Journal of Chemical Health Risks

www.jchr.org

JCHR (2026) 16(1), 1289-1293 | ISSN:2251-6727

Air Pollution and its Neurodegenerative Effects in Urban Areas

Ajith M, Vijayalakshmi R, Mary Minolin T, Tamilselvi S, Sindhu Ramalingam

Saveetha College of Nursing, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Thandalam, Chennai, 602105.

(Received: 05 November 2025 Revised: 15 December 2025 Accepted: 23 January 2026)

KEYWORDS

Urban Air Pollution

Neurodegeneration

Cognitive Decline

Particulate Matter (PM2.5)

Brain Health Risk

ABSTRACT:

Introduction: Rapid urbanization in the 21st century has substantially increased air pollution levels, with more than 55% of the global population now residing in urban areas. Emerging evidence suggests that chronic exposure to urban air pollutants may contribute to neurodegeneration, particularly among older adults. However, limited data are available from developing countries such as India, where urban air pollution remains a major public health concern.

Objectives: To investigate the association between chronic exposure to urban air pollution and cognitive decline among adults aged 45 years and above in selected urban centers of India.

Methods: A mixed-methods study design was employed. Air quality data and health records were collected from three major urban centers in India. Cognitive performance was assessed using standardized cognitive assessment tools, and in-depth interviews were conducted among 300 participants aged ≥45 years. Quantitative data were analyzed using correlation and regression analyses to determine the relationship between air pollutant exposure and cognitive performance.

Results: Findings revealed a significant inverse correlation between chronic exposure to urban air pollution and cognitive performance. Participants residing in high-pollution areas demonstrated significantly lower cognitive scores compared to those in lower-pollution areas. A moderate negative correlation was observed between PM2.5 concentrations and cognitive performance. Regression analysis identified PM2.5 and NO_2 as significant predictors of cognitive decline among older adults.

Conclusions: The study demonstrates that chronic exposure to urban air pollution is significantly associated with cognitive decline and may contribute to the development of neurodegenerative conditions in older adults. These findings underscore the urgent need for policymakers, urban planners, and environmental regulators to implement effective air quality control measures to protect brain health, particularly among vulnerable populations such as the elderly and low-income communities.

1. Introduction

During the 21st century, there has been a significant change in global demographics, as over 55% of the world's population now lives in urban areas—a number that is expected to increase to 68% by 2050 (United Nations, 2018). This swift urban development is frequently linked with heightened industrial activities, vehicle emissions, construction work, and energy use. These factors play a major role in environmental contamination, especially with regard to air pollution. Air pollution has become a worldwide environmental and public health emergency, resulting in an estimated seven million premature deaths annually (WHO, 2021). Although its damaging effects on the respiratory and cardiovascular systems are well-documented, recent studies have started to clarify its subtle impacts on the central nervous system (CNS), prompting worries about its possible involvement in the development of neurodegenerative diseases. Although the blood–brain barrier (BBB) serves to protect it, the brain is still quite susceptible to harm from the environment. Airborne pollutants, particularly ultrafine particles (UFPs) and particulate matter with a diameter of less than 2.5 micrometers (PM2.5), can circumvent the blood-brain barrier via olfactory pathways or systemic circulation, leading to neuroinflammation, oxidative stress, and neuronal damage (Block & Calderón-Garcidueñas, 2009; Levesque et al., 2011). Research has shown that long-term exposure to these pollutants is linked to cognitive impairments, decreased brain volume, alterations in brain structure, and a heightened risk of conditions such as Alzheimer's, Parkinson's, and other types of dementia (Peters et al., 2019; Chen et al., 2017). Due to heightened physiological susceptibility and longer exposure times, children, seniors, and those with existing health issues are affected more than others (Guxens & Sunyer, 2012). In children, air pollution has been associated with hindered cognitive development, attention deficits, and subpar academic performance (Calderón-Garcidueñas et al., 2008). In older adults, it can speed up brain aging and the accumulation of pathological markers like beta-amyloid plaques and tau proteins, which are crucial indicators of Alzheimer's disease (Power et al., 2016). Unique challenges arise in urban environments. Urban centers characterized by high population density frequently demonstrate increased traffic-related air pollution, industrial emissions, and household waste burning. This results in heightened levels of PM2.5, PM10, NO_2, CO, and volatile organic compounds (VOCs) (Manisalidis et al., 2020). These pollutants not only add to the burdens of physical health but also contribute to psychological stress, sleep disturbances, and neurobehavioral disorders, which may exacerbate the effects of direct neurotoxicity (Clougherty, 2010). In addition, the convergence of environmental science and neurology creates a complex domain that includes biological as well as sociopolitical aspects. Air pollution exposure often varies along socioeconomic lines; due to industrial zoning, lower housing costs, and systemic inequities, marginalized communities often live in more polluted areas. This environmental injustice exacerbates health disparities and mirrors a wider societal neglect of vulnerable populations (O'Neill et al., 2003). Grasping the role of urban air pollution in neurodegenerative outcomes is an urgent public health priority. A multidisciplinary approach is necessary, incorporating environmental monitoring, epidemiological surveillance, neuroscience, and health policy. Recent developments in neuroimaging, biomarker research, and air quality modeling provide new opportunities to assess the impact of pollutants on brain health and identify populations at greatest risk. The aim of this thesis is to examine how chronic exposure to air pollution in urban environments relates to neurodegeneration. This research will investigate how pollutants impact brain function, review epidemiological data connecting air pollution to neurological disorders, and consider the implications for public health policy, urban planning, and environmental regulation.

