Comprehensive Strategies to Mitigate PM 2.5-Induced Lung Cancer and Address Public Health Challenges

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Abstract Particulate matter (PM2.5) pollution poses a significant global health challenge, linked to adverse respiratory outcomes and increased lung cancer mortality. Although researchers widely acknowledge this association, they have limited understanding of how PM2.5 concentration and socioeconomic factors influence the spatial dynamics of lung cancer incidence. Research in eastern China and Brazil highlights the correlation between PM2.5 exposure, education levels and heightened cancer mortality risk. However, clear strategies to prevent lung cancer caused by PM2.5 are still lacking and require a thorough synthesis of evidence. Effective management and prevention of PM2.5-induced lung cancer require a holistic approach, encompassing health education, personalized symptom management, regular monitoring, smoking cessation support, environmental modifications, comprehensive care coordination and public health advocacy. By implementing these evidence-based strategies, healthcare providers can mitigate the adverse health effects of PM2.5 pollution and promote respiratory health globally. In conclusion, addressing PM2.5 pollution and its association with lung cancer mortality demands a multifaceted approach, emphasizing collaboration and evidence-based interventions to improve public health outcomes. *(Thai Cancer J 2024;44:118-130)*

Keywords: air pollution, indoor environmental exposure, lung cancer, particulate matter pollution, respiratory tract diseases

Introduction

Particulate matter (PM2.5) is a concerning airborne pollutant sourced from various activities like construction, agriculture and industry posing substantial risks to both public health and the environment[1,2]. Its association with lung cancer, a prominent cause of global cancer-related deaths, highlights the critical need to address PM2.5 pollution[3]. According to the evidence, air PM2.5 is a significant contributor to lung cancer mortality worldwide raising global concern. However, there remains a limited understanding of the spatial dynamics of lung cancer incidence (LCI) and how socioeconomic factors and climate zones influence the relationship between PM2.5 and LCI[3]. The study by Guo and colleagues[3] explained that PM2.5 is a leading cause of lung cancer mortality. Spatial analysis reveals hot spots of lung cancer incidence mainly in eastern China with factors such as PM2.5 concentration and education levels showing significant effects. These findings inform targeted prevention and control strategies for lung cancer and related epidemics. This is consistent with the research of Yu and colleagues[4] showing that long-term exposure to PM2.5 significantly increases the risk of mortality for various cancer types including oral, lung and prostate cancer among others. Researchers observed this association across 5,565 municipalities in Brazil and identified no safe level of PM2.5 exposure for cancer mortality. These findings underscore the urgent need for mitigating air pollution to reduce cancer-related deaths. On the other hand, there are no clear practical methods recommended for preventing PM2.5-induced lung cancer. Currently, only general suggestions exist for minimizing exposure such as wearing masks and using air filtration systems. Therefore, there is a need for evidence synthesis to identify effective prevention methods. The objective of this review is to examine the association between PM2.5 pollution and lung cancer mortality, focusing on spatial dynamics and prevention strategies. It aims to assess global evidence and identify gaps to inform more effective prevention methods. Impacts of PM2.5 on lung health and its role in lung cancer development.

Exposure to PM2.5 significantly impacts lung health, exacerbating respiratory conditions and posing substantial risks to respiratory function. In animal studies, PM2.5 particles have been shown to deeply penetrate the respiratory system, inducing oxidative stress and inflammation, resulting in cellular dysfunction and tissue damage[6-8]. Prolonged exposure to PM2.5 has been associated with accelerated lung cancer progression, primarily through mechanisms involving DNA damage and chronic inflammation[9]. Mitigating PM2.5 exposure is crucial for preventing the development and progression of respiratory diseases, including lung cancer and improving overall public health outcomes. PM2.5 exposure initiates lung cancer by directly damaging DNA in lung cells, while oxidative stress and inflammation exacerbate DNA mutations, promoting cancer initiation and progression[9-12]. Chronic inflammation induced by PM2.5 creates a pro-tumorigenic microenvironment in the lungs, facilitating tumor growth, angiogenesis and metastasis and suppressing immune surveillance mechanisms[9-12].

