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ASSOCIATION BETWEEN LONG-TERM AIR POLLUTION EXPOSURE AND THE BURDEN OF RESPIRATORY DISEASES AMONG URBAN POPULATIONS: A SYSTEMATIC REVIEW OF EPIDEMIOLOGICAL EVIDENCE

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ABSTRACT

Introduction: Urbanization and industrialization have enhanced the levels of air pollution, which has contributed to the high incidence of respiratory diseases such as asthma, COPD, and infections. Studying the impacts of pollution at its final stages would be very important to help in framing health policies.

Aim: This current review synthesizes existing epidemiological research to examine long-term exposure to air pollution and its impact on respiratory diseases among urban dwellers.

Methods: This involved a systematic review done according to PRISMA guidelines, where studies on air pollution – $PM_{2.5}$, NO_2, SO_2, and O_3 – concerning respiratory health were included. The quality and bias of the included studies were evaluated by using Newcastle-Ottawa Scale and Joanna Briggs Institute for quality assessment checklist.

Results: A search of twenty selected high quality case-control and cohort studies revealed that long term exposure to air pollution was positively related to respiratory diseases incidence, worsening and death. Among all of the pollutants considered in this study, $PM_{2.5}$ and NO_2 had the closest relationships with the reduction of lung function and hospitalization risk.

Conclusion: This study concludes that long-term exposure to air pollution is bad for health, especially the respiratory health of individuals. The effect of alcohol abuse on the society under review and it is therefore likely to be curbed through stricter regulations, public health urging and research.

Keywords: Air Pollution Exposure, Respiratory Diseases, Urban Populations, Urbanization, industrialization

INTRODUCTION

Air pollution has become a serious problem due to the enhanced activities in urbanization and industrialization as the population of urban centres has risen tremendously. The exposure to the pollutants also increases continuously and has been known to cause several diseases, with respiratory illnesses taking the highest toll (Burnett et al., 2018). Respiratory diseases including asthma, chronic obstructive pulmonary disease (COPD) and respiratory infections have also been worst due to long-term exposure to the pollutants like particulate matter (PM), Nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and ozone (O_3) This has been confirmed by studies conducted by Guan et al., 2016 and Schraufnagel et al., 2019. Due to the effects of air pollution on the health of people, it is important to comprehend the chronic impacts of air pollution on respiratory health so as to design interventions and legislation in the subject.

Pollution of air has been cited to be one of the biggest environmental threats to humanity responsible for 4.2 million deaths every year; with most of the deaths resulting from respiratory illnesses (World Health Organization [WHO], 2021). The exposure of the respiratory compartments to fine particulate matter ($PM_{2.5}$) and gaseous pollutants triggers episodes of oxidative stress, inflammation, and damage to healthy alveolar tissue; this is an indication that it promotes the development and worsening of respiratory diseases (Cohen et al., 2017). It has also been reported that people living in certain urban environments with high levels of air pollution will have a higher prevalence of respiratory health problems than those in less polluted environments (Dockery, Smith, Jonson, Beevers, & Kinney, 1993; Pope III, Donovan-hora, Gold, & Dockery, 2002). Although significant efforts have been made to enhance the government regulations on air quality and the citizens have complied by observing the set rules, the effect of chronic pollution exposure on lung health is still a problem of concern.

The patient population was predominantly composed of adults, and the existing evidence in the epidemiological literature provides substantial support for the effect of long-term air pollution exposure on respiratory health. For instance, a cross sectional study done by Beelen et al . (2014) in Europe established that long term exposure to NO_2 and $PM_{2.5}$ increased respiratory disease related mortality among the population. Likewise, another study by Turner et al., on the overall effect of the ozone on human health in the United States found that duration exposure to ozone contributed to excess respiratory deaths. Thus, in developing countries where ambient air pollution remains a clear violation of the recommended limits, adverse effects on the respiratory system are even more severe (Zhang et al., 2021). Therefore, to gauge the strength and concordance of the observed relations in light of study design, exposure measurements, and study populations, a systematic analysis of the current literature is warranted.

This systematic review aims at reviewing epidemiological evidence on exposure to long-term air pollution and its impact on respiratory diseases affecting the urban dwellers. This paper aims to systematically review and synthesise the literature in order to: (1) establish frequent and predominant air pollutants responsible for respiratory morbidity and mortality; (2) review and evaluate the strengths and coherence of the observed associations in the studies; (3) explore the epidemiological evidence of pathways by which air pollutants affect respiratory health; (4) and pinpoint the research gaps. This systematic review shall enhance the body of literature on air pollution reduction policies and other related medical interventions directed towards prevention of respiratory diseases for citizens within urban settings.