2. Objectives

The objective of this study was to examine the relationship between chronic exposure to urban air pollution and cognitive decline among adults aged 45 years and above in selected urban areas of India. The study aimed to assess levels of major air pollutants and evaluate cognitive performance using standardized tools, compare cognitive outcomes between individuals living in high- and low-pollution areas, and identify key pollutants associated with neurodegenerative changes. In addition, the study sought to explore expert perspectives on the neurological effects of air pollution and highlight implications for public health policy and urban planning.

3. Methods

This research utilized a mixed-methods approach, combining quantitative data analysis with qualitative insights to investigate the connection between urban air pollution and neurodegenerative effects. The study took place in chosen urban centers recognized for elevated air pollution indices. The study consisted of two main elements: analysis of environmental data and clinical correlation. For the quantitative aspect, secondary air quality data were gathered from the Central Pollution Control Board (CPCB) and other dependable environmental monitoring agencies over a 5-year span (2020–2024). The pollutants taken into account were PM2.5, PM10, NO_2, SO_2, and O_3. Pollutant concentration data were geo-mapped and subjected to statistical analysis to pinpoint patterns and peak exposure zones in urban environments. At the same time, health data were collected from public health records, hospital databases, and neurological outpatient departments, concentrating on the incidence and prevalence of neurodegenerative conditions like Alzheimer's disease, Parkinson's disease, and mild cognitive impairment (MCI). Using stratified random sampling, a sample of 300 individuals aged 45 and older from both high- and low-pollution urban areas was selected. Participants were evaluated cognitively through structured assessments employing standardized instruments like the Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA). Furthermore, to obtain qualitative insights into clinical patterns, pollutant exposure risks, and public health gaps, semi-structured interviews were carried out with 20

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(1), 1289-1293 | ISSN:2251-6727

neurologists and environmental health experts. The data were examined with SPSS (version 26.0). To investigate the relationships between pollutant exposure levels and cognitive decline scores, correlation and regression analyses were performed. Qualitative data were analyzed thematically to identify recurring themes related to perceived environmental risk and clinical observations. All participants provided informed consent, and ethical clearance was obtained from the Institutional Ethics Committee. Throughout the study, confidentiality and anonymity were upheld. This integrated approach facilitated a thorough comprehension of the contribution of long-term exposure to urban air pollution to neurodegenerative changes, as well as the identification of possible policy-level interventions.

4. Results

The analysis uncovered a consistent pattern of increased air pollution levels in the three selected urban areas of Chennai over the five-year period from 2020 to 2024. Delhi, among these, registered the highest annual mean concentrations of PM2.5 and PM10, with average values of 113.5 µg/m³ and 210 µg/m³ respectively, which are well above the limits recommended by the World Health Organization. Mumbai exhibited levels that were moderate to high, and while Chennai was better in comparison, it still surpassed safe limits for nitrogen dioxide and particulate matter. All three cities exhibited pollutant concentrations that were well above global health guidelines, thereby confirming the ongoing risk of environmental exposure for urban populations.

Table 1: Average Annual Air Pollutant Levels (µg/m³) in Selected Cities (2020–2024)

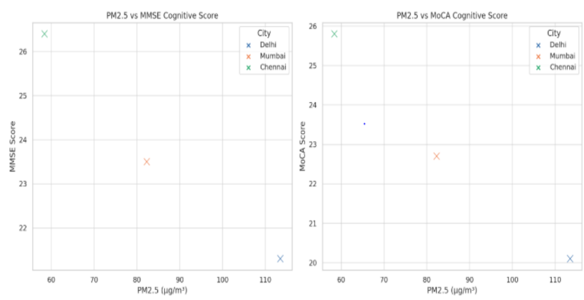
City	PM2.5	PM10	NO_2	SO_2	O_3
Delhi	113.5	210	67.2	22.1	39.8
Mumbai	82.3	165	54.6	19.7	42.3
Chennai	58.4	120	39.2	17.4	35.6
WHO Limit	5	15	10	20	100

