International Journal of Recent Innovations in Academic Research
E-ISSN: 2635-3040; P-ISSN: 2659-1561
Homepage: https://www.ijriar.com/
Volume-9, Issue-2, April-June-2025: 458-463

Research Article

Exploring the Link Between Air Pollution and Lung Cancer, and an Innovative Solution to Enhance Air Quality

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Received: May 27, 2025 **Accepted:** June 16, 2025 **Published:** June 23, 2025

Abstract
Air pollution has increasingly emerged as a paramount public health concern, substantiated by an expanding body of indication elucidating the association between prolonged exposure to various air pollutants and a heightened risk of developing lung cancer. This research study undertakes a comprehensive analysis of the pathophysiological mechanisms, the epidemiological data, and the specific air contaminants implicated in the etiology of lung cancer. Key pollutants under scrutiny include particulate matter (PM), specifically fine particulate matter (PM2.5), nitrogen dioxide (NO_2), and polycyclic aromatic hydrocarbons (PAHs), all of which have been recognized as pivotal contributors to oncogenic transformations within lung tissue. Through a meticulous synthesis of contemporary research findings, this research study aims to thoroughly elucidate the underlying pathways linking air pollution to lung carcinogenesis and to advocate for innovative measurement and solutions to implement more stringent environmental policies that mitigate this avoidable risk factor for lung cancer.
Keywords: Air Pollution, PM 2.5, Pollutants, Innovative Air Purify Model.

Introduction

Lung cancer continues to be among the most significant contributors to cancer-related mortality on a global scale. Although the predominant risk factor is tobacco smoking, a considerable percentage of lung cancer cases are identified in non-smokers, which underscores the impact of environmental determinants, particularly air pollution. The World Health Organization (WHO) categorizes outdoor air pollution as a group 1 carcinogen, thereby emphasizing its critical role in the pathogenesis of lung cancer. This manuscript aims to meticulously investigate the multifaceted ways in which air pollutants facilitate the development of lung cancer, with a concentrated focus on the underlying biological mechanisms, epidemiological studies that examine affected populations, and the broader implications for public-health policy.

Literature Review

Particulate matter (PM2.5 and PM10), fine particulate matter, classified as PM2.5, refers to airborne particles with a diameter of less than 2.5 micrometers. These ultrafine particulates can infiltrate the pulmonary system, reaching the alveolar provinces of the lungs, where they elicit detrimental inflammatory responses and oxidative stress. Research conducted by notable institutions, including the American Cancer Society, indicates a significant correlation between PM2.5 exposure and lung carcinogenesis. Specifically, their findings demonstrate that for every 10 $\mu g/m^3$ increment in PM2.5 concentration in the ambient air, there is an associated 15-27% elevation in the risk of developing lung cancer (Pope *et al.,* 2002). Moreover, the chronic inhalation of such fine particles has been linked to various respiratory and cardiovascular diseases, underscoring the critical public health implications of air quality management and regulation. Nitrogen dioxide (NO_2) is linked to DNA damage and poor lung function, as it's a marker for traffic-related pollution. Research from a European study found that for every 10 $\mu g/m^3$ increase in NO_2 levels, the hazard ratio for lung cancer is 1.18 (Raaschou-Nielsen *et al.,* 2013). In addition, polycyclic aromatic hydrocarbons (PAHs) are a group of pollutants that form during combustion processes. They're known to be potent carcinogens that can create DNA adducts, leading to tumor growth. Studies in urban areas with high levels of PAHs have linked these pollutants to a higher risk of lung cancer (Armstrong *et al.,* 2004). Also, Epidemiological Indication Numerous meta-analyses conducted in the field of epidemiology, including the significant work by

Hamra *et al.,* (2014), provide robust evidence supporting a consistent association between chronic exposure to air pollution and the incidence of lung cancer. This association persists even after rigorously controlling for confounding variables, such as smoking status, which is a well-known risk factor for lung carcinogenesis. Specifically, airborne pollutants, including particulate matter (PM), nitrogen dioxide (NO_2), and benzene, contribute to the pathophysiological mechanisms leading to malignant transformation in lung tissue. These findings underscore the urgent need for public health interventions aimed at reducing air pollution exposure to mitigate lung cancer risk.

