industrial environments.

III. METHODOLOGY

A. Overall assessment strategy

The investigation was designed to integrate atmospheric dispersion modelling within the EIA process to evaluate the

influence of industrial PM₁₀ emissions on surrounding ambient air quality. Rather than examining individual emission sources independently, the assessment considered the combined contribution of all operational activities capable of generating particulate emissions. The overall workflow consisted of source identification, emission quantification, atmospheric characterization, numerical dispersion simulation, and interpretation of predicted concentrations for environmental decision-making.

To ensure confidentiality, all information capable of identifying the industrial facility has been omitted. The study therefore presents the methodology as a generalized industrial case study while preserving the scientific integrity of the modelling approach.

B. Compilation of emission information

A detailed emission database was prepared by consolidating operational information from the industrial facility. PM₁₀-generating activities were first identified and subsequently categorized according to their physical emission characteristics. The inventory included elevated process emissions, operational surface activities, and transportation-induced dust emissions occurring within the facility boundary.

For each source category, appropriate emission parameters required by the dispersion model were established using available operational records and engineering data. These parameters included source geometry, emission rates, release characteristics, spatial coordinates, and operating schedules. Developing a representative emission inventory is widely regarded as the most influential step in regulatory dispersion modelling because the reliability of predicted concentrations depends directly on the quality of source characterization [7].

C. Representation of the atmospheric environment

Meteorological conditions governing pollutant transport were characterized using site-specific observations representative of the assessment period. Surface meteorological parameters, including wind speed, wind direction, ambient temperature, atmospheric stability, and boundary-layer characteristics, were processed using the US EPA AERMET preprocessor to generate model-ready atmospheric inputs.

Topographical influences on plume movement were incorporated through terrain processing using AERMAP. Digital elevation data were used to determine receptor elevations and terrain characteristics across the modelling domain. Inclusion of site-specific meteorology and terrain information improves the capability of regulatory dispersion models to reproduce realistic atmospheric transport processes [3].

D. Numerical simulation of PM₁₀ dispersion

Ground-level PM₁₀ concentrations were simulated using AERMOD. The model applies steady-state Gaussian dispersion principles combined with planetary boundary layer parameterization to estimate pollutant transport from multiple emission sources under varying atmospheric conditions [8].

A receptor network covering a 10 km × 10 km modelling domain was established to evaluate the spatial variation of PM₁₀ concentrations surrounding the industrial facility. The modelling framework permitted simultaneous simulation of emissions originating from point sources, operational area sources, and transport-related activities, thereby providing a cumulative representation of industrial particulate dispersion.

E. Interpretation of predicted air quality

Predicted PM₁₀ concentrations were analyzed to determine the magnitude and spatial distribution of environmental impacts. Particular emphasis was placed on identifying dominant emission categories, assessing cumulative pollutant concentrations, and locating areas experiencing comparatively higher particulate exposure.

Model outputs were evaluated with reference to the applicable National Ambient Air Quality Standards (NAAQS) for PM₁₀ to determine environmental acceptability of the predicted concentrations. In addition to regulatory compliance, the results were interpreted to identify operational activities requiring priority mitigation and to support environmentally informed management decisions.

F. Quality assurance and study constraints

Quality assurance was maintained throughout the modelling exercise by adopting regulatory modelling procedures recommended by the United States Environmental Protection Agency. Standard preprocessing tools, validated dispersion algorithms, and consistent input datasets were employed to minimize computational uncertainty.

Despite the robustness of the modelling framework, the assessment remains subject to uncertainties associated with emission estimation, operational variability, and meteorological fluctuations. Consequently, the predicted concentrations should be interpreted as representative estimates under the evaluated operating conditions rather than absolute environmental measurements. Nevertheless, the adopted methodology provides a scientifically defensible basis for Environmental Impact Assessment and industrial air quality management.

IV. RESULTS AND DISCUSSION

A. Characteristics of predicted PM₁₀ distribution

The atmospheric dispersion simulations revealed distinct spatial variations in ground-level PM₁₀ concentrations across the assessment domain. The predicted concentration pattern was governed by the combined influence of emission source characteristics, atmospheric stability, prevailing wind conditions, and terrain features. Rather than exhibiting a uniform distribution, particulate concentrations decreased progressively with increasing distance from the emission sources because of atmospheric dilution and turbulent mixing.

