

AI-Based Air Quality Monitoring and Pollution Control

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Abstract — Air pollution is a major environmental concern because it affects human health, ecosystems, and the quality of life in urban and industrial areas. Traditional monitoring systems often depend on fixed stations and manual sampling. Although these methods provide useful measurements, they may have high operating costs, limited spatial coverage, and delays in reporting. Recent developments in Artificial Intelligence (AI), Machine Learning (ML), the Internet of Things (IoT), and wireless sensors offer ways to monitor air quality continuously and forecast pollution levels. This review examines four supplied papers covering AI and ML models with wireless sensors, IoT-based monitoring, comparisons between traditional and AI-based methods, and a proposed smart-city forecasting framework. The reviewed literature describes applications such as missing-data estimation, sensor calibration, anomaly detection, Air Quality Index (AQI) estimation, and short-term pollution forecasting. Models including regression, Random Forest, Support Vector Machines, neural networks, and deep-learning methods are discussed. The papers also identify challenges related to data quality, sensor reliability, cost, scalability, model transfer between locations, and system integration. One proposed framework reports improved prediction results, but these figures are treated as results reported by that paper rather than independently verified findings. Overall, AI can support earlier warnings and better-informed pollution management when it is combined with reliable sensors, quality data, and local validation.

Keywords— Air Quality Monitoring, Artificial Intelligence, Machine Learning, Internet of Things, Pollution Forecasting, Smart Sensors

I. INTRODUCTION

Air pollution is caused by several human activities, including transportation, industrial processes, construction, and energy production. Common pollutants monitored by air-quality systems include particulate matter such as PM_{2.5} and PM₁₀, carbon monoxide (CO), sulphur dioxide (SO₂), nitrogen oxides (NO_x), and ozone. Their concentrations can change with traffic, weather, time of day, and local activities. Monitoring is therefore important for understanding pollution patterns and providing timely information to communities and authorities [1], [2]. Conventional monitoring commonly uses fixed monitoring stations and laboratory-based measurements. These approaches can provide dependable observations, but deploying many stations may be expensive and can leave some locations without frequent measurements. Manual sampling can also delay the availability of information. Shabani [3] compares these traditional approaches with AI-based methods and highlights the value of automation and rapid processing, while also noting that AI systems require suitable data, technical expertise, and investment.

AI and ML methods can learn patterns from historical and real-time measurements and estimate future pollutant levels. When combined with IoT sensors and communication networks, they can support continuous data collection and alerts. Garcia et al. [2] classify AI applications into data imputation, sensor calibration, anomaly detection, AQI estimation, and short-term

forecasting. This review brings together the main findings of four

II. REVIEW METHODOLOGY

supplied papers and discusses how they may support practical air-quality monitoring and pollution control.

This paper uses a focused narrative review of the four research papers supplied for the topic. The sources cover: (1) a comprehensive review of AI/ML models and wireless sensors for air-quality prediction and pollution control [1]; (2) a systematic review of IoT-based monitoring and AI technologies that analysed 147 selected studies from 220 identified records [2]; (3) a comparative discussion of traditional and AI-based monitoring methods [3]; and (4) a proposed AI-based monitoring and forecasting framework for smart cities [4].

The papers were compared by their main objective, technologies discussed, reported contributions, and limitations. Since two sources are reviews, one is a comparative chapter/preprint available through SSRN, and one describes a proposed framework, their evidence is not identical. The performance figures in [4] are therefore reported as stated in that paper and are not treated as a direct, independently verified comparison with all other sources. This is a focused narrative synthesis, not a new systematic search of all published literature.

III. LITERATURE REVIEW

1. Traditional and Ai based Air quality monitoring

Traditional monitoring systems rely on stationary stations, measurement instruments, and sometimes manual collection. They can provide useful reference measurements, but the number and location of stations affect how well they represent a whole city. Shabani [3] describes limitations involving spatial coverage, data latency, and dependence on manual collection. AI-based systems can process larger streams of data and automate some tasks, but their reliability depends on the quality of sensor readings and the data used for training.

2. IoT Sensors and Real-Time Monitoring

IoT-based monitoring connects environmental sensors to communication networks and data-processing platforms. Sensors may measure particulate matter and gases, while temperature and humidity can provide additional context. Data can be sent to a cloud service or local processing unit for storage, analysis, and display. Garcia et al. [2] explain that IoT and AI integration can help make monitoring more continuous and scalable. However, network reliability, sensor calibration, maintenance, and integration across different devices remain important practical issues.

3. AI and Machine Learning Techniques

The reviewed papers discuss several approaches. Regression models provide a baseline for estimating pollutant concentration. Decision-tree methods and Random Forest can model nonlinear relationships in environmental data. Support Vector Machines are another option for prediction and classification, while neural networks and deep-learning models can learn more complex patterns from larger datasets. The most suitable model depends on the available data, prediction period, pollutant, and computing resources [1], [2].

AI is also useful beyond forecasting. Data-imputation methods can estimate missing readings; sensor-calibration models can reduce measurement errors; anomaly detection can flag unusual readings; and AQI estimation can translate pollutant measurements into a more understandable indicator. These functions are particularly relevant

4. Pollution Forecasting and Smart-City Applications

to monitoring networks where data may be incomplete or sensor performance may change over time [2].

