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The Persistent Failure of Reactive Policies and Long-Term Stagnation: Unpacking the Limits of Delhi's Air Quality Interventions

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ABSTRACT

Background: *Delhi's air quality is, by any measure, a serious and ongoing crisis. The city consistently records some of the worst Air Quality Index (AQI) levels in the world — worse than much larger industrial cities in China, and worse than cities currently experiencing armed conflict, such as Iran. This paper investigates the structural and policy reasons behind the persistence of Delhi's air pollution problem despite decades of regulatory intervention.*

Methodology/Principal Findings: *Drawing on a systematic review of policy documents, judicial records, emission inventories, and published scientific literature, the paper identifies the principal emission sources — vehicle traffic, industrial activity, poor waste management, crop residue burning in neighbouring states, and geography-driven temperature inversions — and evaluates the effectiveness of interventions including judicial mandates, vehicle fuel conversion programmes, forecasting systems, and agricultural residue management schemes. The central finding is that government responses have almost always been reactive and short-term, addressing symptoms rather than root causes. The 2009 Punjab Preservation of Subsoil Water Act is identified as an underappreciated driver of concentrated stubble-burning episodes. Court-mandated measures such as smog towers are found to lack scientific justification at the scale required, while the diesel-to-CNG conversion stands out as a genuinely effective structural intervention.*

Conclusions/Significance: *Real improvement requires committing to long-term, source-specific, and regionally coordinated strategies. Immediate priorities include updating emission inventories (last comprehensively revised in 2016–17), expanding the ambient monitoring network to at least 100 stations across Delhi's airshed, and diversifying agricultural cropping patterns in Punjab and Haryana away from the rice-wheat monoculture that drives annual burning episodes.*

Keywords: Air quality, Delhi, crop residue burning, reactive policy, temperature inversion, PM2.5, judicial intervention, National Clean Air Programme

1. Introduction

Delhi became a Union Territory in 1956 and was designated the National Capital Territory (NCT) in 1992. Like most large Indian cities, its climate varies significantly across the year: spring (February to April) is warm and occasionally dusty; summer (May to June) is hot and humid, with temperatures sometimes reaching 40°C; the monsoon runs from July to September; post-monsoon (late September to early November) brings cooler, clearer conditions; and winter (late November to early February) is cold and foggy, with temperatures sometimes dropping below 10°C. It is during this last season that Delhi's air quality typically reaches its worst levels.

The causes of Delhi's pollution problem are well documented. Heavy vehicle traffic, construction activity, industrial emissions, and the burning of crop residue in neighbouring states all play a role. These factors are made significantly worse by the city's winter weather conditions. The policy record, however, is one of repeated short-term emergency interventions rather than sustained structural reform. The present paper examines why that pattern has persisted, what the consequences have been, and what a more effective approach would look like.

The paper proceeds as follows. Section 2 describes the methodological approach. Section 3 examines the geographic and climatic factors that amplify Delhi's pollution. Section 4 reviews the contribution of population growth and vehicle traffic. Section 5 analyses the stubble-burning problem in Punjab and Haryana. Section 6 surveys the air quality forecasting systems currently in operation. Section 7 evaluates the roles of the judiciary, regulatory bodies, and the Union Government. Section 8 sets out the discussion, and Section 9 the conclusions and policy recommendations.

2. Materials and Methods

This paper employs a qualitative, document-based systematic review methodology. The study draws on four principal source categories: (i) primary legislative and regulatory documents, including acts of Parliament, Supreme Court and National Green Tribunal orders, and government scheme guidelines; (ii) peer-reviewed scientific literature on air quality, emission inventories, and source apportionment for the Delhi-NCR region; (iii) technical documentation and publicly available outputs from operational air quality forecasting systems, including CAMS, SAFAR, EWS-IITM, and the Urban Emissions Programme; and (iv) official government reports and budget disclosures relating to crop residue management and clean air programmes.

Sources were identified through a structured search of Google Scholar, the Central Pollution

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

Control Board (CPCB) and Ministry of Environment, Forest and Climate Change (MoEFCC) online repositories, and the websites of the forecasting platforms listed in Section 6. Search terms included combinations of: Delhi air quality, PM2.5, stubble burning, crop residue, temperature inversion, NCAP, EPCA, CAQM, and judicial intervention. Priority was given to sources published between 2009 and 2026, with earlier foundational documents (e.g. M. C. Mehta v. Union of India, 1986) included where directly relevant.

