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Comprehensive Review of Air Pollution Mapping Techniques Using ArcGIS and MATLAB: Methods, Applications, and Best Practices

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Abstract: Air pollution poses a significant risk to public health, contributing to a substantial portion of the Global Burden of Disease (GBD). As urban populations grow, air quality issues become more critical, especially in developing countries like India. This review paper explores the latest methodologies and technologies used in air quality analysis and modelling, focusing on Geographic Information Systems (GIS), computational tools like MATLAB, and multi-criteria decision-making frameworks. The paper emphasizes the role of these tools in understanding, predicting, and addressing air pollution challenges. By examining case studies and recent research, we identify best practices and propose strategies for effective air quality management.

Keywords: Air Quality Analysis, Modelling, Geographic Information Systems (GIS), MATLAB, Air Pollution, Public Health

I. INTRODUCTION

Air pollution is a growing concern worldwide, with over two million deaths annually attributed to urban air pollution, according to the World Health Organization (WHO). This issue is particularly acute in developing countries, where rapid urbanization and industrialization contribute to deteriorating air quality. India, with 39 of the world's 50 most polluted cities, exemplifies this problem.

Given the complex nature of air pollution, a multi-disciplinary approach is necessary to understand and mitigate its effects. Geographic Information Systems (GIS), computational modelling, and remote sensing offer robust spatial analysis and air quality prediction tools. This review paper aims to provide an overview of these technologies, highlighting their applications in air quality assessment and decision-making.

II. AIR QUALITY MODELLING WITH GIS AND MATLAB

ArcGIS and MATLAB are two prominent tools for air quality modelling. ArcGIS provides a comprehensive platform for spatial analysis, allowing users to visualize pollutant dispersion and identify high-risk areas. MATLAB offers robust capabilities for mathematical modelling and data analysis, enabling researchers to simulate air pollution scenarios and predict future trends.

In the Greater Cochin region of Kerala, India, researchers utilized ArcGIS and MATLAB to study air quality disturbance zones from 2014 to 2023. The analysis focused on key pollutants such as nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and Respirable Suspended Particulate Matter (RSPM), using data from the Kerala State Pollution Control Board (KSPCB). By combining ArcGIS's spatial mapping with MATLAB's mathematical modelling, the study identified pollution hotspots and projected future trends up to 2028.

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1. Multi-Criteria Decision-Making for Air Quality Management

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making framework that can be integrated with GIS to support air quality management. By considering multiple factors such as traffic flow, meteorological conditions, and industrial activities, AHP provides a structured approach to evaluating air pollution scenarios.

Fatma Sahin *et al.* (2020) utilized AHP in combination with GIS to investigate air pollution in urban areas. The integration of these methodologies allows for a comprehensive analysis, enabling urban planners and policymakers to make informed decisions regarding air quality management.

2. Case Studies and Applications

Several studies have demonstrated the effectiveness of GIS and MATLAB in air quality analysis:
Masooda *et al.* (2017): This study integrated and predicted carbon monoxide (CO) emissions with ArcGIS to create digital maps highlighting pollution hotspots. This approach supported policymakers in developing effective pollution control strategies and enforcing air quality standards.

Abdul Atiq Siddiqui *et al.* (2019): This research utilized MATLAB to propose an Air Quality Index (AQI) model based on fuzzy logic. The model classified air quality ranging from "Good" to "Severe," providing a practical tool for assessing air quality and guiding public health responses.

Lei Huang *et al.* (2017): This study explored various methods for air pollutant concentration simulation, including kriging, inverse distance weighing (IDW), and conventional dispersion models. The research highlighted the importance of high-precision data and the challenges associated with complex simulation processes.

L. Matejicek (2005) explored how Geographic Information Systems (GIS) can manage data from monitoring systems, mathematical models, and remote sensing for air pollution analysis. While air pollutant distribution simulations are typically done on standalone systems, GIS is an efficient platform for integrating and supporting decision-making. It organizes data into map layers with various attributes and uses spatial interpolation, raster algebra, and case-oriented analysis to create additional layers. Remote sensing data, including aerial and satellite imagery, enhances the analysis. A series of GIS extensions further expands the system's capabilities, enabling a more versatile approach to air quality studies.

Shafat Khan *et al.* (2018) examines the rapid growth in the GIS software industry over the past decade, focusing on two GIS programs: Esri's commercial ArcGIS and the open-source QGIS. The paper contrasts these programs, assessing their suitability for sustainable spatial planning based on software quality and task-specific needs. It guides spatial planning organizations on deciding whether to replace ArcGIS with QGIS, considering their specific requirements and resources. The study does not claim one is universally superior, as suitability depends on organizational needs and preferences.

Sheldon Lee *et al.* (2019) presents a textbook that introduces fundamental mathematical models alongside advanced applications, with a focus on guiding readers through the modelling process and underlying assumptions. Aimed at students new to computer programming and mathematical modelling, the book provides a comprehensive overview of key concepts. It emphasizes practical skills, demonstrating how to use procedural programming in MATLAB to simulate and approximate solutions to various mathematical models. The book serves as a resource for understanding the basics of mathematical modelling while offering insights into more complex applications, making it suitable for beginners seeking to build foundational knowledge in this field. [10] discussed that K-means transformation, histogram equalization, linear contrast stretching, and share-based features are all used to detect leukemia. A method for automatically classifying leukocytes using microscopic images is proposed.

Awkash Kumar *et al.* (2022) highlight air pollution as a major concern in urban areas, particularly in developing countries. Notably, four out of the five cities with the world's worst air quality are in India. The study emphasizes the need for constant monitoring of air pollutants like sulphur dioxide (SO2), nitrogen dioxide (NO2), and suspended particulate matter (SPM). These pollutants are tracked through established air monitoring stations, which provide crucial data to understand and address the serious environmental and public health issues caused by urban air pollution. [5] discussed about detection of leukaemia using a small picture

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handling method that distinguishes between red blood cells and young white cells. Visual examination of minuscule photos by looking at alterations such as surface, calculation, shading, and measurable research of photographs is now the only recognisable proof of blood trouble.

III. Future Directions and Recommendations

The review of existing studies suggests several areas for further research and development:

Urban Planning and Design: Future studies should focus on developing standard procedures for urban planning that consider air quality impacts [6].

Biodegradable Air Filtration Systems: there is a crucial need for sustainable air filtration systems, highlighting the limitations of conventional materials [9]. Research into biodegradable alternatives could be crucial in addressing indoor air pollution.

Integration of Remote Sensing and GIS: Incorporating satellite data into GIS can enhance spatial analysis, providing a broader perspective on air pollution patterns. Further research into this integration could improve the accuracy and effectiveness of air quality modelling.

IV. Conclusion

The use of advanced technologies like ArcGIS and MATLAB has proven effective in addressing air pollution challenges. These tools offer valuable insights into spatial distribution, pollutant dispersion, and future predictions. Multi-criteria decision-making frameworks, such as AHP, further support comprehensive air quality management. Ongoing collaboration among researchers, urban planners, and policymakers is essential to develop effective strategies for reducing air pollution and mitigating its impact on public health and the environment.

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