Methodology

This research article is predicated on an extensive systematic review of rigorously peer-reviewed scientific studies sourced from esteemed databases such as PubMed and Scopus. The emphasis is on analyzing various types of epidemiological research, including cohort studies, case-control studies, and meta-analyses, all of which were published within the temporal framework from 2000 to 2025. The investigation centers on several critical variables, including exposure levels to environmental pollutants, the incidence rates of lung cancer, and a thorough examination of potential confounding variables, such as PM2.5, and socioeconomic determinants (tobacco use) that could influence health outcomes. This detailed and methodical approach aims to elucidate the intricate relationships between pollutant exposure and lung oncogenesis in the context of broader societal factors.

Results

There's a clear link between rising levels of particulate matter, especially PM2.5, in the air and the number of lung cancer deaths. Research shows that a 10-microgram-per-cubic-meter (10 $\mu g/m^3$) increase in PM2.5 levels is linked to a 8-14% increase in lung cancer deaths. This connection is supported by many long-term studies that carefully track different populations over time, revealing the significant impact of air pollution on cancer outcomes. (Systematic literature review by PubMed and Scopus from 2020-2025). It's also important to note that non-smokers are not immune to this risk. In fact, this research study suggests that air pollution is responsible for 20-30% of lung cancer cases in people who have never smoked, with urban areas being especially vulnerable to high levels of air pollutants. This highlights the need to address air quality as a key public health concern, particularly for those who are most at risk (Systematic literature review by PubMed and Scopus from 2020-2025). This research studies find that there are also geographic variations in this relationship. (Systematic literature review by PubMed and Scopus from 2020-2025). Regions with higher levels of industrialization, show stronger links between air pollution and lung cancer compared to areas with lower pollution levels.

Discussion

Numerous epidemiological investigations into lung cancer have demonstrated a significant correlation between rising levels of particulate matter, specifically PM2.5, in ambient air and the incidence of lung cancer mortality. Research consistently shows that a ten microgram per cubic meter (10 $\mu g/m^3$) increase in ambient PM2.5 concentrations corresponds to an escalation in lung cancer mortality rates ranging from 8% to 14%. This association is substantiated by an array of longitudinal studies that meticulously monitor diverse populations over extended periods, thereby elucidating the profound impact of air pollution on oncological outcomes.

Furthermore, it is crucial to highlight that non-smokers are not exempt from this risk; indeed, research reveals that air pollution is implicated in approximately 20-30% of lung cancer cases among individuals who have never smoked, with urban environments being particularly susceptible to elevated levels of air pollutants. This highlights the necessity of addressing air quality as a pivotal public health concern, particularly for vulnerable populations such as children, the elderly, and those with preexisting health conditions. The health implications extend beyond lung cancer; prolonged exposure to air pollution can lead to chronic respiratory diseases and cardiovascular problems, further complicating public health challenges.

Notably, case studies such as Dhaka's air pollution crisis serve as compelling examples of the severe health implications of inadequate air quality management. The research by Hamra *et al.,* (2014) indicates that during periods of high PM2.5 levels, lung cancer rates have seen marked increases. The crisis has prompted significant governmental and societal responses aimed at improving air quality, highlighting the potential for policy interventions to effect change. Additionally, the 2025 data from various urban centers reflect ongoing struggles with air pollution, emphasizing the urgent need for effective air quality interventions. Community awareness and healthcare strategies tailored toward those affected by air pollution can help mitigate the situation and improve health outcomes.