A human epidemiological study conducted in China observed 844 incident cases of lung cancer and 701 lung cancer-related deaths during the follow-up period[12]. The study revealed nonlinear exposure-response curves for both lung cancer incidence and mortality associated with PM2.5 exposure. Upon adjusting for confounding factors, individuals exposed to higher PM2.5 quintiles demonstrated significantly elevated risks for both lung cancer incidence (HR range: 1.44-2.45, 95% CI) and mortality (HR range: 1.83- 2.95, 95% CI)[12]. The evidence from Thailand highlights the significant concern of PM2.5 and PM10 pollutants in upper northern Thailand. A retrospective cohort study involving 9,820 lung cancer patients diagnosed from 2003 to 2018, utilizing data from the Chiang Mai Cancer Registry, revealed a mortality rate of 68.2 per 100 persons per year of follow-up. Cox proportional hazard models identified associations between mortality risk and various factors. Additionally, factors consist of gender, age, cancer stage, smoking history, alcohol-use history, calendar year of enrollment and time-updated PM2.5, PM10, NO_2 and O_3 concentrations. Multivariate analysis indicated independent associations between the risk of death and factors such as gender, age, cancer stage, the calendar year of enrollment and fluctuating residential PM2.5 concentrations. Researchers observed higher survival probabilities with lower annually averaged PM2.5 and PM10 concentrations. They advise lung cancer patients living in areas with high pollutant levels to minimize their exposure to these pollutants to improve survival rates, as elevated levels of PM2.5 and PM10 are associated with increased mortality risk.[13] In addition, we conducted a search of medical evidence and found results that demonstrate the association between PM2.5 exposure and lung cancer as shown in Table 1.

Table 1 Association between PM2.5 exposure and lung cancer in recent studies[14-16]

Study, year	Primary outcome	RR (95% CI)
Yue, et al., 2020	Lung cancer	1.12 (1.07,1.16)
Chen, et al., 2021	The number of hospitalizations	1.10 (1.05,1.16)
Bouchriti, et al., 2023	Short term mortality	1.01 (1.00,1.02)
	Long term mortality	1.16 (1.10,1.22)
	Long term morbidity	1.23 (1.12,1.37)

Table 1 summarizes findings from epidemiological studies investigating the relationship between PM2.5 exposure and various health outcomes. Yue et al. (2020) observed a 12% increased risk of lung cancer (RR: 1.12, 95% CI: 1.07-1.16) with PM2.5 exposure. Chen et al. (2021) found a 10% higher risk of respiratory-related hospitalizations (RR: 1.10, 95% CI: 1.05-1.16). Bouchriti et al. (2023) reported significant associations between PM2.5 exposure and short-term mortality (RR: 1.01, 95% CI: 1.00-1.02), long-term mortality (RR: 1.16, 95% CI: 1.10-1.22) and long-term morbidity (RR: 1.23, 95% CI: 1.12-1.37). These findings underscore the adverse health impacts of PM2.5 exposure including increased risks of lung cancer incidence, respiratory hospitalizations, mortality and morbidity, emphasizing the urgency of mitigating PM2.5 pollution to safeguard public health. In clinical practice, the data from Table 1 can be generalized to inform patient care and public health interventions. For example, clinicians can use this information to educate patients about the risks associated with PM2.5 exposure and advise them on ways to minimize their exposure, such as staying indoors during periods of high pollution, using air purifiers and wearing masks when outdoors in polluted areas. Additionally, healthcare providers can advocate for policies aimed at reducing PM2.5 pollution on a larger scale, such as stricter regulations on emissions from vehicles and industrial sources. By integrating this evidence into clinical practice, healthcare professionals can help mitigate the adverse health effects of PM2.5 pollution and improve patient outcomes.