The highest concentrations were predicted within the vicinity of active industrial operations where emissions were continuously generated. Downwind regions experienced comparatively higher particulate concentrations, reflecting the dominant influence of prevailing wind direction on pollutant transport as shown in figure 1. Similar dispersion behaviour

has been reported in previous industrial air quality investigations employing Gaussian dispersion models [9,10].

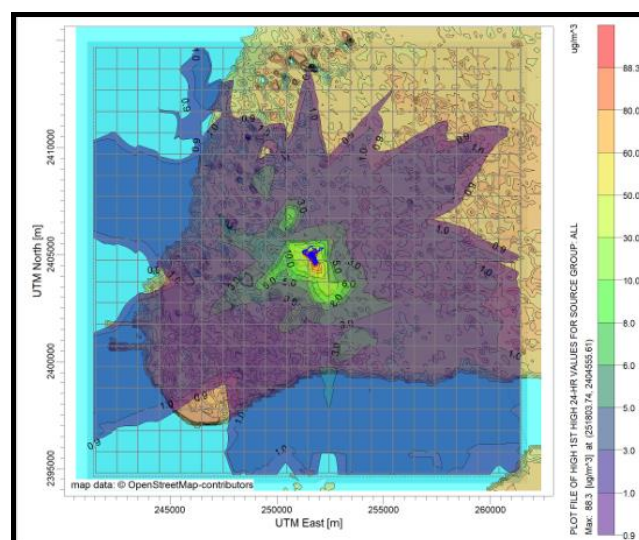


Fig. 1. Predicted cumulative PM₁₀ concentration contours within the modelling domain

B. Relative contribution of industrial emission sources

The integrated modelling approach enabled evaluation of the relative influence of different emission categories on ambient PM₁₀ concentrations. Although all identified sources contributed to the cumulative particulate load, their environmental significance differed according to release characteristics and atmospheric dispersion behavior.

Ground-level operational activities, including material handling and landfill-related processes, generated comparatively higher local concentrations because emissions were released close to the receptor height with limited initial dispersion. Transport-related fugitive emissions also contributed substantially to ambient PM₁₀ owing to continuous movement of heavy vehicles and resuspension of deposited dust along internal road networks.

In contrast, elevated process stacks produced comparatively lower ground-level impacts despite continuous emissions. Increased release height promoted plume rise and atmospheric dilution before pollutants reached the receptor level, thereby reducing their contribution to near-field ambient concentrations.

These observations highlight that emission magnitude alone does not determine environmental impact. Source geometry, release elevation, and local meteorological conditions collectively influence the spatial distribution of particulate matter as shown in table 1. Similar findings have been reported where observed that near-surface emissions frequently dominate local air quality compared with elevated releases [11].

TABLE I. SUMMARY OF PREDICTED MAXIMUM PM₁₀ CONCENTRATIONS FROM INDIVIDUAL EMISSION SOURCES

Emission Sources	PM10 Concentrations
Point Sources	12.01 µg/m ³
Area Sources	13.04 µg/m ³
Transport-related fugitive	81.01 µg/m ³

emissions	
All Sources	88.3 $\mu\text{g}/\text{m}^3$

C. Effect of meteorological conditions on dispersion

Meteorological conditions exerted a significant influence on pollutant dispersion throughout the assessment period. Wind direction controlled the preferential transport pathway of emitted particulates, whereas wind speed governed the extent of atmospheric dilution. Stable atmospheric conditions restricted vertical mixing and promoted localized pollutant accumulation, while unstable conditions enhanced turbulent diffusion and reduced ground-level concentrations as shown in figure 2.

The predicted concentration contours exhibited strong alignment with the prevailing wind direction, confirming that atmospheric transport processes primarily controlled the dispersion behaviour of emitted PM_{10} . Incorporating representative meteorological observations into the modelling framework therefore provided a more realistic assessment of potential environmental impacts than would have been possible using generalized meteorological assumptions.

