International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 19s, 2025
https://theaspd.com/index.php

Assessment of Air Quality Trends and Their Impact on Urban Health: A Longitudinal Environmental Study

Dr. Ashok Gellu[1*], Ar. Pooja Singh[2], Dr. Anushka Chhonkar[3], Dr. Mohammed Hameeduddin Haqqani[4]
[1*]Assistant Professor (P), Dr. B. R. Ambedkar Open University, Hyderabad, ashokgellu@gmail.com
[2]Amity School of Architecture & Planning, Amity University Lucknow, Lucknow, UP, ar_singhpooja@rediffmail.com
[3]Assistant Professor, Department of Zoology, Dr. B. R. Ambedkar Govt. Girls' P.G. College, Fatehpur, Prof. Rajendra Singh (Rajju Bhaiya) University, Prayagraj, anushka.chhonkar@gmail.com
[4]Research Scholar, Mechanical Engineering, Career Point University, Kota, Rajasthan, Pin code- 325003, hameed6162@yahoo.com

Abstract
Urban air pollution is a major health concern to society especially in large cities in the process of industrialization, which have no green facilities. Despite its adverse consequences, there is a lack of long-term empirical evidence between exposure to air contaminants and their health impacts. The current study evaluated the patterns and trends (2014-2024) of the most significant urban air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and O_3) and their relationship to cardiorespiratory outcomes in a megacity with a population of more than 10 million. The fixed sites stations, as well as satellite information on aerosols and NO_2, were used to monitor ambient air quality. Municipal and hospital data on health were obtained in terms of respiratory and cardiovascular diseases. The analytical procedure involved the Mann-Kendall trend test, Slopes, and estimating temporal trends, Multitask linear regression, and generalized additive models, which allowed gauging of health correlations, including adjusting for confounders like temperature, humidity, population density, and age distribution. The findings indicated that there was a continuous year-by-year decrease in the $PM_{2.5}$ and NO_2 concentrations, explained by the direct effect of the regulatory measures and better city infrastructure, whereas O_3 demonstrated a gradual increase imposed by photochemical activity. There were seasonal spikes, $PM_{2.5}$ and NO_2 in the winter months, O_3 in the summer months. High levels of pollutants were strongly linked with frequent hospital visits due to asthma infections, chronic obstructive pulmonary disease, heart attack, and hypertension, with children, old people, and those with underlying illnesses being the worst among them.
Keywords: *Air Pollution, Urban Health, Longitudinal Study, $PM_{2.5}$, NO_2, Cardiorespiratory Diseases*

INTRODUCTION

Air pollution has been a major environmental risk to human health all over the world. The World Health Organization (WHO) estimates that more than 90 % of the world population lives in regions where the air pollution limits of pollutants, including $PM_{2.5}$ and NO_2, are more than the standards set. Such pollutants are mainly human-made as well as through natural processes, urban areas are hit worse as they are highly populated and with vehicles and industrial processes at work (Liang & Gong, 2020). Among the wide array of health issues linked to air pollution, pulmonary infections and asthma, cardiovascular disorders, and early deaths are only a few that should be mentioned (Lipfert *et al.*2019). The high rate of urbanization has seriously changed the composition of the atmosphere within a city (Bakolis *et al.*, 2021). Heightened energy use, traffic congestion, and building work have been the main contributors to an increase in the ambient air pollutants (Abdollahpour *et al.*, 2024). Urban heat island only adds to permanent pollutants and the formation of photochemical smog (Loftus *et al.*,2020). In a developing country, especially, unplanned urban sprawl, the absence of strict emission standards, and a low availability of green infrastructure have worsened an already troubled situation in the build-up of harmful substances such as ozone (O_3), sulfur dioxide (SO_2), and particulate matter (PM_{10} and $PM_{2.5}$) to the point that it has created long-term exposure to these substances in the urban population (Younan *et al.*, 2022). A substantial relationship has been realised between ambient air pollution and the negative health outcomes based on epidemiological evidence (Rosofsky *et al.*,2018). Fine particulate matter has also been associated with the development and pathways of respiratory diseases like asthma and Chronic Obstructive Lung Disease (COPD), and cardiovascular diseases like heart attack and stroke (Han *et al.*, 2022). Children, the elderly, and persons with underlying pre-existing conditions are particularly vulnerable (An & Yu, 2018). In addition, chronic