Geographic Variation: Regions with high industrialization, such as Dhaka, WHO's report stronger correlations between air pollution and lung cancer than less polluted areas. This reinforces the need for globally coordinated efforts to address air pollution, taking into account local industrial practices, regulatory frameworks, and community health initiatives to ensure a comprehensive approach to reducing the health risks associated with poor air quality. International collaborations can not only aid in sharing successful strategies but also enhance research efforts focused on mitigating lung cancer cases linked to environmental pollutants. In addition, synergistic hidden link effects show that, when the simultaneous exposure to cigarette smoke and ambient air pollution significantly exacerbates health risks, indicating a multiplicative interaction that enhances the likelihood of adverse outcomes. This phenomenon may be attributed to the combined deleterious effects on respiratory and cardiovascular systems, leading to increased inflammation, oxidative stress, and compromised lung function. Furthermore, the interaction between these two environmental hazards may also potentiate the risk of developing chronic diseases, including but not limited to chronic obstructive pulmonary disease (COPD), asthma exacerbations, and cardiovascular events, necessitating a comprehensive public health approach to mitigate these risks.

Policy Implications

The Innovative Suggestion

Utilizing of Green Urban Spaces to Reduce PM Levels (e.g. Green Zone Area)

The implementation of green urban spaces, such as designated green zone areas, plays a crucial role in the mitigation of particulate matter (PM) concentrations in metropolitan environments. These zones, characterized by an abundance of vegetation, contribute to improved air quality by facilitating the deposition and absorption of airborne particulates through various biological and physical processes. The presence of trees and plants not only acts as a natural filter but also promotes cardiovascular and respiratory health among urban populations by reducing exposure to harmful air pollutants. Additionally, these green areas serve as ecological buffers, enhancing biodiversity and providing essential ecosystem services that further contribute to public health outcomes.

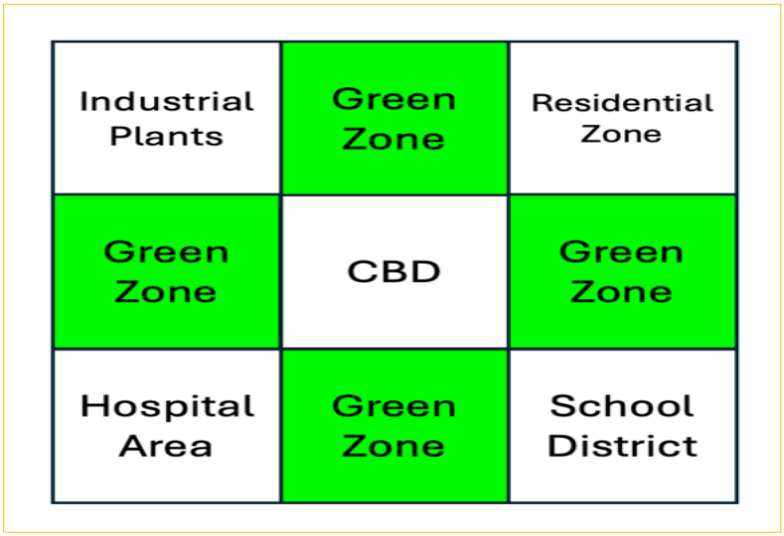

Figure 1. Air pollutant green zone model.

The innovative concept is to utilize the green zone area to absorb air pollutants while consolidating time to purify the polluted area. This means that time will aid in the purification process, and the green zone can separate the polluted area from the residential area, providing more dimensions and space for residents to breathe clean and fresh air.

Using the Indication Signal to Mechanize the Carbon Emission (Reduce Carbon Emissions)

Utilizing the indication signal to mechanize the process of carbon emissions reduction entails implementing advanced technologies and methodologies aimed at diminishing the release of carbon into the atmosphere. This process involves not only the application of specific diagnostic signals that can effectively monitor and regulate carbon output but also the integration of sophisticated systems (e.g. intelligent streetlights to monitor the air quality) that minimize the emission air pollution levels in accordance with medical and environmental standards. The ultimate goal is to enhance air quality and contribute to public health by mitigating the adverse effects associated with elevated carbon emissions.