The analytical framework distinguishes between reactive, short-term interventions (emergency bans, crisis-driven judicial orders) and structural, long-term interventions (fuel conversion programmes, emission standard reform, agricultural diversification). Each major policy measure reviewed is assessed against this framework, with reference to available evidence on effectiveness. Where quantitative outcome data are available in the literature — such as post-CNG conversion emission reductions — these are reported. Where such data are absent, the assessment is qualitative and draws on the weight of expert commentary in the reviewed literature.

3. Geographic and Climatic Factors

One of the less obvious but most important contributors to Delhi's pollution crisis is its geography. In winter, the Himalayan range to the north traps cold air over the city — a condition known as temperature inversion. Normally, warm air near the ground rises and carries pollutants upward and away. During an inversion, a layer of warm air sits on top of cooler surface air and acts like a lid, preventing pollutants from dispersing. The result is that everything emitted in and around Delhi — vehicle exhaust, dust, smoke — stays trapped near ground level.

This physical trapping mechanism is the primary reason why Delhi's air quality deteriorates so sharply in late autumn and early winter. It is also the reason why emissions from neighbouring states matter so much: smoke generated in Punjab and Haryana during stubble-burning season does not simply dissipate but is instead channelled toward Delhi and held there by the inversion layer. Any policy framework that does not take this regional meteorological dynamic into account will be structurally inadequate.

4. Population Growth and Vehicle Emissions

Delhi's population density and the sheer volume of vehicle traffic on its roads contribute significantly to baseline pollution levels. Events like Diwali, when large amounts of firecrackers are used, cause additional short-term spikes. However, these factors alone do not explain why Delhi's air quality is so much worse than other large Indian cities with comparable traffic volumes. The more distinctive factor is what happens in the fields outside the city, discussed in the following section.

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

That said, vehicle emissions remain one of the most tractable and significant sources of year-round pollution in Delhi. The Bharat Stage VI (BS-VI) emission norms, which came into force in 2020, represent a meaningful tightening of standards. Earlier court-ordered interventions — most notably the conversion of the public bus fleet and para-transit vehicles from diesel to Compressed Natural Gas (CNG) — produced measurable improvements. According to available data, PM2.5 and SO_2 emissions from buses, auto-rickshaws, and taxis fell by more than 90 percent following that conversion. This remains one of the clearest examples of a structural, rather than merely reactive, intervention producing a lasting improvement in Delhi's air quality.

5. Crop Residue Burning

5.1 Agricultural Calendar and the Stubble-Burning Cycle

Punjab and Haryana, the agricultural states immediately to Delhi's west, grow large quantities of rice and wheat. Rice (paddy) is harvested between June and October, and wheat is planted around mid-November. To clear their fields quickly between harvests, farmers traditionally burn the leftover paddy stubble. The result is a concentrated burst of smoke and particulate matter in October and November, precisely when Delhi's temperature inversions are trapping air close to the surface. This combination is largely responsible for the severe pollution episodes that have become a defining feature of Delhi's autumn and early winter.

5.2 The Role of the Punjab Preservation of Subsoil Water Act (2009)

The stubble-burning problem got considerably worse after the Punjab Preservation of Subsoil Water Act was passed in 2009. The law was intended to protect groundwater by delaying the planting of paddy until later in the season, which shortened the window between the paddy harvest and the wheat sowing. That compressed timeline pushed farmers toward faster clearing methods — mostly burning — and because all the farms face the same deadline, it all happens simultaneously. The legislation thus had the unintended consequence of concentrating and intensifying the very practice it did not address.

This is a significant policy finding. A well-intentioned groundwater conservation measure substantially worsened Delhi's air quality by compressing the stubble-clearing window. It illustrates a broader pattern in which sectoral policies are designed without adequate cross-sectoral impact assessment — a systemic gap that any serious clean air framework must address.

5.3 Crop Residue Management Programmes

Since 2018–19, the Union Ministry of Agriculture and Farmers' Welfare has subsidised the purchase of equipment such as happy-seeders, rotavators, combine harvesters, and super-straw

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

management systems for farmers in Punjab, Haryana, and Uttar Pradesh. By March 2021, approximately INR 24.4 billion (roughly USD 298 million) had been spent on this programme. An additional INR 6.91 billion (USD 84 million) went toward converting stubble into biomass briquettes and pellets that can be used as fuel in industrial boilers.

These in situ and ex situ residue management programmes have had some impact, but they address the symptom rather than the underlying problem. The root cause goes back to the Green Revolution: Punjab and Haryana were encouraged to specialise in water-intensive rice and wheat cultivation, and the entire agricultural calendar in these states is now structured around those two crops. Genuinely solving the stubble-burning problem would require diversifying away from that monoculture — a politically difficult reform that no government has seriously attempted.