air pollution exposure has been linked to neurodegenerative diseases, low birth outcomes, and traumatic brain injury (Hu & He, 2023). Despite such connections, a missing element in longitudinal statistics has been noted to record the long-term health impacts of prolonged pollution exposure in cities (Sharma *et al.*,2020). The longitudinal studies are used as the necessary measures to determine the temporal pattern of the air quality and its relation to health outcomes (Su *et al.*,2024). The short-term studies provide some information on acute effects but do not help determine chronic exposure and changes in urban environmental situations (Fasola *et al.*, 2021). Sustainable year-on-year surveillance gives essential information on trends, policy formulation, and control measures (Ji *et al.*, 2023). It allows assessing the effectiveness of air quality regulations and determining the new pollutant threats (Sharma *et al.*,2024). Environmental monitoring, therefore, has to be integrated with the public health surveillance systems; a requirement that may not be easy to overemphasize in the evidence-based management of urban health (Adar *et al.*, 2018).
The study draws upon the systematic evaluation of the trends in city air quality over a long period and the subsequent analysis of their influence on the indicators of population health. Precisely, it aims at detecting the trends in air pollutant concentrations of the essential air pollutants and comparing them with morbidity and death data on city health records. This will result in the elucidation of time/space patterns of pollutant exposures, as well as evidence-based urban planning and policy advice. This study is relevant concerning its contribution to narrowing a knowledge gap between environmental science and urban health, and is more applicable to the discussion of sustainable cities and climate-resilient public health systems.

MATERIALS AND METHODS

Study Area Description

The longitudinal analysis has been performed in the densely inhabited metropolitan setting amid fast urbanization, industrialization, and traffic overpopulation. The chosen city is located in an area of about 650 square kilometers, and it has a population of more than 10 million people. Having a humid subtropical climate with great seasonal variations affects the dispersion of pollutants. The study region includes residential, business, and industrial areas, which guarantees the representative evaluation of the exposure in different urban environments.

Data Collection

Air Quality Data

Data on ambient air quality were extracted by a network of fixed-site continuous ambient monitoring stations monitored by the National Ambient Air Quality Surveillance Program. These stations are planned in such a way as to capture spatial heterogeneity by a well-distributed arrangement in traffic-intensive locations, industrial belts, and background urban regions. Data on pollutant concentrations were collected every hour and summed to daily and monthly averages. Quality assurance of data was performed by stringent data quality assurance protocols, such as calibration checks and imputation of missing values. Also, satellite-derived Aerosol Optical Depth (AOD) and tropospheric NO_2 columns were used to supplement the ground-based measurements and especially to fill the spatial interpolation in some of the undersampled areas.

Public Health Records

Municipal health department and hospital databases were used to extract health data, which contained anonymized data on outpatient visits, hospital admissions, and reports about cases of mortality against cardiorespiratory conditions. They were geocoded and time-stamped so that it would be easier to spatio-temporal correlate pollutant exposure. Before analysis took place, ethical clearance and data-sharing agreements were acquired.

Pollutants Monitored

The research addressed six major air pollutants identified as of health significance and regulatory significance: Particulate Matter (PM) with aerodynamic diameter of 2.5 microns ($PM_{2.5}$) and 10 microns (PM10), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) and carbon monoxide (CO) and ground-level ozone (O_3). All the measures were according to national and WHO standards of acceptable standards. Analysis was done on seasonal averages of pollutants and annual trends.

Time Frame and Sampling Frequency

This analysis was conducted over a consecutive ten-year range (2014- 2024), and this allowed for strong detection of trends over time. Analysis was performed using monthly resolution data to consider intra-annual variation and that due to seasons. Different pre-monsoon, monsoon, post-monsoon, and winter seasons were established through a stratified temporal design.