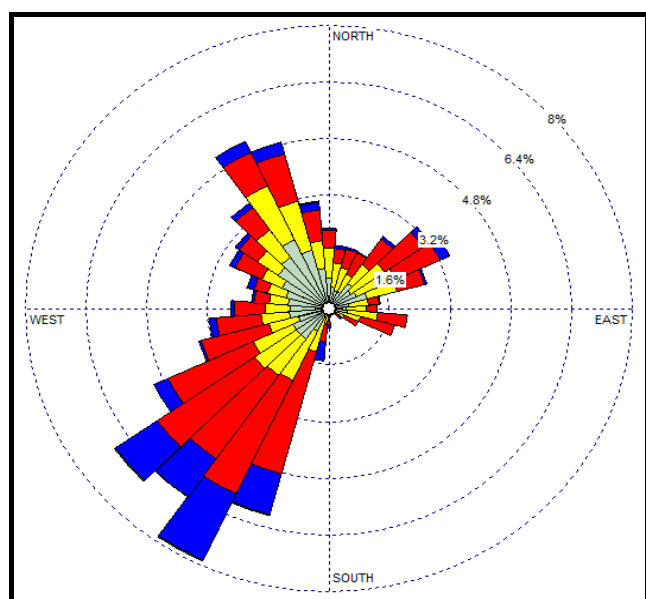


Fig. 2. Wind rose showing prevailing meteorological conditions during the study period

D. Environmental impact evaluation

Environmental significance was assessed by comparing the predicted cumulative PM_{10} concentrations with the applicable NAAQS. The modelling results indicated that the cumulative concentrations remained within the prescribed regulatory limits under the evaluated operating conditions, suggesting that routine industrial activities are unlikely to result in unacceptable deterioration of ambient air quality.

Although regulatory compliance was achieved, the analysis clearly identified transportation-related activities and operational surface emissions as the principal contributors to localized particulate concentrations as shown in table 2. This finding emphasizes that effective environmental management should extend beyond conventional stack emission control and

include operational practices capable of reducing fugitive dust generation.

Appropriate mitigation measures include periodic water sprinkling on haul roads, paving or stabilisation of unpaved surfaces, speed restrictions for heavy vehicles, enclosure of material handling operations, regular housekeeping, optimisation of traffic movement, and strengthening of greenbelt development around the facility boundary. Implementation of these measures would further reduce particulate emissions and enhance long-term environmental performance.

TABLE II. COMPARISON OF PREDICTED CUMULATIVE PM_{10} CONCENTRATIONS WITH THE APPLICABLE NAAQS.

Parameters	Concentration in Ambient Air NAAQS Guidelines	Concentration in Ambient Air Actual
	24 Hrs. Average	24 Hrs. Average
Particulate matter-10 (PM_{10})	100 $\mu\text{g}/\text{m}^3$	88.3 $\mu\text{g}/\text{m}^3$

E. Comparison with published investigations

The present investigation supports the growing body of evidence demonstrating that integrated atmospheric dispersion modelling is an effective component of Environmental Impact Assessment for industrial developments. Previous studies have similarly reported that fugitive emissions often dominate local particulate concentrations despite relatively modest emission rates because of their release near ground level [9,12].

Furthermore, the findings are consistent with recent research highlighting the importance of combining detailed emission inventories with site-specific meteorological observations to improve prediction accuracy and environmental decision-making [10]. Unlike many previous investigations that considered isolated emission sources, the present study evaluated point, area, and transport-related emissions within a single modelling framework, thereby providing a more comprehensive understanding of cumulative particulate impacts.

The adopted methodology therefore demonstrates how atmospheric dispersion modelling can be integrated into Environmental Impact Assessment to support regulatory compliance, identify priority emission sources, and guide implementation of practical pollution mitigation strategies for industrial facilities.

V. CONCLUSION

The present study demonstrated the value of integrating atmospheric dispersion modelling into the EIA process for evaluating PM_{10} emissions from complex industrial operations. By combining emissions from elevated process stacks, operational area sources, and transportation-related fugitive activities within a single modelling framework, the investigation provided a comprehensive understanding of pollutant dispersion under representative meteorological conditions. The adopted methodology enabled simultaneous assessment of individual source contributions and cumulative environmental impacts, thereby supporting a more holistic evaluation of industrial air quality.

The modelling outcomes indicated that ground-level fugitive emissions associated with operational activities and internal transportation exerted a greater influence on ambient PM₁₀ concentrations than elevated stack emissions. This behavior highlights the importance of considering source configuration and release characteristics, in addition to emission magnitude, during environmental assessments. Comparison of predicted concentrations with the applicable National Ambient Air Quality Standards confirmed that the evaluated industrial operations were unlikely to produce unacceptable ambient air quality impacts under the assessed operating conditions.