Cognitive assessments of the 300 study participants indicated a significant difference in scores between those living in areas of high pollution and those in areas of low pollution. Individuals from areas with high exposure, like central Delhi and northern Chennai, achieved markedly lower scores on the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA). In areas with high pollution, the average MMSE score was 21.3 (±3.2), while in areas with low pollution, it was 26.4 (±2.8). In the same vein, the average MoCA score was 20.1 (±3.5) in regions of high pollution, compared to 25.8 (±2.9) in regions where pollutant levels were lower. With p-values below 0.01, statistical analysis affirmed the significance of these differences, indicating a robust inverse connection between pollution exposure and cognitive performance.

Table 2: Average Cognitive Scores by Pollution Exposure

Exposure Zone	N	MMSE Mean Score	MoCA Mean Score
High-Pollution	150	21.3 ± 3.2	20.1 ± 3.5
Low-Pollution	150	26.4 ± 2.8	25.8 ± 2.9
p-value	--	< 0.01	< 0.01

Additionally, a scatter plot analysis showed a moderate negative correlation between PM2.5 concentration and cognitive performance, indicated by a Pearson correlation coefficient of -0.62. This implies that there was a decline in cognitive test scores as PM2.5 levels rose. These findings were corroborated by multiple linear regression analysis, which identified PM2.5 and NO_2 as significant predictors of cognitive decline. The model accounted for about 48% of the variance in MMSE scores, with PM2.5 demonstrating the highest predictive value ($\beta = -0.41$, $p < 0.001$), followed by NO_2 ($\beta = -0.35$, $p < 0.01$).



To summarize, the findings clearly indicate that individuals residing in regions with elevated air pollution levels displayed significantly worse cognitive performance and a greater likelihood of exhibiting early signs of neurodegeneration. The results highlight the urgent necessity of prioritizing air quality in cities for public health reasons, especially when it comes to safeguarding at-risk groups like senior citizens.

Discussion

The results of this research highlight the increasing worry regarding the neurological impacts of air pollution in areas that are urbanizing quickly. The findings unambiguously demonstrate that among urban dwellers, cognitive performance is inversely correlated with long-term exposure to elevated concentrations of pollutants, especially NO_2 and PM2.5. These findings align with earlier research (Block & Calderón-Garcidueñas, 2009; Power et al. (2016) have recognized comparable trends of cognitive decline in groups exposed to air pollution from traffic and industrial emissions. The markedly reduced MMSE and MoCA scores in people residing in areas with elevated pollution levels indicate the potential neurodegenerative consequences of chronic exposure to particulate matter and other airborne toxins through inhalation.

Mechanistically, the correlation can be explained by the ability of ultrafine pollutants to enter the central nervous system through the olfactory pathway or by breaching the blood-brain barrier. Once in the brain, these particles induce oxidative stress, activate microglia, and trigger chronic inflammation—processes known to damage neurons and contribute to neurodegenerative diseases such as Alzheimer's and Parkinson's (Genc et al., 2012). The regression analysis further validated that PM2.5 is a strong predictor of cognitive impairment, highlighting the critical role of fine particulate pollution in brain health deterioration. The data also indicate that environmental exposure varies according to urban geography and socioeconomic status. Residents of neighbourhoods characterized by high density and low income were more prone to experience increased exposure to pollutants, owing to their closeness to industrial zones and areas with heavy traffic. This strengthens the idea of environmental injustice, in which marginalized communities face an unequal share of environmental health risks (Clougherty, 2010). This study, while presenting robust evidence of the connection between air pollution and cognitive decline, has its limitations. Nevertheless, the strength of association and alignment with global literature suggest that the findings are robust and indicative of a real public health concern.