Table 2 Summary of epidemiological studies on incidence rates

Study country	Reference	Study period	Study type	Study	Incidence
California, USA	McDonnell et al. 2000[17]	1977-1992	Cohort	AHSMOG	0.0034
United States	Pope et al. 2011[18]	1988-1994	Cohort	ACS-air pol extend	0.0040
United States	Hart et al. 2011[19]	1985-2000	Cohort	TrIPS	0.0149
California, USA	Lipsett et al. 2011[20]	1997-2005	Cohort	CTS	0.0032
United States	Lepeule et al. 2012[21]	1975-2009	Cohort	Harvard Six Cities Study	0.0781

Study country	Reference	Study period	Study type	Study	Incidence
Canada	Hystad et al. 2013[22]	1994-1997	Case control	National Enhanced Cancer Surveillance System Case-Control Study	0.4053
United States	Puett et al. 2014[23]	1998-2010	Cohort	NHS	0.0168
United States	Hart et al. 2015[24]	1986-2003	Cohort	NLCS	0.2776
Canada	Weichenthal et al. 2016[25]	1991-2009	Cohort	Can-CHEC	0.0166
United States	Gharibvand 2016[26]	2002-2011	Cohort	AHSMOG-2	0.0031
Canada	Tomczak 2016[27]	1980-1985	Cohort	Canadian National Breast Screening Study	0.0104
Netherlands	Beelen et al. 2008[28]	1986-1997	Cohort	Netherland Cohort study Of Diet and Cancer.	0.0161
United Kingdom	Carey et al. 2013[29]	2003-2007	Cohort	Clinical Practice Research Datalink	0.0063
Italy	Cesaroni et al. 2013[30]	2001-2010	Cohort	Rome Longitudinal Study	0.0097

Study country	Reference	Study period	Study type	Study	Incidence
European Union	RaaschouNeilsen et al. 2013[31]	1990	Cohort	-	0.0067
China	Cao et al. 2011[32]	1991-2000	Cohort	China National Hypertension follow-up survey	0.0088
Japan	Katanoda et al. 2011[33]	1983-1995	Cohort	Three Prefecture Cohort	0.0066

Remark: RR = Relative Risks, HR = Hazard Ratio

Table 2 shows a range of epidemiological studies examining incidence rates across various countries and periods, offering critical insights for healthcare policymakers. Predominantly cohort studies such as those by McDonnell et al. (2000) in California and Lepeule et al. (2012) in the United States, reported incidence rates of 0.0034 and 0.0781, respectively. Additionally, a notable case-control study by Hystad et al. (2013) in Canada revealed a significantly higher incidence rate of 0.4053. The studies encompass periods from the early 1980s to the late 2000s, with incidence rates reflecting diverse populations and methodologies. For healthcare policymakers, these findings emphasize the necessity of considering geographical and temporal variations in incidence rates when designing and implementing public health interventions. Although smaller incidence rates, such as those reported by McDonnell et al. (0.0034) and Lipsett et al. (0.0032), might initially seem less concerning, they can represent substantial public health issues over time, especially within large populations. Conversely, higher incidence rates, such as the 0.4053 reported by Hystad et al., necessitate immediate and substantial action due to the potentially large number of affected individuals and the consequent healthcare burden. In summary, both small and large incidence rates warrant serious consideration. Smaller rates may signal emerging issues requiring early intervention, whereas larger rates demand prompt and robust public health responses to prevent widespread impact. These data underscore the importance of long-term epidemiological research in informing and shaping effective health policies tailored to specific regional and population health trends.

Strategies for preventing PM2.5-induced lung cancer

In addressing patients exposed to PM2.5 a multifaceted approach is essential. This approach involves education, symptom management, monitoring, environmental adjustments, smoking cessation, comprehensive care and public health advocacy. Given the significant health risks posed by PM2.5, particularly to individuals with respiratory conditions such as asthma, COPD and lung cancer, effective management strategies are pivotal for enhancing patient outcomes and alleviating the burden of respiratory diseases. Each facet of PM2.5 management will be explored to mitigate its adverse health effects and advance respiratory well-being globally. Refer to Table 3 for an overview of preventive and management strategies specifically targeting PM2.5-induced lung cancer.