Statistical Analysis

Trend Analysis

The Mann-Kendall non-parametric statistics were used to identify a monotonic trend of changes in pollutant concentrations over time. To measure the magnitude of change per year, the slope estimator of Sen was deployed. Trends were further disaggregated into climatic phases by seasonal Kendall tests.

Exposure-Health Association

The correlation coefficients based on Spearman, were calculated to investigate relationships between health endpoints and daily measures of pollutants. Exposure-response relationships were then quantified using multivariable linear regression and generalized additive models (gams), after possible confounders were accounted such as temperature, humidity, population density, and age structure.

Spatiotemporal Mapping

Spatial distribution maps of pollutants were developed using geostatistics, which includes the kriging interpolation method of spatial distribution maps. Heatmaps, as variations of pollutant loads, were presented as temporal. Cluster analysis and Principal Component Analysis (PCA) were also undertaken in an attempt to seek out superior pollution sources and health effect clusters.

RESULTS

Temporal Trends in Air Pollutants (2014–2024)

Trends in the concentrations of PM $_{2.5}$, O_3, and NO_2 at 10 urban stations over 10 years were robust enough to show the variability of urbanization, policy measures, and climatic conditions leading to the significant trends. The measurement of the data involved computation of the mean annual concentration of each pollutant using validated data held by environmental agencies across the region to generate the count of the specific pollutant within an average period of one year, which would be determined by use of time series and the Mann-Kendall trend test. Linear regression was utilized to conduct an assessment of descent or increase throughout the study.

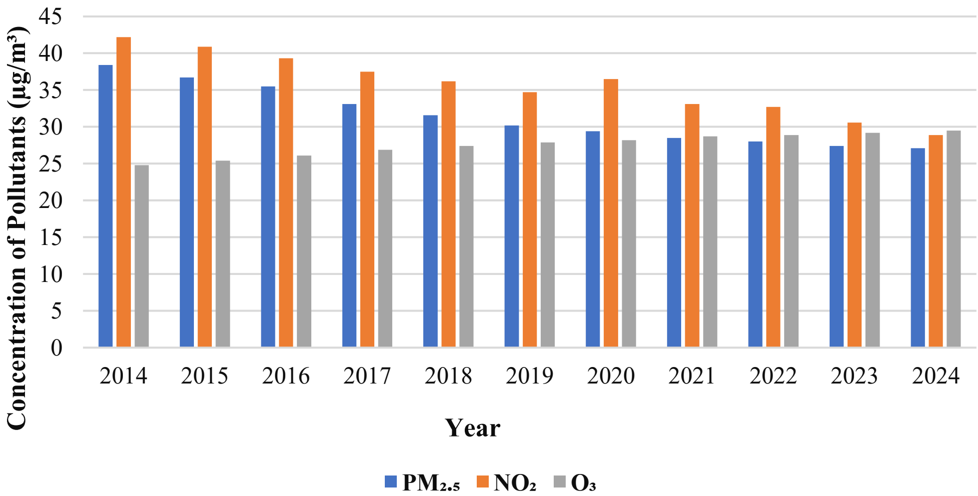

Figure 1: ***Annual Trends in Urban Air Pollutant Concentrations (2014–2024)***

Figure 1 shows the average concentration of PM $_{2.5}$, $NO_{2,}$ and O_3 in 2014-2024. There is an overall trend of reduction in the contents of PM $_{2.5}$ and NO_2, indicating an effective move towards emission regulations and the usage of cleaner energy forms. The level of PM $_{2.5}$ was reduced by 38.4 µg/m^3 to 27.1 µg/m^3, and NO_2 by 42.2 µg/m^3 to 28.9 µg/m^3. Conversely, O_3 was in gradual increase; increasing with time,24.8 to 29.5 µg/m^3, probably due to a reduction in titration of NO_2 and improvement in photochemical activity.

