

A Systematic Review of the Short and Long Term Effects of PM_{2.5} and PM₁₀ Exposure on Respiratory Morbidity and Mortality in Jakarta

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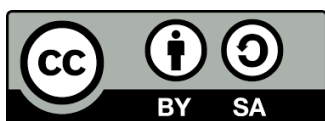
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Abstract

Particulate air pollution represents a persistent public health challenge, particularly in densely populated urban settings. Jakarta experiences particulate matter concentrations that frequently exceed recommended air quality standards, raising concerns about their potential effects on respiratory health. However, locally available evidence on the respiratory consequences of particulate matter exposure remains scattered across studies with varying designs and outcomes. This review synthesized the available evidence on the associations between PM_{2.5} and PM₁₀ exposure and respiratory morbidity and mortality among populations in Jakarta and the Greater Jakarta area. Relevant studies published between 2015 and 2025 were identified through systematic searches of PubMed, ScienceDirect, and Google Scholar. Observational and ecological studies examining ambient or indoor PM_{2.5} and/or PM₁₀ exposure in relation to respiratory health outcomes were considered eligible. Information on study characteristics, exposure assessment, respiratory outcomes, effect estimates, and statistical significance was extracted and synthesized. Six studies met the eligibility criteria. Across the included evidence, PM_{2.5} exposure showed relatively consistent associations with adverse respiratory outcomes, including acute respiratory infections, pneumonia, asthma-related outcomes, and mortality. One study reported that a 50 µg/m³ increase in long-term PM_{2.5} exposure was associated with an 11.9% increase in COVID-19 mortality. In comparison, findings for PM₁₀ were less consistent, with several analyses reporting weak or statistically non-significant associations. Differences in study design, exposure assessment, and outcome definitions further limited direct comparison across studies. Overall, the available evidence indicates that particulate matter, particularly PM_{2.5}, is an important environmental concern for respiratory health in Jakarta. The limited and heterogeneous evidence for PM₁₀ highlights the need for further investigation. Future research using longitudinal designs and individual-level exposure assessment is needed to better characterize exposure-response relationships and strengthen the evidence base for air quality management and respiratory disease prevention.



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INTRODUCTION

Air pollution remains one of the leading environmental determinants of morbidity and mortality worldwide, particularly in rapidly urbanizing regions (Behera et al., 2024; Jiang et al., 2026; Maji et al., 2023; Yang et al., 2023; Zhang et al., 2022). The World Health Organization (WHO) estimates that ambient air pollution is responsible for more than 4 million premature deaths annually, largely attributable to cardiovascular and respiratory diseases (World Health Organization, 2021). Among various air pollutants, particulate matter (PM) has consistently been identified as one of the most harmful pollutants due to its ability to penetrate deep into the respiratory tract and enter systemic circulation (Schraufnagel et al., 2019).

Particulate matter is commonly classified based on aerodynamic diameter, with PM_{2.5} (particles $\leq 2.5 \mu\text{m}$) and PM₁₀ (particles $\leq 10 \mu\text{m}$) being the most widely studied fractions. PM_{2.5} is particularly concerning because its small size allows it to reach the alveoli, induce oxidative stress, trigger inflammation, and exacerbate existing respiratory conditions (Brook et al., 2010). Long-term exposure to PM_{2.5} has been associated with an increased incidence of chronic obstructive pulmonary disease (COPD), asthma, lung cancer, and all-cause respiratory mortality, whereas short-term exposure has been linked to acute respiratory infections and hospital admissions (Guarnieri & Balmes, 2014).

Urban populations in low- and middle-income countries are disproportionately affected by particulate air pollution due to rapid industrialization, high traffic density, and limited regulatory enforcement (Landrigan et al., 2018). Jakarta, as one of the largest megacities in Southeast Asia, experiences persistently elevated levels of PM_{2.5} and PM₁₀, frequently exceeding WHO Air Quality Guidelines (Health Effects Institute, 2023). Exposure patterns in such megacities are further influenced by seasonal variations, meteorological factors, and population density, increasing vulnerability to pollution-related respiratory outcomes (Cohen et al., 2017).

Despite growing global evidence linking particulate matter exposure to adverse respiratory health outcomes, local epidemiological data remain essential for informing context-specific public health interventions (Banwari, 2025; de Paula Nunes et al., 2026; Ji et al., 2025; Salim, 2026). Differences in pollutant composition, exposure duration, baseline health status, and healthcare access may modify the magnitude of health effects across regions (Thurston et al., 2017). Therefore, synthesizing evidence on the short-term and long-term respiratory impacts of PM_{2.5} and PM₁₀ exposure in Jakarta is crucial to support policy development, environmental regulation, and preventive health strategies.

