Vehicular Air Pollution and Its Control Measures

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Abstract

Vehicular air pollution is a major environmental concern in urban areas. The growing number of cars, buses, trucks, motorcycles, and other vehicles has increased emissions of harmful substances into the atmosphere. Major vehicle-related emissions include carbon monoxide (CO), nitrogen oxides (NO), particulate matter (PM), hydrocarbons (HC), sulfur oxides (SO), and carbon dioxide (CO_2). These emissions can affect human health, air quality, and the environment. This paper discusses the main sources and types of vehicular air pollution, its effects, and methods for controlling vehicle emissions.

Keywords: vehicular emissions; air pollution; transport; human health; emission control

1. Introduction

Air pollution occurs when harmful substances—including gases, particles, and chemical compounds—are released into the atmosphere at levels that can adversely affect human health or the environment. Road traffic contributes to urban air pollution through a mix-ture of exhaust and non-exhaust emissions, while emitted gases can also contribute to pol-lutants formed in the atmosphere.[1] The composition and concentration of traffic-related pollution vary with vehicle fleet, road activity, location, and time; measurements at two Toronto roadside sites, for example, found traffic-related $PM_{2.5}$ contributions varied by site and time of day.[2]

This paper provides a narrative overview of vehicle-related pollutant sources, associated health and environmental effects, and emission-control approaches. It distinguishes tailpipe controls from measures addressing non-exhaust particles and travel activity, because improvements in one part of the emissions mix do not necessarily reduce all traffic-related pollution.[3], [4]

2. Review Approach

This narrative synthesis draws on academic papers identified in PubMed, OpenAlex, and Semantic Scholar on 24 October 2026. Searches covered three topics: vehicle-emission sources, health effects of traffic-related air pollution, and vehicle-emission control mea-sures. The paper is not a systematic review: it did not use a preregistered protocol, formal eligibility criteria, or a formal risk-of-bias assessment. The available source material for this draft consisted of abstracts and indexed excerpts rather than full-text articles; conse-quently, the discussion is limited to the methods and findings reported in those records.

3. Sources and Types of Vehicular Air Pollution

3.1 Exhaust emissions

Exhaust pollution is produced by internal-combustion processes and exhaust after-treatment. Commonly discussed pollutants include CO, nitrogen oxides (NO), hydrocarbons and other volatile organic compounds, and particulate matter; vehicle emissions also include CO_2, which is relevant to climate change as a greenhouse gas rather than being interchangeable with local toxic air pollutants.[5], [6] The pollutant mix depends on the engine, fuel, vehicle class, operating conditions, and effectiveness of the after-treatment system. A review of vehicle-control technologies describes three-way catalysts as a major means of reducing CO, hydrocarbons, and NO from gasoline vehicles, while diesel vehicles use different after-treatment approaches to control NO and soot.[7]

3.2 Evaporative and non-exhaust emissions

Fuel evaporation is a separate source of vehicle-related volatile organic compounds. A fleet-based assessment of gasoline vehicles found that evaporative losses contributed ma-terially to total hydrocarbon emissions and noted that control efforts had focused more on tailpipe emissions than on evaporation.[8]

Not all traffic-related particles come from the tailpipe. Non-exhaust sources include brake, tyre, and road wear, as well as road dust resuspended by moving vehicles.[1] These sources can materially contribute to urban particulate pollution, but their relative share depends on particle size, site, fleet, road surface, and measurement method. In Delhi, one high-resolution inventory estimated annual vehicular PM_{10} emissions at 31.5 Gg and attributed 86% to non-exhaust sources, chiefly resuspended dust; this estimate is specific to that study's methods and city.[9] At two Toronto near-road sites, source apportionment found that exhaust, brake wear, and road-dust resuspension all contributed to $PM_{2.5}$, with traffic sources varying substantially between sites and rush-hour periods.[2]

The differing estimates are not contradictory: one is a citywide PM_{10} emissions inven-tory, while the other apportions ambient $PM_{2.5}$ measured at two roadside locations. To-gether, they show why control strategies need to account for both tailpipe and non-exhaust sources, and why local source measurements matter.[2], [9]

4. Effects of Vehicular Air Pollution

4.1 Effects on human health

Traffic-related air pollution is a complex mixture, so epidemiological studies often estimate associations with the mixture or use pollutants such as NO_2, black carbon, or particulate matter as indicators of exposure. A Health Effects Institute systematic review included 353 studies and judged the evidence for associations between long-term traffic-related expo-sure and all-cause, circulatory, ischemic heart disease, and lung-cancer mortality, asthma onset in children and adults, and acute lower respiratory infections in children to be high or moderate-to-high; confidence was lower for several other outcomes.[10]

Short-term outcomes have also been investigated. In a study of 249 adolescents in New York City and a nearby suburban community, increases in black carbon were associated with more wheeze, shortness of breath, and chest tightness; associations with black car-bon and NO_2 were larger for some symptoms among urban adolescents and adolescents with asthma.[11] Because exposure to traffic involves correlated pollutants and source mixtures, these results do not by themselves establish that a single measured pollutant caused each outcome.[10], [11]

4.2 Effects on air quality and the environment

Traffic emissions can increase pollutant concentrations near roads and contribute to the formation of secondary pollutants. Vehicle-related nitrogen oxides and volatile organic compounds participate in atmospheric chemistry that forms secondary particulate mat-ter and ground-level ozone.[1] Roadside concentrations and source contributions are not uniform: a Toronto study found that traffic-related $PM_{2.5}$ contributions differed between a downtown site and a highway site and were elevated during morning rush hours.[2]