6. Air Quality Forecasting and Alert Systems

Air quality forecasting for Delhi was first introduced ahead of the 2010 Commonwealth Games and was later proposed as a standard tool for all polluted cities under the National Clean Air Programme (NCAP) in 2019. The basic idea is to use weather data and emissions information to predict pollution levels a few days in advance, so that authorities and the public can take protective action before conditions deteriorate.

Several forecasting systems currently provide short-term (three- to five-day) air quality predictions for Delhi:

Copernicus Atmosphere Monitoring Service (CAMS): Operated by the European Union (https://atmosphere.copernicus.eu), CAMS combines satellite data with atmospheric models to generate forecasts at resolutions of 40 km globally and 10–12 km for selected regions. Results can be visualised at https://www.windy.com. Historical data from 1990 onward is also available for trend analysis.

Early Warning System (EWS) for Delhi — IITM: Hosted at https://ews.tropmet.res.in, this system draws on multiple modelling platforms including WRF-Chem, GEOS, and WACCM. It produces hourly concentration maps and comparisons with real monitoring data from the Central Pollution Control Board (CPCB) network. It also includes fog and visibility forecasts for Delhi.

NASA-GEOS System: Operated by NASA's Global Modelling and Assimilation Office, this system provides a ten-day forecast for Delhi through the GEOS-5 model, accessible via the EWS portal. Its reanalysis archives (including MERRA-2) go back to 1990.

SAFAR: Available at https://safar.tropmet.res.in, SAFAR combines ground measurements, emission inventories, and modelling to produce three-day forecasts. Originally built for Delhi, it

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

now also covers Mumbai, Pune, and Ahmedabad.

SILAM: Developed by the Finnish Meteorological Institute, SILAM is a global chemical transport model that provides customised forecasts for the Delhi NCR region through an agreement with the Indian Meteorological Department. Results appear on the EWS portal.

Urban Emissions Programme: Uses the WRF-CAMx modelling system and publishes hourly concentration maps, source apportionment data, and real-time comparisons at https://www.delhiairquality.info.

One promising direction for the future is ensemble forecasting — combining outputs from multiple models to produce more reliable predictions than any single system can provide. This approach is already common in weather forecasting and deserves more serious investment in the air quality context.

7. Judicial and Institutional Engagement

7.1 The Role of the Supreme Court

Perhaps the most unusual aspect of Delhi's air quality story is how central the courts have been to driving action. The Supreme Court of India has intervened repeatedly, usually in response to Public Interest Litigations (PILs) filed by citizens. These interventions have often come precisely because elected governments — both at the state and national level — were slow to act. The legal basis for this was established in the landmark M. C. Mehta v. Union of India case (1986), in which the Court interpreted the right to clean air as a fundamental right under Article 21 of the Constitution.

Some of the Court's interventions have been genuinely effective. Others have been more ad hoc — ordered quickly in response to a crisis without a strong evidence base. The record illustrates both the value of judicial oversight as a backstop against executive inaction, and the limits of litigation as a substitute for sustained regulatory governance.

Environment Pollution (Prevention and Control) Authority (EPCA): The EPCA was set up in 1998 on the Supreme Court's orders, under the Environment Protection Act of 1986. Its mandate was to oversee pollution control across Delhi and the surrounding states of Haryana, Uttar Pradesh, and Rajasthan. In practice, it largely confined itself to submitting reports to the Court and never fully exercised its regulatory powers. Independent observers have been fairly critical of its performance, and it was ultimately replaced by the Commission for Air Quality Management (CAQM) in 2020.

Diesel-to-CNG Conversion: Following a PIL filed by M. C. Mehta in 1998, the Supreme Court

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Volume:11, Issue:06 "June 2026"

ordered all public transport buses and para-transit vehicles in Delhi to convert from diesel to CNG. As noted above, PM2.5 and SO2 emissions from these vehicles fell by more than 90 percent after conversion.

Diwali Firecracker Restrictions: In 2015, three young children filed a PIL seeking a ban on the sale of fireworks around Diwali. The Court subsequently imposed restrictions on firecracker sales during this period, recognising the measurable spike in pollution that Diwali causes each year.

Petcoke Ban: In 2017, the Court banned the use of petroleum coke — a high-sulphur industrial fuel — in all non-cement industries in the NCR Delhi area, citing its outsized contribution to sulphur dioxide levels.