The objectives of this study were as follows: (1) to synthesize scientific evidence on the short-term and long-term effects of PM_{2.5} and PM₁₀ exposure on respiratory morbidity and mortality among Jakarta residents; (2) to evaluate the strength and consistency of associations between particulate matter exposure and various respiratory health outcomes, including acute respiratory infections, pneumonia, asthma exacerbations, hospital visits, and mortality; (3) to assess the methodological quality of the studies included in the review through risk-of-bias assessment; and (4) to identify research gaps and provide recommendations for more targeted longitudinal research and public health interventions in Jakarta.

METHOD

This study was conducted as a systematic review to analyze the short-term and long-term effects of particulate matter exposure (PM_{2.5} and PM₁₀) on respiratory morbidity and mortality in Jakarta. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A systematic literature search was performed using PubMed, ScienceDirect, and Google Scholar to identify relevant articles published between 2015 and 2025.

The search strategy combined keywords related to exposure, outcomes, and study location, including “PM_{2.5},” “PM₁₀,” “particulate matter,” “air pollution,” “respiratory morbidity,” “respiratory mortality,” and “Jakarta.” Articles were included if they used observational or ecological study designs, assessed exposure to ambient or indoor PM_{2.5} and/or

PM₁₀, reported respiratory health outcomes (including acute respiratory infections, pneumonia, asthma, hospital visits, or mortality), and involved populations residing in Jakarta or the Greater Jakarta area. Studies were excluded if they lacked outcome analysis, were conducted outside Jakarta, did not provide effect estimates or statistical significance, or lacked relevant exposure or outcome data.

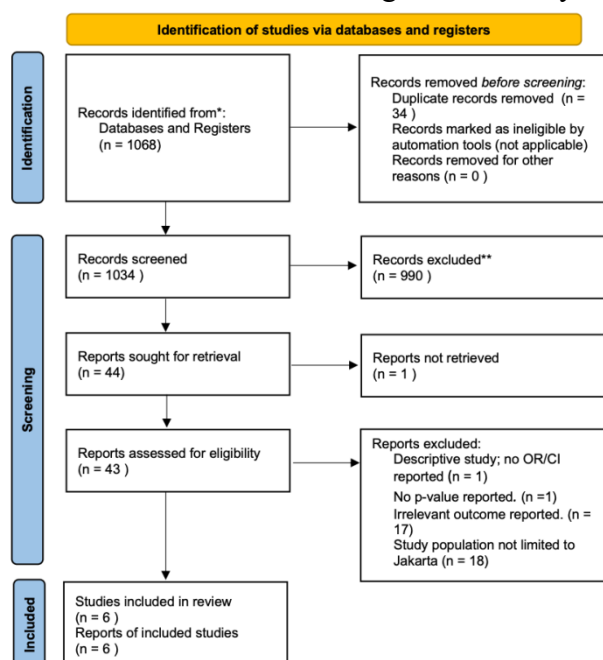
Following duplicate removal, titles and abstracts were screened, followed by full-text assessments to determine eligibility. Data extracted from the included studies included author and publication year, study design, population characteristics, exposure assessment methods, respiratory outcomes, effect estimates, and statistical significance. The study selection process was presented in a PRISMA flow diagram.

Risk-of-bias assessment was performed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools according to each study design, including cross-sectional, ecological, and case-crossover studies. Based on the appraisal results, studies were categorized as having low or moderate risk of bias. Common methodological limitations included insufficient adjustment for confounding factors and the use of aggregated exposure data.

RESULTS AND DISCUSSION

The systematic literature search identified relevant studies from PubMed, ScienceDirect, and Google Scholar. After removal of duplicate records, titles and abstracts were screened, followed by full text assessment based on the predefined eligibility criteria. A total of six studies fulfilled the inclusion criteria and were included in this systematic review. The study selection process is illustrated in the PRISMA flow diagram.

Figure 1. PRISMA Chart Flow Diagram for Study Selection



The included studies comprised various observational designs, including ecological, cross sectional, and case crossover studies. Study populations ranged from school aged children to the general population of Greater Jakarta, with sample sizes varying from small school based

samples to large population level datasets. Exposure assessment methods included ambient and indoor measurements of PM_{2.5} and PM₁₀, while respiratory outcomes evaluated across studies included acute respiratory infections, pneumonia, asthma exacerbations, hospital visits, and mortality. A summary of study characteristics and key findings is presented in Table 1.