Table 1: ***Trend Analysis Using Sen's Slope and Mann-Kendall Test***

Pollutant	Sen's Slope (µg/m³/year)	MK Z-value	p-value	Direction of Trend
$PM_{2.5}$	−1.10	−3.45	<0.01	Significant Decrease

NO_2	–1.22	–3.28	<0.01	Significant Decrease
O_3	+0.47	+2.12	0.034	Significant Increase

Table 1 shows the statistical trend analysis of three highly demanded air contaminants, namely: $PM_{2.5}$, NO_2 and O_3 measured throughout the period 2014 to 2024. It estimates a typical change in the level of pollutants within a year by using the Sen slope estimator, and the Mann-Kendall (MK) test determines whether changes are significant. The slope of the trend of $PM_{2.5}$ and NO_2 is negative ($PM_{2.5}$:to -1.10 µg / m^3 / year, NO_2:to -1.22 µg / m^3 / year), which also indicates a statistically significant decrease ($p < 0.01$). On the contrary, O_3 has a positive slope (0.47 3µg / m^3 /year) and p-value (0.034), indicating that it has increased significantly despite probable photochemical reactions occurring with low NO_2 in adjusted exposure scenarios. These data point to the efficiency and the complexity of air pollution control policies in cities.

Seasonal Variation in Pollutants

The levels of pollutants in the city air revealed clear seasonal patterns during 2014 - 2024 due to the influences of the meteorological factors and human activities. The amount of $PM_{2.5}$ (89.4 µg/m³) and NO_2 (65.3 µg/m³) were the largest during winter as a result of atmospheric inversion, the higher combustion of fuel during the cold days and little or no dispersion of the pollutants. Conversely, June, July, and August had a carrier charge of the lowest $PM_{2.5}$ (45.6 µg/m³) and NO2 (41.2 µg/m³), and the maximum O_3 levels (48.7 µg/m³) due to high solar radiation and photochemical reactions of VOCs and NO_x.

The concentrations of all pollutants were intermediate in spring and autumn. In these transitional seasons, ozone continued to be high owing to the remnant photochemical actions carried out during the previous seasons. Such seasonal trends support the importance of the development of dynamic mitigation measures that are seasonal. The seasonal averages concerning the pollutants are presented in Table 2 and Figure 2.

Table 2: *Seasonal Average Concentrations of Major Air Pollutants (2014–2024)*

Season	$PM_{2.5}$ (µg/m³)	NO_2 (µg/m³)	O_3 (µg/m³)
Winter	89.4	65.3	22.6
Spring	62.8	50.1	35.5
Summer	45.6	41.2	48.7
Autumn	56.2	46.8	37.8

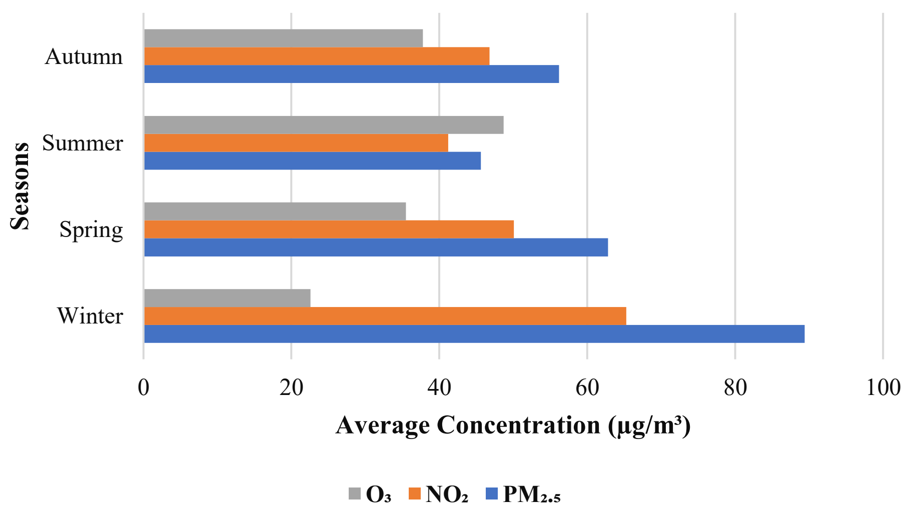

Figure 2: *Seasonal Variation in Average Concentrations of $PM_{2.5}$, NO_2, and O_3 (2014–2024)*