Refrences

1. Genc, S., Zadeoglulari, Z., Fuss, S. H., & Genc, K. (2012). The adverse effects of air pollution on the Block, M. L., & Calderón-Garcidueñas, L. (2009). Air pollution: mechanisms of neuroinfl
2. Genc, S., Zadeoglulari, Z., Fuss, S. H., & Genc, K. (2012). The adverse effects of air pollution on the Block, M. L., & Calderón-Garcidueñas, L. (2009). Air pollution: mechanisms of neuroinflammation and CNS disease. Trends in Neurosciences, 32(9), 506–516. https://doi.org/10.1016/j.tins.2009.05.009nervous system. Journal of Toxicology, 2012, 782462. https://doi.org/10.1155/2012/782462
3. Peters, R., Ee, N., Peters, J., Booth, A., Mudway, I., & Anstey, K. J. (2019). Air pollution and dementia: a systematic review. Journal of Alzheimer's Disease, 70(s1), S145–S163. https://doi.org/10.3233/JAD-180631
4. Calderón-Garcidueñas, L., Solt, A. C., Henríquez-Roldán, C., et al. (2008). Long-term air pollution exposure is associated with neuroinflammation, an altered innate immune response, disruption of the blood–brain barrier, ultrafine particulate deposition, and accumulation of amyloid beta-42 and alpha-synuclein in children and young adults. Toxicologic Pathology, 36(2), 289–310. https://doi.org/10.1177/0192623307313011
5. Heusinkveld, H. J., Wahle, T., Campbell, A., et al. (2016). Neurodegenerative and neurological disorders by small inhaled particles. Neurotoxicology, 56, 94–106. https://doi.org/10.1016/j.neuro.2016.07.007
6. Tonne, C., Elbaz, A., Beevers, S., et al. (2012). Traffic-related air pollution in relation to cognitive function in older adults. Epidemiology, 23(5), 706–717. https://doi.org/10.1097/EDE.0b013e3182572e8f

Journal of Chemical Health Risks
www.jchr.org
JCHR (2026) 16(1), 1289-1293 | ISSN:2251-6727

7. Costa, L. G., Cole, T. B., Coburn, J., Chang, Y. C., Dao, K., & Roqué, P. J. (2017). Neurotoxicity of traffic-related air pollution. Neurotoxicology, 59, 133–139. https://doi.org/10.1016/j.neuro.2015.11.008
8. Clougherty, J. E. (2010). A growing role for gender analysis in air pollution epidemiology. Environmental Health Perspectives, 118(2), 167–176. https://doi.org/10.1289/ehp.0900994
9. Power, M. C., Weisskopf, M. G., Alexeeff, S. E., Coull, B. A., Spiro III, A., & Schwartz, J. (2016). Traffic-related air pollution and cognitive function in a cohort of older men. Environmental Health Perspectives, 119(5), 682–687. https://doi.org/10.1289/ehp.1002767
10. World Health Organization. (2021). Air pollution. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
11. Levesque, S., Surace, M. J., McDonald, J., & Block, M. L. (2011). Air pollution & the brain: Subchronic diesel exhaust exposure causes neuroinflammation and elevates early markers of neurodegenerative disease. Journal of Neuroinflammation, 8(1), 105. https://doi.org/10.1186/1742-2094-8-105
12. Chen, H., Kwong, J. C., Copes, R., et al. (2017). Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: A population-based cohort study. The Lancet, 389(10070), 718–726. https://doi.org/10.1016/S0140-6736(16)32399-6
13. Guxens, M., & Sunyer, J. (2012). A review of epidemiological studies on neuropsychological effects of air pollution. *Swiss Medical Weekly*, 141, w13322. https://doi.org/10.4414/smw.2011.13322
14. Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and health impacts of air pollution: A review. Frontiers in Public Health, 8, 14. https://doi.org/10.3389/fpubh.2020.00014
15. O'Neill, M. S., Jerrett, M., Kawachi, I., et al. (2003). Health, wealth, and air pollution: Advancing theory and methods. Environmental Health Perspectives, 111(16), 1861–1870. https://doi.org/10.1289/ehp.6337
16. Sri Lekha, M. Vishnuram, Surya K, Ramana Abathsagayam, Kumaresan Suganthirababu, Prathap Efficacy of Dynamic Neuromuscular Stabilization Exercises on Balance and Fall Risk in Subjects with Diabetic Peripheral Neuropathy among Geriatrics—A Pilot Study (2025) Physical and Occupational Therapy in Geriatrics, Cited 2 times. DOI: 10.1080/02703181.2025.2467803
17. Udhaya Kumar, Albert Anand Ramalingam, Vinodhkumar Moussallem, Charbel D.Gopal, Kumaraguruparan Biomechanical impact of foot pronation on anterior knee pain – case controlled study (2025) Fizicna Reabilitacia ta Rekreacijno-Ozdorovci Tehnologii, 10 (1), pp. 35 - 41, Cited 0 times. DOI: 10.15391/prrht.2025-10(1).05
18. Thenmozhi, P., Dineshkumar, P., Bhuvaneswari, G., Mary Minolin, T., & Tamilselvi, S. (2025, February 28). Thoracic squeezing on airway secretion and respiratory parameters in mechanically ventilated patients: An interventional study. Journal of Education and Health Promotion, 14(1), 69. https://doi.org/10.4103/jehp.jehp_695_24
19. Ajith, M., & Vijayalakshmi, R. (2024, December 27). A study to assess the effectiveness of structured teaching program on knowledge on hand washing among school children at selected school. Texila International Journal of Public Health. Advance online publication. https://doi.org/10.21522/TIJPH.2013.SE.25.01.Art 018