Smog Towers: In November 2019, the Court directed the Union Government and Delhi Government to install smog towers across the city. The scientific community has been broadly sceptical of this measure. Large-scale smog towers can improve air quality in a very localised area but cannot meaningfully address city-wide ambient pollution. This intervention is a clear example of reactive policy adopted without adequate evidence review.

7.2 National Green Tribunal (NGT)

The National Green Tribunal (NGT) was established by Parliament in 2010 specifically to handle environmental disputes. India was only the third country in the world to create a dedicated environmental court, after Australia and New Zealand. The NGT has broad jurisdiction and can take up issues on its own initiative based on news reports or public representations.

In the context of Delhi's air quality, two notable NGT actions are worth mentioning. In *Vardhaman Kaushik v. Union of India*, the NGT ordered the de-registration of diesel vehicles older than ten years and petrol vehicles older than fifteen years in the NCR. In *Smt. Ganga Lalwani v. Union of India and Ors.*, the Tribunal took up crop burning directly, ordering states to develop alternatives such as composting and deploying Indian Space Research Organisation (ISRO) satellite services to monitor burning incidents.

7.3 The Union Government

Because Delhi is the national capital, it receives a disproportionate share of media and political attention relative to other cities in the Indo-Gangetic Plain that suffer equally bad or worse air quality. Union Government action on Delhi's pollution has generally lagged behind judicial pressure, but there have been some more proactive moves, particularly around vehicle emission standards (the shift to BS-VI norms) and fuel quality regulations.

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

8. Discussion

The evidence reviewed in this paper supports a consistent diagnosis: Delhi's air quality crisis has persisted not because the causes are unknown or the solutions unavailable, but because government responses have almost always been reactive and short-term, addressing symptoms rather than root causes. Comprehensive clean air action plans have been in place since as far back as 1997. What has been lacking is consistent, long-term implementation.

The COVID-19 lockdowns offered an unplanned demonstration of what is possible: when emissions from all major sources dropped simultaneously, air quality improved quickly and noticeably. That finding is actually encouraging, because it confirms that the problem is solvable if the right actions are taken at scale.

The sources requiring the most attention are well established: vehicle exhaust, road and construction dust, cooking and heating emissions, open waste burning, and industrial pollution. Long-term fixes — expanding public transport, promoting clean cooking fuels, enforcing industrial emission standards, better waste management, and increasing green cover — have appeared on Delhi's clean air plans for decades. The binding constraint is political will, not knowledge.

On the monitoring side, Delhi's existing network of Continuous Ambient Air Quality Monitoring Stations (CAAQMS) is too sparse to accurately capture how pollution varies across the city. To properly cover Delhi's airshed of roughly 100 km × 100 km, at least 100 monitoring stations would be needed. A practical approach would combine reference-grade monitors with well-calibrated low-cost sensors, supplemented by satellite data and modelling in areas where physical monitors are not present.

Health data should also be more systematically linked to air quality monitoring. Hospital admission records for conditions like Chronic Obstructive Pulmonary Disease (COPD), asthma, cardiovascular disease, and lung cancer could help quantify the real human cost of pollution episodes — and make a stronger case for prioritising interventions.

Finally, emission inventories and source apportionment studies need to be updated regularly — ideally every two to three years. The most recent comprehensive study used data from 2016–17. That is now nearly a decade out of date. Without current data, it is difficult to know whether interventions are working or where new problems are emerging. Regular updates to these inventories should be treated as a basic requirement of any serious clean air programme, not an optional extra.

ISSN: 2455-8834

Volume:11, Issue:06 "June 2026"

9. Conclusions

This paper has argued that Delhi's air quality problem is a governance failure as much as an environmental one. The science is reasonably clear, the evidence base is substantial, and a range of effective interventions are known. What has been missing is the political commitment to implement them consistently and at the necessary scale.

Three priorities stand out from the analysis presented here. First, crop residue burning must be addressed through agricultural diversification in Punjab and Haryana, not merely through machinery subsidies that incentivise a different method of residue management. Second, emission inventories and source apportionment data must be updated on a regular cycle; operating policy on decade-old data is not a credible basis for a serious clean air programme. Third, the ambient monitoring network must be expanded substantially — to at least 100 stations — to support accurate, spatially resolved assessment of pollution levels across the city and its airshed.

These conclusions do not exhaust the agenda. Expanding public transport, scaling up clean cooking fuel access, tightening industrial enforcement, and improving solid waste management are all necessary components of a long-term solution. What distinguishes these from the emergency bans and reactive orders that have characterised previous responses is that they address root causes rather than symptoms. Delhi's clean air plans have identified these priorities for decades. The question is whether the political conditions now exist to act on them.

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