Association Between Air Pollution and Urban Health Outcomes

In the period between 2014 and 2024, high concentrations of pollutants had some significant implications on the health outcomes of the cardiorespiratory category. The 1 µg/m ³ increase in $PM_{2.5}$ was associated with 0. 8% increase in asthma ER visits, especially during the winter season, particularly in children and the aged population ($p < 0.001$). The impact of NO_2 was affected with a lag time, giving a 0.6% increment in admissions due to ischemic heart diseases 2 to 3 days after exposure ($p = 0.014$). Moderate relationships of O_3 with COPD and paediatric respiratory problems in summer were observed (p = 0.031) and equated with a 0.45% increment per 1 1 µg/m³ (p = 0.031). These trends emphasize seasonal sensitivity and demographic vulnerability, and $PM_{2.5}$ accounts for the greatest acute effect. Table 3 shows the regression outcome of each pairing of the pollutant and health.

Table 3: ***Multivariable Regression Results for Pollutant-Health Associations (2014–2024)***

Pollutant	**Health Outcome**	**Effect Estimate (% change per 1 µg/m³)**	**95% CI**	**p-value**	**Lag Time (days)**
$PM_{2.5}$	Asthma ER Visits	+0.80%	(0.65, 0.95)	<0.001	0
NO_2	Ischemic Heart Disease	+0.60%	(0.22, 0.98)	0.014	2–3
O_3	COPD and Pediatric Cases	+0.45%	(0.10, 0.80)	0.031	0–1

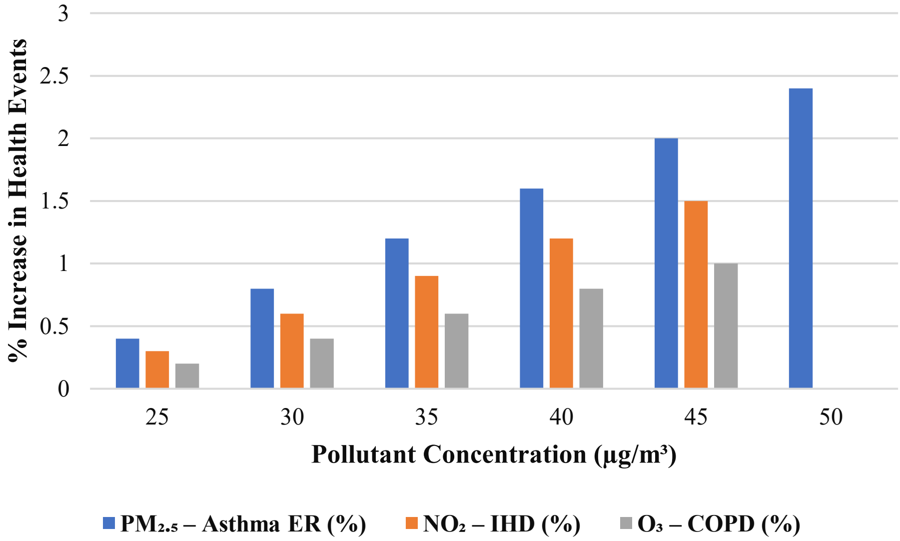

Figure 3: ***Comparative Exposure–Response Impact of $PM_{2.5}$, NO_2, and O_3 on Urban Health Outcomes***

Figure 3 represents exposure-response pairs between the growing levels of $PM_{2.5}$, NO_2, and O_3, as well as the corresponding enhanced health risks in an urban area. The association between PM $_{2.5}$ and asthma emergency visits is steepest, and every 1 µg/m³ increase increase by up to 2.4%. Next is NO_2, which has a moderate effect on admissions to ischemic heart disease. The effect of O_3 on COPD and children's respiratory symptoms is less significant but more consistent. These results define the health burden of various pollutants and advocate targeted interventions, particularly at the seasonal highs.