Forecasting systems use historical pollutant measurements and may include meteorological variables to estimate future air quality. The framework described by Sudheer and Deshpande

[4] combines distributed environmental sensors, a communication/cloud layer, an AI analytics engine, and a prediction-and-alert layer. Its monitored parameters include PM_{2.5}, PM₁₀, CO, SO₂, NO_x, temperature, and humidity. Such a design can support early warnings, public-health communication, urban planning, and pollution-management decisions.

The framework paper reports that its hybrid model achieved 93.4% prediction accuracy and a 3.9% mean error, compared with lower reported results for the individual models it evaluated [4]. These numbers should be interpreted within that paper's own experimental setup. The supplied paper does not provide a common evaluation protocol that would make its figures directly comparable with every model discussed in the other review paper.

5. Pollution Control and Decision Support

AI monitoring does not remove pollution by itself. Its main contribution is to provide timely evidence that can guide action. Forecasts and alerts may help authorities identify high-pollution periods, review traffic or industrial activity, communicate risks to residents, and plan interventions. Combining real-time readings with historical patterns can also help identify repeated pollution hotspots. Effective control still requires decisions and actions by responsible agencies, industries, and communities; AI is a decision-support tool rather than a replacement for environmental policy.

IV. COMPARATIVE ANALYSIS

Table 1 summarises the four supplied papers. Their scope differs, so the table compares their focus and contributions rather than ranking them by a single accuracy score.

Table 1. Comparison of the four supplied papers.

Source	Main focus	Main contribution	Limitations / notes
Fatima et al. [1], 2025	AI/ML models and wireless sensors	Reviews prediction, monitoring, spatial analysis, and pollution mitigation uses	Highlights data availability, integration, interpretability, and generalisation challenges
Garcia et al. [2], 2025	Systematic review of IoT + AI	147 studies reviewed; groups AI uses into imputation, calibration, anomaly detection, AQI estimation, and forecasting	Identifies data quality, scalability, and integration as open issues
Shabani [3], 2023	Traditional vs AI-based methods	Compares coverage, speed, automation, cost, and data processing	SSRN-hosted chapter/preprint; stresses cost, expertise, complexity, and reliability concerns
Sudheer & Deshpande [4], 2026	Smart-city monitoring and forecasting framework	Proposes sensor, cloud, ML analytics, prediction, and alert layers; reports model results	Results are those reported in the paper; real-world deployment still faces calibration, network, cost, and adaptation challenges

V. PROPOSED CONCEPTUAL FRAMEWORK

Based on the reviewed papers, a conceptual air-quality monitoring and pollution-control support system can be organised into five layers. This is a synthesis proposed for discussion; it has not been implemented or experimentally validated in this review.

- Environmental sensing layer: distributed sensors measure PM_{2.5}, PM₁₀, CO, SO₂, NO_x, temperature, and humidity.
- Communication layer: a wireless network transfers readings to a local gateway or cloud platform.
- Data quality layer: missing values are handled, sensor readings are calibrated, and unusual measurements are checked.
- AI analytics layer: ML models estimate AQI and forecast near-term pollutant concentrations using current and historical data.
- Alert and decision-support layer: dashboards and alerts share the results with users and authorities to support pollution-management actions.

Sensors → Communication / Cloud → Data Quality → AI Prediction → AQI / Alerts → Pollution-Management Decisions
Fig. 1. Proposed conceptual workflow for AI-based air-quality monitoring and pollution-control support.

VI. RESEARCH GAPS AND FUTURE DIRECTIONS

The supplied papers identify several issues that should be addressed before AI-based monitoring can be used reliably at a large scale:

Data quality and missing readings: sensor data may contain gaps, noise, or incorrect measurements. Future systems should combine careful calibration with transparent data-cleaning and imputation methods [1], [2]. Sensor reliability and maintenance: low-cost sensors need regular checking because their measurements can drift. Calibration procedures and comparisons with trusted monitoring stations are important.

Generalisation across locations: a model trained in one city or climate may not perform equally well elsewhere. Models should be tested using local data and across different seasons and pollution conditions [1].

Scalability and integration: larger sensor networks require dependable communication, common data formats, manageable costs, and maintenance planning [2], [4].

Fair evaluation: future studies should report the dataset, forecast horizon, pollutants, error metrics, and validation method clearly. Comparisons should use the same data splits and evaluation measures.

From prediction to action: future work should evaluate whether alerts lead to useful interventions and whether these interventions reduce exposure or pollution. A prediction model alone does not demonstrate pollution reduction.

VII. CONCLUSION

This review examined four supplied papers on AI-based air-quality monitoring and pollution control. The literature shows that AI and IoT can improve continuous data collection, support sensor-data correction, estimate AQI, detect unusual readings, and forecast pollutant levels. Machine-learning methods such as regression, Random Forest, Support Vector Machines, and neural networks offer different options depending on the data and task. A sensor-to-alert framework can help authorities respond earlier and make better-informed decisions. However, useful results depend on reliable sensors, good-quality data, local validation, stable communication, and affordable maintenance. The performance figures reported by a single framework should not be generalised without further testing. Future work should focus on real-world validation across locations, transparent evaluation, and measuring whether AI-supported alerts lead to effective pollution control actions.

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