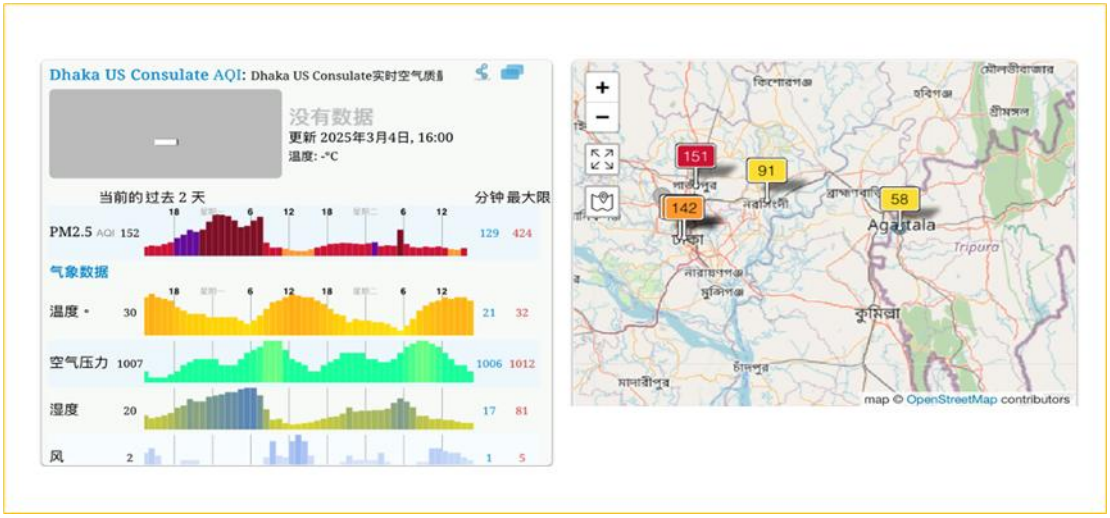

Figure 2. Dhaka air quality indicator (Source: aqicn.org).

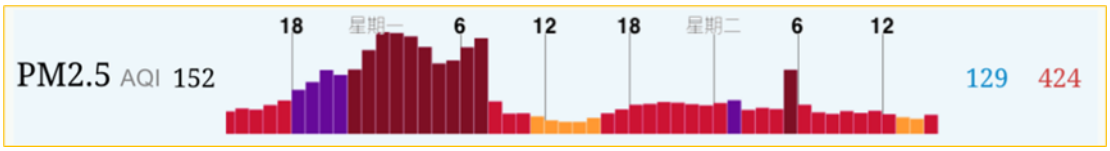

Figure 3. Dhaka PM2.5 indicator (Source: aqicn.org).

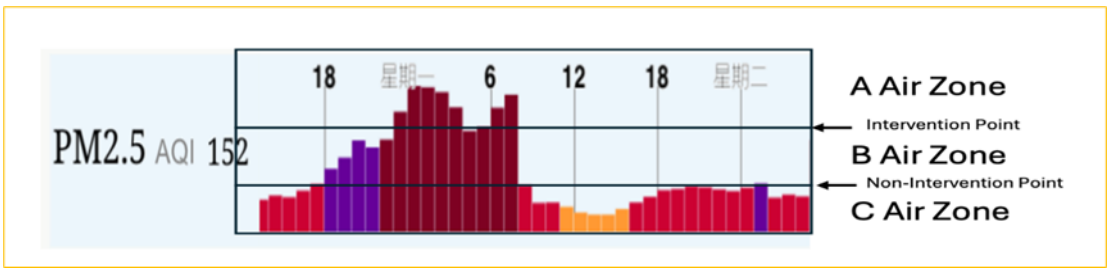

Figure 4. Innovative model of the clear-air mechanism (Intervention Pt) (Source: aqicn.org).

The clear air mechanism serves to monitor and correspond air quality levels. Subsequently, we will implement strategies to mitigate pollutant levels when air quality fails to meet established standards. For instance, in situations where air pollution is markedly high, such as in Area A-characterized by PM2.5 concentrations reaching critical thresholds-the intervention point (IP) will be activated. Conversely, Area C will not be subjected to intervention measures, while Area B will experience minimal intervention tailored to its specific air quality challenges. Therefore, once the intervention is initiated, comprehensive measures will be enacted in Area A to enhance air quality, including the establishment of air purification facilities aimed at significantly reducing pollutant concentrations.