Table 1. Data Extracted from Included Studies

Author (Year)	Title	Study Design	Population (P)	Exposure (I)	Comparison (C)	Outcomes & Findings	Significance
Amalia, Resosudarmo & Bennett (2013)	<i>The Health Impact of Air Pollution on Children in Jakarta</i>	Cross-sectional (SUSEN AS 2004 survey)	Children in Jakarta Metropolitan Area; ≈200,000 households	Ambient PM ₁₀ (long-term)	Lower exposure subdistricts	PM ₁₀ correlated with restricted activity days (RAD) and respiratory illnesses	p<0.05; no OR/CI reported
Haryanto, Trihandini & Nugraha (2024)	<i>Indirect Effects of PM_{2.5} Exposure on COVID-19 Mortality in Greater Jakarta, Indonesia: An Ecological Study</i>	Ecological time-trend	Residents of Greater Jakarta; 12 municipalities (≈30M population)	Short-term & long-term PM _{2.5}	Lower exposure	Long-term PM _{2.5} linked to ↑ COVID-19 mortality; short-term inverse correlation	+50 µg/m ³ long-term PM _{2.5} → +11.9% COVID-19 mortality (p<0.05)
Mulia, Rahardjo & Pratama (2020)	<i>Indoor Air Pollution and Respiratory Function on Primary School Students in West Jakarta, Indonesia</i>	Cross-sectional	100 primary school students, West Jakarta (age 10–11)	Indoor PM _{2.5} (classrooms)	Lower levels	Indoor PM _{2.5} ↑ → obstructive pulmonary symptoms; no link with airborne bacteria	χ ² tests, p<0.05; no OR/CI
Haryanto, Jalaludin & Asyary (2025)	<i>Associations Between Ambient PM_{2.5} Levels and Children's Pneumonia and Asthma During the COVID-19 Pandemic in Greater Jakarta (Jabodetabek)</i>	Ecological (2020–2022 pandemic)	Children in 11 Greater Jakarta cities; 73,694 pneumonia cases & 15,825 asthma cases	Short-term PM _{2.5} (monthly)	Lower levels	Pneumonia strongly linked to PM _{2.5} ; asthma weaker, NS	Pneumonia: r=0.61, p=0.004; Asthma: NS

Author (Year)	Title	Study Design	Population (P)	Exposure (I)	Comparison (C)	Outcomes & Findings	Significance
Adilasari, Setiani & Raharjo (2025)	<i>Association Between PM_{2.5} and PM₁₀ with Acute Respiratory Infection in North and East Jakarta</i>	Analytical observational + spatial	≈2.26M residents across 6 subdistricts (Kelapa Gading, Koja, Tanjung Priok, Cilincing, Pulogadung, Cakung); ARI cases from Puskesmas	Ambient PM _{2.5} & PM ₁₀ (2024)	Lower concentrations	PM _{2.5} significantly associated with ARI; PM ₁₀ not significant	PM _{2.5} : Z=2.640, p=0.008; PM ₁₀ : NS
Anggakusuma, Utama & Agustian (2024)	<i>Ambient Air Pollution and Visit of Asthma Patients: Case Study in DKI Jakarta 2017</i>	Time-stratified case-crossover	Asthma patients (ICD-10 J45) visiting 5 Puskesmas (Cakung, Kebon Jeruk, Kelapa Gading, Pasar Minggu, Senen) in 2017	Ambient PM ₁₀ (lag 1–3 days)	Lower PM ₁₀ exposure (control days ±7,14)	PM ₁₀ not significantly associated with asthma visits	OR ~1.00; 95% CI crossed 1; p>0.05 (NS)

Overall, exposure to PM_{2.5} demonstrated consistent associations with adverse respiratory health outcomes. Both short and long term increases in PM_{2.5} levels were associated with higher respiratory morbidity, including acute respiratory infections, pneumonia, and asthma exacerbations. Several studies also reported increased mortality associated with elevated PM_{2.5} concentrations, particularly during periods of high pollution. One ecological study found that a long term increase of 50 µg/m³ in PM_{2.5} concentration was associated with an 11.9% increase in COVID-19 related mortality.

In contrast, the evidence regarding PM₁₀ exposure was less consistent. Some studies reported weak or non-significant associations between PM₁₀ concentrations and respiratory outcomes, particularly asthma related healthcare visits. While cross sectional data suggested correlations between PM₁₀ exposure and respiratory symptoms, analytical studies generally did not demonstrate statistically significant associations.

Risk of bias assessment using the Joanna Briggs Institute Critical Appraisal Tools indicated that two studies were classified as having low risk of bias, while four studies were assessed as having moderate risk. The most common methodological limitations included inadequate adjustment for potential confounders and reliance on aggregated exposure data.