Beyond demonstrating regulatory compliance, the study illustrates how atmospheric dispersion modelling can be applied as an environmental management tool for identifying dominant emission sources, prioritizing pollution control measures, and supporting evidence-based decision-making. The findings suggest that effective particulate matter management should focus on operational improvements such as dust suppression, traffic management, routine housekeeping, enclosure of material handling activities, and strengthening of vegetative barriers around industrial facilities.

Although the assessment employed internationally accepted modelling procedures and representative site-specific datasets, uncertainties associated with emission estimation and meteorological variability remain inherent to predictive modelling studies. Future investigations may strengthen the assessment through long-term meteorological datasets, seasonal emission inventories, field validation of model predictions, and integration of health risk assessment and cumulative exposure analysis.

Overall, the proposed framework demonstrates that atmospheric dispersion modelling is an effective analytical component of Environmental Impact Assessment and provides a practical methodology for supporting sustainable industrial planning, regulatory compliance, and proactive environmental protection.

REFERENCES

- [1] Glasson, J., Therivel, R., & Chadwick, A. (2013). Introduction to Environmental Impact Assessment (4th ed.). Routledge.
- [2] Canter, L. W. (1996). Environmental Impact Assessment (2nd ed.). McGraw-Hill.
- [3] United States Environmental Protection Agency (US EPA). (2023). Guideline on Air Quality Models (40 CFR Part 51, Appendix W). U.S. Environmental Protection Agency.
- [4] Radzuan, H. S. M., & Martin, J. (2024). An evaluation of air quality impact prediction undertaken as part of Environmental Impact Assessment in India. *Heliyon*, 10, e31263. <https://doi.org/10.1016/j.heliyon.2024.e31263>
- [5] World Health Organization. (2021). WHO Global Air Quality Guidelines: Particulate Matter (PM_{2.5} and PM₁₀), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. World Health Organization.
- [6] Pope, C. A., III, & Dockery, D. W. (2006). Health effects of fine particulate air pollution: Lines that connect. *Journal of the Air & Waste Management Association*, 56(6), 709–742. <https://doi.org/10.1080/10473289.2006.10464485>
- [7] Cimorelli, A. J., Perry, S. G., Venkatram, A., Weil, J. C., Paine, R. J., Wilson, R. B., Lee, R. F., Peters, W. D., & Brode, R. W. (2005). AERMOD: A dispersion model for industrial source applications. Part I: General model formulation and boundary layer characterization. *Journal of Applied Meteorology*, 44(5), 682–693. <https://doi.org/10.1175/JAM2227.1>
- [8] Perry, S. G., Cimorelli, A. J., Paine, R. J., Brode, R. W., Weil, J. C., Venkatram, A., Wilson, R. B., Lee, R. F., & Peters, W. D. (2005). AERMOD: A dispersion model for industrial source applications. Part II: Model performance against seventeen field study databases. *Journal of Applied Meteorology*, 44(5), 694–708. <https://doi.org/10.1175/JAM2228.1>
- [9] Holmes, N. S., & Morawska, L. (2006). A review of dispersion modelling and its application to the dispersion of particles. *Atmospheric Environment*, 40(30), 5902–5928. <https://doi.org/10.1016/j.atmosenv.2006.06.003>
- [10] Pandey, G., Venkatram, A., & Arunachalam, S. (2024). Modeling the air quality impact of aircraft emissions: Is area or volume the appropriate source characterization in AERMOD? *Air Quality, Atmosphere & Health*, 17, 1425–1434. <https://doi.org/10.1007/s11869-024-01517-2>
- [11] Hongthong, A., & Nakapan, S. (2023). Assessing the impact of a waste incinerator on the environment using the MAIAC-AOD and AERMOD models. *Frontiers in Environmental Science*, 11, 1240705. <https://doi.org/10.3389/fenvs.2023.1240705>
- [12] Bayraktar, O. M., & Mutlu, A. (2024). Analyses of industrial air pollution and long-term health risk using different dispersion models and WRF physics parameters. *Air Quality, Atmosphere & Health*, 17, 2277–2305. <https://doi.org/10.1007/s11869-024-01573-8>
- [13] Seinfeld, J. H., & Pandis, S. N. (2016). Atmospheric Chemistry and Physics: From Air Pollution to Climate Change (3rd ed.). John Wiley & Sons.