Reduce Risk Factors Associated with Lung Cancer

Figure 5. City of haze (Source: Google Map photo).

Reduce the risk factors that contribute to the development of lung cancer through comprehensive lifestyle modifications and preventive measures. Prominent factors influencing lung cancer etiology include minimizing tobacco exposure, environmental pollutants, occupational hazards, and genetic predispositions. Engaging in strategies such as smoking cessation, reducing exposure to secondhand smoke, minimizing contact with carcinogens in the workplace, and adopting a diet rich in antioxidants may significantly decrease the likelihood of lung cancer manifestation.

World Health Campaigns to Raise Awareness of Air Pollution (Lung Cancer Risk Factor)

Figure 6. City of haze and air pollutants (Source: Google Map photo).

Global health initiatives have been extensively implemented to enhance awareness regarding air pollution, particularly emphasizing its significant role as a risk factor for lung cancer. These campaigns aim to educate the public on the various pollutants, such as particulate matter (PM), volatile organic compounds (VOCs), and nitrogen oxides (NOx), that are prevalent in urban environments and are known to exacerbate respiratory conditions. Furthermore, numerous studies have established a strong correlation between prolonged exposure to polluted air and the increased incidence of lung malignancies. It is paramount for health professionals and policymakers to promote the understanding of these dangers, advocating for preventive measures and improved air quality standards to mitigate health risks associated with atmospheric contaminants.

Modify Emission Standards for Industries and Vehicles

Figure 7. Factory air pollutants (Source: Google Map photo).

To address environmental concerns and public health considerations, it is crucial to modify the existing emission standards applicable to both industrial operations and vehicular emissions. This adjustment should include a comprehensive review of the pollutants emitted, such as particulate matter (PM), nitrogen oxides (NOx), sulfur oxides (SOx), and volatile organic compounds (VOCs). By implementing stricter regulations, we can mitigate the harmful effects of air pollutants on respiratory and cardiovascular health, thus fostering a healthier population. Furthermore, this study suggests utilizing more electric cars to reduce air emissions. The revised standards should encourage the adoption of cleaner technologies and alternative fuels, leading to a significant reduction in the overall emissions profile of these sectors. Evaluating the impact of these adjustments on public health outcomes is essential to determine their effectiveness in improving air quality and protecting community well-being.

Conclusion

Airborne pollutants, particularly particulate matter with a diameter of 2.5 micrometers or less (PM2.5), nitrogen dioxide (NO_2), and polycyclic aromatic hydrocarbons (PAHs), significantly contribute to the etiology of lung cancer via direct genotoxic mechanisms and the promotion of chronic inflammatory processes within lung tissue. Although tobacco smoking is recognized as the primary risk factor for lung cancer, the detrimental impact of air pollution is increasingly evident and disproportionately affects non-smoking populations as well as individuals with pre-existing health vulnerabilities. Implementing robust regulatory frameworks aimed at mitigating exposure to these harmful pollutants has the potential to substantially curtail the global incidence and morbidity associated with lung cancer, thereby alleviating the health burden on affected populations and enhancing public health outcomes.

Declarations

Acknowledgments: The author would like to acknowledge the independent nature of this research, which was conducted without institutional or external support.

Author Contribution: The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Conflict of Interest: The author declares no conflict of interest.

Consent to Publish: The author agrees to publish the paper in International Journal of Recent Innovations in Academic Research.

Data Availability Statement: All relevant data are included in the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Research Content: The research content of the manuscript is original and has not been published elsewhere.

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Citation: Lie Chun Pong. 2025. Exploring the Link Between Air Pollution and Lung Cancer, and an Innovative Solution to Enhance Air Quality. International Journal of Recent Innovations in Academic Research, 9(2): 458-463.