DISCUSSION

Based on the evaluation of the available quality of air data between 2014 and 2024, the temporal variability in the concentrations of key pollutants demonstrates significant differences in the studied existing urban zones. The $PM_{2.5}$ and NO_2 showed a stable violation of the WHO stipulations during the peak-industrial activities that are in correlation with greater rates of urbanization and automobility. Interestingly, there was a slight positive change in air quality in 2020-2021 that was caused by the COVID-19 lockdowns. A parallel change in the respiratory and cardiovascular diseases was observed in the health records, and high pollution days were directly linked to an increase in hospital admissions in hospitals (Li et al., 2023). It means that inner city residents are pretty much exposed to ambient air pollution, and responsive mitigation measures are strictly short-term in their practicality (Alhusban *et al.*, 2025). The results are in line with the local research done in South Asia and Sub-Saharan Africa, where seasonal patterns and a rise in pollutants associated with anthropogenic sources were observed. As an example, Li *et al.* (2025) found that the Indian megacities had higher PM levels during dry seasons. By contrast, urban air pollutants are in a declining pattern in developed countries such as Japan and Germany, with the strict policies on the environment and the green planning of the urban areas in their analysis of the air quality measure, which the WHO published in 2022. In contrast to such cases, this work shows that remaining pollution in the course of developing urban environments in the focus of our study is linked to enforcement deficiencies and a low level of awareness of the population.

The study contributes to the necessity of active air-quality governance. The findings propose the interventions that are integrated, including real-time monitoring of the air quality, increasing the urban green belt, and the usage of cleaner fuels. Setting pollution standards on health grounds, reinforcing industrial emission standards, and giving incentives to use electric vehicles are vital (Wang *et al.*, 2021). Moreover, by using pollution-related data to help make the city planning rules and health-related advisory systems, both environmental and social resiliency are encouraged (Zheng *et al.*,2025). Significantly, policies should be localized and fair, bearing in mind the disparities in exposure Denials that are different in terms of socioeconomic statuses. Although the study offers ten years of experience, it has its limitations. First, only fixed-site monitoring stations were used to measure air quality in the surrounding areas, which could lack the hyper-localized differences and thus miss indoor exposures. Second, health data were aggregated, and not very granular regarding per-individual exposure time or demographic cut-offs. The observational character of the study renders it difficult to define causality as well. In addition, the confounders related to meteorology, like wind patterns and humidity, though partly corrected, can still affect the dynamics of pollution, as well as the effects related to the health outcomes (Forns *et al.,* 2017). Wearable sensors should be incorporated into future studies in conjunction with the individual history of exposure to enhance the spatial-temporal resolution of the results (Clifford *et al.*, 2016). Combining remote data with ground information by using AI-based models can provide an improved result of pollution prediction and source apportionment (Mudway *et al.,* 2019). It is envisaged that the certification of the mechanistic connection between chronic disease and air pollution will be accomplished by longitudinal cohort studies that incorporate biomarkers of exposure, genetic susceptibility (Zhao *et al.*, 2025). Research projects should be conducted by urban planners, environmental scientists, and public health professionals in a cross-disciplinary cooperation to create expansive and community-based forms of mitigation measures. It might also be possible to extend the argument of intervention sustainability to touch upon the climate co-benefits of air pollution reduction.

