

Beyond the Hype: The Real Challenges of Artificial Intelligence in Air Pollution Management

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Dear Editor,

Artificial intelligence (AI) is increasingly applied to address global challenges, including air pollution. AI helps reduce greenhouse gas emissions and improve air quality by providing innovative solutions and analytics. Advances in areas such as traffic management, continuous air quality monitoring, energy optimization, and public participation have significantly influenced how we address environmental challenges (1).

However, these applications face key challenges such as limited data quality, heterogeneous information sources, and the complexity of deep learning models, which reduce reliability in real-world settings and highlight the need for closer evaluation of AI performance in prediction and decision-making (2).

By processing vast amounts of data from sensors, satellites, and other sources, AI algorithms can predict air quality and provide real-time feedback on pollution levels in different areas, enabling proactive and effective decision-making to control pollution hotspots and protect public health. In addition, AI-based smart traffic systems and algorithms can significantly reduce harmful emissions in cities by reducing congestion and increasing fuel efficiency; for example, AI-enabled traffic lights can dynamically adjust to traffic conditions, reducing vehicle waiting times and overall traffic congestion (2).

On the other hand, the limited quality and accessibility of data, especially in deprived areas, coupled with the diversity and heterogeneity of sources such as ground sensors, satellite imagery, and meteorological data, make seamless

model integration difficult, as differences in spatial and temporal scales require extensive preprocessing and assimilation to effectively combine these heterogeneous datasets (2).

Using machine learning algorithms and big data analytics, AI identifies innovative ways to optimize energy production and consumption processes, thereby helping to reduce waste and carbon footprints in industries. AI-based energy management systems also play an effective role in reducing air pollution by increasing efficiency and expanding the use of clean resources. Analyzing weather data, solar radiation, wind speed, and energy consumption patterns helps to predict production and consumption in wind and solar power plants; for example, deep learning algorithms can forecast low-solar-production periods in advance, allowing better storage or consumption planning and reducing reliance on fossil-fuel power plants (3).

The use of AI, particularly deep learning, can impose notable environmental impacts, as training large models requires substantial energy and may increase carbon emissions; for example, training large AI models can increase energy use and carbon emissions. To mitigate these effects, strategies such as developing lighter models, compressing networks, using energy-efficient data centers, and applying transfer learning are recommended (2).

Another important aspect of AI in air pollution management is its ability to encourage public awareness and citizen engagement in environmental issues. With AI-powered platforms and applications, citizens can access real-time data on air quality, receive pollution alerts, and

Table 1. Key advantages and limitations of artificial intelligence in air pollution management

Domain	Advantages	Limitations
Air quality monitoring	Real-time monitoring and accurate prediction of pollution levels using large-scale data from sensors and satellites	High dependency on accurate, continuous, and high-quality data infrastructure
Traffic and urban management	Reduction of traffic congestion and vehicle emissions through intelligent traffic control systems	High implementation cost and need for advanced digital infrastructure
Energy optimization	Improved efficiency of energy production and increased integration of renewable energy sources	Energy-intensive training of deep learning models may increase carbon footprint
Decision-making and policy support	Enables evidence-based environmental policymaking and smart city planning	Limited model interpretability and potential algorithmic bias
Public engagement	Enhances public awareness and citizen participation through AI-powered platforms	Privacy concerns and unequal access to AI technologies
Model robustness and scalability	Ability to analyze complex, multi-source environmental data	Poor performance when data are incomplete, biased, or heterogeneous

participate in community activities to reduce pollution. By empowering citizens with data and tools to inform their choices, AI fosters a culture of environmental responsibility and collective action (4).

To maximize the impact of AI, it is necessary to address limitations such as data quality, privacy, and algorithmic bias so that the technology is used responsibly and ethically; also, the scalability and economic implications of AI technologies may create barriers to large-scale applications, especially in less developed countries. To effectively harness AI for air pollution management, a multidisciplinary and responsible approach is needed, involving collaboration between governments, researchers, and the private sector (5).

Analysis shows that integrating AI with IoT and multi-layered predictive models can enhance environmental policymaking and support practical pollution-reduction strategies. This positions AI as a tool for evidence-based decision-making and sustainable urban planning, contributing to cleaner smart cities. Future research should focus on developing practical predictive models and advancing AI-driven environmental policies. However, key challenges of AI models include limited interpretability, difficulties in harmonizing disparate data, and limited adaptability to dynamic pollution patterns driven by climate change. One of the most critical limitations of artificial intelligence is its strong dependency on accurate and robust data collection infrastructures; without reliable, high-quality input data, AI systems may generate biased or misleading outputs, ultimately undermining their effectiveness in real-world air pollution management. These advantages and limitations are summarized in Table 1. At the same time, there are promising future applications such as multimodal models, explainable AI techniques, and self-adaptive models.

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The authors declare that they have no conflict of interest.

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