Table 3 Strategies for PM2.5 management and lung cancer prevention

Strategy	Details
Health education	Comprehensive education on PM2.5 risks is vital, ensuring patients grasp short-term symptoms exacerbation and long-term outcomes like heightened lung cancer and cardiovascular risks. Healthcare providers offer practical measures such as air quality checks, limiting outdoor activities during peak pollution and using HEPA filters indoors. Emphasizing consistent adherence to these strategies is key for sustained health protection.
Symptom management	Symptom management for PM2.5-related respiratory symptoms is personalized to symptom severity and tendency. Short-acting bronchodilators such as albuterol offer relief during acute episodes of wheezing or breathlessness. Corticosteroids may be prescribed for persistent symptoms or exacerbations to alleviate airway inflammation. Non-pharmacological interventions such as breathing exercises, chest physiotherapy and pulmonary rehabilitation plans improve respiratory functions and quality of life for patient with chronic respiratory conditions.

Strategy	Details
Regular monitoring	Regular monitoring is vital for evaluating the efficacy of symptom management approaches and identifying changes in respiratory health over time. Lung function tests for instance, spirometry and peak flow measurements quantify airflow limitation and track disease progression. Imaging studies are valuable for assessing lung structure and ascertaining complications like pneumonia or lung cancer. Close monitoring empowers the intervention and adjustment of treatment plans to optimize patient outcomes.
Smoking cessation	Quitting smoking is crucial for individuals exposed to PM2.5. Healthcare providers should provide comprehensive cessation support, including counseling, medications and supportive services. Motivational interviewing techniques can assist patients in assessing their readiness to quit and crafting personalized cessation plans suited to their preferences and desires.
Environmental modifications	Identifying and mitigating sources of indoor and outdoor air pollution is crucial for reducing PM2.5 exposure. Healthcare providers can work with patients to assess their homes and implement interventions like improving ventilation, installing air filters and reducing indoor pollutants such as tobacco smoke and mold. Encouraging patients to avoid outdoor activities in highly polluted areas and to use masks or respirators when needed can also help minimize exposure to ambient PM2.5.
Comprehensive care	For patients with lung cancer, comprehensive care involves a multidisciplinary approach that considers both medical and environmental factors. This includes coordination among oncologists, pulmonologists and other healthcare professionals to advance individualized treatment plans

	tailored to each patient's specific needs and goals. Supportive care services can improve the quality of life and overall well-being of patients with lung cancer, particularly those with advanced disease.
Public health advocacy	Advocating for policies and initiatives to reduce air pollution and promote clean air standards is crucial for safeguarding public health on a broader scale. Healthcare providers play a vital role in these efforts by raising awareness about the health risks of air pollution, engaging in community outreach events and collaborating with stakeholders to develop evidence-based strategies for pollution control and environmental conservation. Supporting legislative measures aimed at limiting industrial emissions, promoting renewable energy sources and enhancing urban planning and transportation infrastructure can yield significant benefits for both population health and environmental sustainability.

Conclusion

The well-documented association between PM2.5 exposure and lung cancer mortality underscore the pressing need for effective prevention and management strategies. Global evidence highlights significant spatial dynamics in lung cancer incidence influenced by PM2.5 concentration and socioeconomic factors. Despite PM2.5 being a leading cause of lung cancer mortality worldwide, practical prevention methods remain unclear. Nonetheless, research indicates that long-term PM2.5 exposure significantly elevates mortality risk for various cancer types, emphasizing the critical importance of mitigating air pollution to reduce cancer-related deaths. The evidence synthesis presented emphasizes the multifaceted approach required to manage PM2.5-exposed patients and prevent PM2.5-induced lung cancer. Through comprehensive education, symptom management, regular monitoring, smoking cessation, environmental modifications, comprehensive care and public health advocacy, healthcare providers can mitigate the adverse health effects of PM2.5 pollution and promote respiratory health globally. Implementing evidence-based strategies and advocating for pollution control measures can contribute to reducing the burden of lung cancer and improving overall public health outcomes on a broader scale.

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