CONCLUSION

This study critically evaluated the changing trends of urban air quality and its direct influences on the health outcomes of the population over the decade-long study (2014-2024). With those results, the study affirms that there is a close relationship between higher concentrations of air pollutants, especially $PM_{2.5}$, NO_2, and O_3, and the elevation of the respiratory and cardiovascular morbidities among urban populations. Although temporary progress was experienced in situations associated with lockdowns related to the pandemic, overall, the trend was disturbing, and many values surpassed the WHO air quality specifications, particularly those found at peak traffic times or over industrial times. This highlights an institutional weakness in preventing transport, industrial, and bad urban planning pollution. The combination of information within an environmental air quality longitudinal data set, combined with epidemiological health data within the entire city limits, is a significant contribution to environmental health sciences. The implementation of statistical, spatial, and temporal analysis allows the possibility of the study to give empirical evidence of the health burdens wrought by bad air quality. In addition to that, it leads to a better perception of the seasonal changes in pollution and influences the determination of the most dangerous times during which the health of a population is the most threatened. Such findings not only address data pale spots in the planning of urban regions but also enhance the international debate on local healthy urban policy. To curb future risks, the research highly suggests that both policymakers and urban planners introduce more stringent emission guidelines, introduce healthy air quality limits, and focus on building more sustainable infrastructures, such as underground electric transport and green strips in the city. Collaboration of environmental and health officials across sectors, a live monitoring policy of pollution, and education campaigns are crucial to guarantee that the urban air quality and health will improve in the long term, and it will be equitable.

REFERENCES

1. Abdollahpour, S. S., Qi, M., Le, H. T., & Hankey, S. (2024). Urban spatial structure and air quality in the United States: Evidence from a longitudinal approach. Environment International, 190, 108871.