Exhaust controls can reduce some pollutants without eliminating the traffic contribution to particulate matter. In Paris-region scenario modeling, introducing very-low-emission vehicles was projected to reduce street-level NO_2 concentrations more than PM concentra-tions; the study attributed the more limited PM reduction to the continuing contribution of tyre, brake, and road-wear emissions.[4] CO_2 should be considered separately in this context because it is principally a greenhouse gas, while pollutants such as NO_2 and fine particles are central to local air-quality and health assessments.[5], [6]

5. Measures to Control Vehicular Emissions

5.1 Vehicle and engine technologies

Engine improvements and exhaust after-treatment have reduced several regulated exhaust pollutants. Three-way catalytic converters reduce CO, hydrocarbons, and NO from gasoline vehicles; diesel particulate filters and other after-treatment systems target soot and NO.[7] However, technological performance measured in controlled tests does not always translate into equivalent performance during real-world driving. A review of UK vehicle-emissions evidence reported that real-world emissions have at times exceeded laboratory measurements and that the effectiveness of diesel after-treatment has varied across vehicles.[5]

Fleet renewal and stronger standards can therefore be useful, but they require enforcement and verification under actual driving conditions. In Beijing, a combination of new-vehicle standards and other controls coincided with declining fleet-average emission factors and lower total emissions of CO, hydrocarbons, NO, and PM_{10} between 1998 and 2009; the authors also described uneven outcomes among policy approaches, including failure of one taxi retrofit program.[12]

5.2 Fuels and vehicle maintenance

Fuel quality and maintenance complement vehicle technology. Low-sulfur fuels can reduce sulfur-related emissions and enable effective operation of some after-treatment systems; inspection and maintenance programs can identify high-emitting in-use vehicles.[5], [12] Scenario modeling for Greater Cairo projected that inspection and maintenance would reduce PM_{10} and toxic pollutants by 35–54.8% relative to its 2030 “do nothing” scenario, while fuel-enhancement scenarios produced pollutant-specific reduc-tions.[13] These are modeled scenario results, not measurements of reductions already achieved, and their magnitude depends on the assumptions used in the model.[13]

5.3 Transport planning and travel-demand measures

Measures that reduce vehicle-kilometres traveled or shift trips to public transport can com-plement technical controls. In the Greater Cairo model, a public-transport improvement scenario was projected to reduce car emissions by an average of 32.8% across the modeled emission types, while a road-expansion scenario was projected to increase emissions by an average of 37% compared with the “do nothing” scenario, consistent with the model’s assumption

that added road capacity induces additional traffic.[13] These projections il-lustrate that infrastructure choices can affect traffic activity as well as emissions per vehi-cle.

Public transport, active travel networks, traffic management, and land-use planning should be considered together with vehicle standards. A review of urban transport inter-ventions emphasizes that packages of mutually reinforcing policies are more promising than relying on a single technology or intervention.[14] The design should also consider where exposure occurs, since reducing emissions across a fleet and reducing exposure at a particular roadside location are related but distinct objectives.[15]

5.4 Policies and regulatory approaches

Emission standards, vehicle inspection, fuel-quality rules, and targeted controls on older or high-emitting vehicles form complementary policy tools. Beijing's experience illus-trates the potential for combined standards, fuel improvements, public transport, and traffic measures, as well as the risk of relying on retrofit programs without reliable im-plementation.[12] A policy should be evaluated against pollutant-specific outcomes: con-trols that substantially reduce exhaust NO_2 or soot may produce smaller changes in PM where non-exhaust sources remain important.[2], [4]

6. Discussion

The evidence supports a multi-source approach to vehicular air pollution control. Engine and after-treatment technologies can reduce exhaust pollutants, but non-exhaust parti-cles and evaporative emissions require separate attention.[1], [5] The importance of non-exhaust PM is evident in both Delhi's citywide PM_{10} inventory and Toronto's roadside $PM_{2.5}$ source apportionment, although their estimates cannot be directly compared be-cause they describe different particle sizes, outcomes, and spatial scales.[2], [9]

Control effectiveness is pollutant- and setting-specific. Cairo's modeled scenarios favored public-transport improvements for reducing modeled car emissions and inspection and maintenance for modeled PM_{10} and toxic pollutants, whereas Beijing's historical review found benefits from standards and fuel controls but also described a retrofit failure.[12],
[13] These findings argue for locally tailored packages and evaluation using measured emissions and ambient concentrations, rather than assuming that a policy's modeled or regulatory performance guarantees the same real-world air-quality improvement.[5], [12]

The evidence base also has limitations. Health studies frequently assess correlated pollu-tant mixtures, and source-apportionment estimates vary with site and method; long-term health evidence is stronger for some outcomes than others.[2], [10] The sources reviewed here therefore support the general importance of traffic-related exposure and integrated controls, but do not establish one universal ranking of pollutants or interventions for every city.

7. Conclusion

Vehicular air pollution includes exhaust, evaporative, and non-exhaust emissions, and their relative contributions vary by vehicle fleet, pollutant, and location. The reviewed evidence links long-term traffic-related exposure with several important health outcomes, while also showing that exhaust controls alone may not address particulate pollution from brake, tyre, road wear, and resuspended dust. Effective control therefore requires a com-bination of cleaner vehicles and fuels, maintenance and enforcement, and transport plan-ning that limits unnecessary vehicle use and exposure. The most appropriate mix should be selected and assessed locally, with attention to both measured air quality and health outcomes.

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