Figure 2. Risk of Bias Assessment of Included Studies

Study (Author, Year)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Overall Risk of Bias
Anggakusuma et al., 2017	✓	✓	✓	✓	✓	✓	✓	✓		✓	Low
Resosudarmo et al., 2013	✓	✓	?	?	✓	✓	✓	✓			Moderate
Haryanto et al., 2024	✓	✓	✓	✓	?	–	✓				Moderate
Mulia et al., 2020	✓	✓	✓	✓	✓	✓	✓	✓			Low
Haryanto et al., 2025	✓	✓	✓	✓	?	–	✓				Moderate
Adilasari et al., 2025	✓	✓	✓	✓	?	?	✓	✓			Moderate

This systematic review demonstrates that exposure to particulate matter, particularly PM_{2.5}, is consistently associated with adverse respiratory health outcomes in Jakarta. The findings indicate that both short and long term PM_{2.5} exposure contribute to increased respiratory morbidity, including acute respiratory infections, pneumonia, and asthma exacerbations, as well as increased mortality. These results are in line with global evidence identifying PM_{2.5} as the most harmful fraction of particulate air pollution due to its ability to penetrate deep into the alveoli and induce systemic inflammation (Pope & Dockery, 2006; Schraufnagel, 2020).

The stronger and more consistent associations observed for PM_{2.5} compared with PM₁₀ can be explained by differences in particle size and biological mechanisms. Fine particles are capable of reaching the lower respiratory tract and entering the bloodstream, triggering oxidative stress, endothelial dysfunction, and immune dysregulation, which increase susceptibility to infections and exacerbate chronic respiratory diseases (Kelly & Fussell, 2015; Anderson et al., 2012). In contrast, PM₁₀ particles tend to deposit in the upper airways, which may partly explain the weaker and less consistent associations with clinical outcomes observed in this review.

The association between long-term PM_{2.5} exposure and increased COVID-19 mortality observed in one included study supports growing evidence that chronic air pollution exposure may worsen outcomes of respiratory viral infections. Long term exposure to PM_{2.5} has been shown to impair pulmonary immune defense mechanisms and increase baseline cardiopulmonary vulnerability, thereby amplifying the severity of acute infections (Ciencewicki & Jaspers, 2007; Domingo & Rovira, 2020). These findings are consistent with international studies reporting higher COVID-19 mortality in regions with elevated ambient PM_{2.5} concentrations (Wu et al., 2020).

Despite the overall consistency of findings for PM_{2.5}, heterogeneity in study design, exposure assessment methods, and outcome definitions limits direct comparison across studies. Most included studies relied on ecological or aggregated exposure data, which may introduce exposure misclassification and residual confounding. Nevertheless, the risk of bias assessment indicated an overall low to moderate risk of bias, supporting cautious confidence in the observed associations.

From a public health perspective, the findings highlight the urgent need for strengthened air quality control and health surveillance in Jakarta. Reducing PM_{2.5} exposure through emission control, urban planning, and early warning systems during pollution peaks may substantially reduce the respiratory disease burden. Further longitudinal and individual-level

studies are needed to better quantify exposure response relationships and inform targeted interventions.

CONCLUSION

This systematic review addressed the existing evidence gap regarding the respiratory health impacts of particulate matter exposure in Jakarta by synthesizing findings from recent observational studies conducted in this highly polluted megacity. The results demonstrated that PM_{2.5} exposure, both in the short term and long term, was consistently associated with increased respiratory morbidity and mortality, whereas evidence regarding PM₁₀ remained limited and inconclusive. By integrating local epidemiological data, this review advanced current knowledge by providing Jakarta-specific evidence that complements and strengthens the global understanding of the health effects of particulate air pollution.

The findings provided a strong scientific basis for prioritizing PM_{2.5} as a critical target in air quality management and public health interventions. Given Jakarta's persistently elevated PM_{2.5} concentrations, reducing exposure may provide substantial benefits in lowering the burden of respiratory diseases, including infection-related morbidity and mortality. These results support the integration of air pollution mitigation strategies into urban health policies, the implementation of early warning systems during pollution episodes, and enhanced protection for vulnerable populations.

This review also highlighted important methodological limitations in the existing literature, including reliance on ecological study designs and aggregated exposure data. Future research should focus on longitudinal cohort studies and individual-level exposure assessments to better quantify exposure–response relationships and clarify potential causal pathways. Further studies investigating interactions between air pollution, comorbidities, and emerging respiratory infections are also warranted to support the development of more targeted and effective interventions.

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