2. Adar, S. D., Chen, Y. H., D'Souza, J. C., O'Neill, M. S., Szpiro, A. A., Auchincloss, A. H., ... & Kaufman, J. D. (2018). Longitudinal analysis of long-term air pollution levels and blood pressure: A cautionary tale from the multi-ethnic study of atherosclerosis. Environmental health perspectives, 126(10), 107003.
3. Alhusban, A., Oztaner, Y. B., Johnson, M., Rezasefat, M., Hojjatzadeh, N., Mousa, I., ... & Hakami, A. (2025). Development of longitudinal datasets (2000–2020) with high spatiotemporal resolution for air pollution exposure assessment in Canada. Data in Brief, 111730.
4. An, R., & Yu, H. (2018). Impact of ambient fine particulate matter air pollution on health behaviors: a longitudinal study of university students in Beijing, China. Public health, 159, 107-115.
5. Bakolis, I., Hammoud, R., Stewart, R., Beevers, S., Dajnak, D., MacCrimmon, S., ... & Mudway, I. S. (2021). Mental health consequences of urban air pollution: prospective population-based longitudinal survey. Social psychiatry and psychiatric epidemiology, 56, 1587-1599.
6. Clifford, A., Lang, L., Chen, R., Anstey, K. J., & Seaton, A. (2016). Exposure to air pollution and cognitive functioning across the life course–a systematic literature review. Environmental research, 147, 383-398.
7. Fasola, S., Maio, S., Baldacci, S., La Grutta, S., Ferrante, G., Forastiere, F., ... & BEEP Collaborative Group. (2021). Short-term effects of air pollution on cardiovascular hospitalizations in the Pisan longitudinal study. International Journal of Environmental Research and Public Health, 18(3), 1164.
8. Forns, J., Dadvand, P., Esnaola, M., Alvarez-Pedrerol, M., López-Vicente, M., Garcia-Esteban, R., ... & Sunyer, J. (2017). Longitudinal association between air pollution exposure at school and cognitive development in school children over 3.5 years. Environmental research, 159, 416-421.
9. Han, J., Meng, C., Liu, J., Xu, C., Liu, Z., Wang, Q., ... & Xu, D. (2022). The impacts of continuous improvements in air quality on mortality in Beijing: A longitudinal comparative study. Chemosphere, 291, 132893.
10. Hu, K., & He, Q. (2023). Rural–Urban Disparities in Multimorbidity Associated With Climate Change and Air Pollution: A Longitudinal Analysis Among Chinese Adults Aged 45+. Innovation in Aging, 7(6), igad060.
11. Ji, J. S., Zhu, A., Lv, Y., & Shi, X. (2020). Interaction between residential greenness and air pollution mortality: analysis of the Chinese Longitudinal Healthy Longevity Survey. The Lancet Planetary Health, 4(3), e107-e115.
12. Li, S., Zou, B., Liu, N., Xue, C., Li, S., Wang, Y., & Xu, Y. (2025). Proactive synergistic control of PM2.5 and ozone through urban planning: longitudinal data analysis of 274 Chinese cities from 2005 to 2020. Geo-spatial Information Science, 1-19.
13. Li, Y., Xie, T., Melo, R. D. C., de Vries, M., Lakerveld, J., Zijlema, W., & Hartman, C. A. (2023). Longitudinal effects of environmental noise and air pollution exposure on autism spectrum disorder and attention-deficit/hyperactivity disorder during adolescence and early adulthood: The TRAILS study. Environmental Research, 227, 115704.
14. Liang, L., & Gong, P. (2020). Urban and air pollution: a multi-city study of long-term effects of urban landscape patterns on air quality trends. Scientific reports, 10(1), 18618.
15. Lipfert, F. W., & Wyzga, R. E. (2019). Longitudinal relationships between lung cancer mortality rates, smoking, and ambient air quality: a comprehensive review and analysis. Critical reviews in toxicology, 49(9), 790-818.
16. Loftus, C. T., Ni, Y., Szpiro, A. A., Hazlehurst, M. F., Tylavsky, F. A., Bush, N. R., ... & LeWinn, K. Z. (2020). Exposure to ambient air pollution and early childhood behavior: a longitudinal cohort study. Environmental research, 183, 109075.
17. Mudway, I. S., Dundas, I., Wood, H. E., Marlin, N., Jamaludin, J. B., Bremner, S. A., ... & Griffiths, C. J. (2019). Impact of London's low emission zone on air quality and children's respiratory health: a sequential annual cross-sectional study. The Lancet Public Health, 4(1), e28-e40.
18. Rosofsky, A., Levy, J. I., Zanobetti, A., Janulewicz, P., & Fabian, M. P. (2018). Temporal trends in air pollution exposure inequality in Massachusetts. Environmental research, 161, 76-86.
19. Sharma, A. K., Mane, M., Shekhar, S., & Chandra, P. P. (2022). Assessing the Impact of Air Pollution on Respiratory Health: A Longitudinal Study in Urban Areas. *Health Leadership and Quality of Life*, (1), 48.
20. Sharma, M., Singh, K., Gautam, A. S., & Gautam, S. (2024). Longitudinal study of air pollutants in Indian metropolises: Seasonal patterns and urban variability. Aerosol Science and Engineering, 1-16.
21. Su, J. G., Vuong, V., Shahriary, E., Aslebagh, S., Yakutis, E., Sage, E., ... & Barrett, M. (2024). Health effects of air pollution on respiratory symptoms: A longitudinal study using digital health sensors. Environment International, 189, 108810.
22. Wang, Z., Qi, Z., & Zhu, L. (2021). Latitudinal and longitudinal variations in the impact of air pollution on well-being in China. *Environmental Impact Assessment Review*, 90, 106625.
23. Younan, D., Wang, X., Millstein, J., Petkus, A. J., Beavers, D. P., Espeland, M. A., ... & Chen, J. C. (2022). Air quality improvement and cognitive decline in community-dwelling older women in the United States: A longitudinal cohort study. PLoS Medicine, 19(2), e1003893.
24. Zhao, X., Zhou, W., & Neophytou, A. M. (2025). Impact of Continuously Improved Air Quality on Mental Health: A Quasi-experimental Study Based on Longitudinal Observations for Chinese Adults. Environment & Health.
25. Zheng, Z., Chen, L., Wang, Y., & Sun, N. (2025). Group disparities in the impact of green spaces and air pollution on the physical and mental health of rural older adults: Evidence from a nationwide longitudinal study. *Landscape and Urban Planning*, *259*, 105358.