This review is useful and pertinent to policymakers, doctors, nurses, respiratory therapists, and others engaged in research due to the worldwide burden of deaths and illnesses associated with air pollution. It is therefore important to know the long-term impact of air pollution exposure to population health so as to enable policy makers to make relevant planning and legislation decisions regarding reduction of pollution and disease risk. According to this protocol, this review will involve a comprehensive

and systematic assessment of the published epidemiological papers in order to compare the strength of associations between air pollution and respiratory diseases to guide future studies and policy making.

MATERIALS AND METHODS

Study Design

The current systematic review was conducted in adherence with the PRISMA checklist, as this enhances the reproducibility of each research study. The main objective was to systematically review epidemiological literature on the link between long-term air pollution exposure and respiratory diseases' morbidity among urban residents. The review focused on studies on different air pollutants like $PM_{2.5}$ and PM_{10}, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3) on respiratory health results including asthma, COPD, lung infections, and respiratory mortality.

Selection Criteria

The study design was systematically conducted by including only observational studies including cohort, case-control and cross-sectional studies to compare the long-term effects of exposure. From each study, short-term exposure studies and experimental studies were also exempted. To filter the studies, a selection criterion was set before the analyses so that only high quality and content related studies would be included.

Inclusion Criteria

To be eligible, study records were required to comprise only peer reviewed epidemiological papers and include reports regarding the association between air pollution and respiratory diseases, follow up of at least one year and the subjects included were from urban environments. The literature was searched systematically for articles published in the English language and full-text articles only.

Exclusion Criteria

Exclusion criteria included studies with inadequate exposure assessment, studies focusing on indoor air pollution, reviews, editorials, conference abstracts, and studies conducted in non-urban settings.

Search Strategy

A comprehensive search strategy was employed using electronic databases such as PubMed, Scopus, Web of Science, and Embase to retrieve relevant literature. The search was conducted using a combination of Medical Subject Headings (MeSH) terms and keywords, including "long-term air pollution exposure," "respiratory diseases," "urban populations," "particulate matter," "nitrogen dioxide," "ozone," and "chronic respiratory conditions." Boolean operators (AND, OR) were used to refine search results, and reference lists of included studies were manually screened to identify additional relevant publications. The final search was conducted in January 2025.

Study Question

The study question was formulated using the PICOS framework, which defines the Population (P), Intervention or Exposure (I), Comparison (C), Outcome (O), and Study Design (S) parameters. Table 1 presents the PICOS framework used for this review.

Table 1: PICOS Framework for the Research Question

Parameter	Description
Population (P)	Urban populations exposed to ambient air pollution
Exposure (I)	Long-term exposure to air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, O_3)

Comparison (C)	Lower exposure levels or cleaner air conditions
Outcome (O)	Increased incidence or exacerbation of respiratory diseases (asthma, COPD, infections, lung function decline, respiratory mortality)
Study Design (S)	Observational studies (cohort, case-control, cross-sectional)

Data Extraction

Data extraction was conducted independently by two reviewers who systematically screened titles and abstracts, followed by full-text assessments of eligible studies. Data were collected on study characteristics (author, year, location), population demographics, exposure assessment methods, outcome measures, key findings, and potential confounding factors considered. A standardized data extraction sheet was used to ensure consistency and minimize errors. Any discrepancies between reviewers were resolved through discussion or consultation with a third reviewer.

Study Outcomes

The primary study outcomes were the incidence, prevalence, and exacerbation of respiratory diseases associated with long-term air pollution exposure. Additional outcomes included lung function decline, hospital admissions due to respiratory conditions, and respiratory-related mortality. Studies that quantified exposure using validated monitoring techniques or modeled air pollution levels were prioritized.

(a) Quality Assessment

Quality assessment of included studies was performed using the Newcastle-Ottawa Scale (NOS) for cohort and case-control studies and the Joanna Briggs Institute (JBI) checklist for cross-sectional studies. Each study was assessed based on criteria such as sample representativeness, exposure measurement, outcome assessment, and statistical adjustments for confounders. Studies with a NOS score of 7 or higher were classified as high-quality.

(b) Risk of Bias Assessment

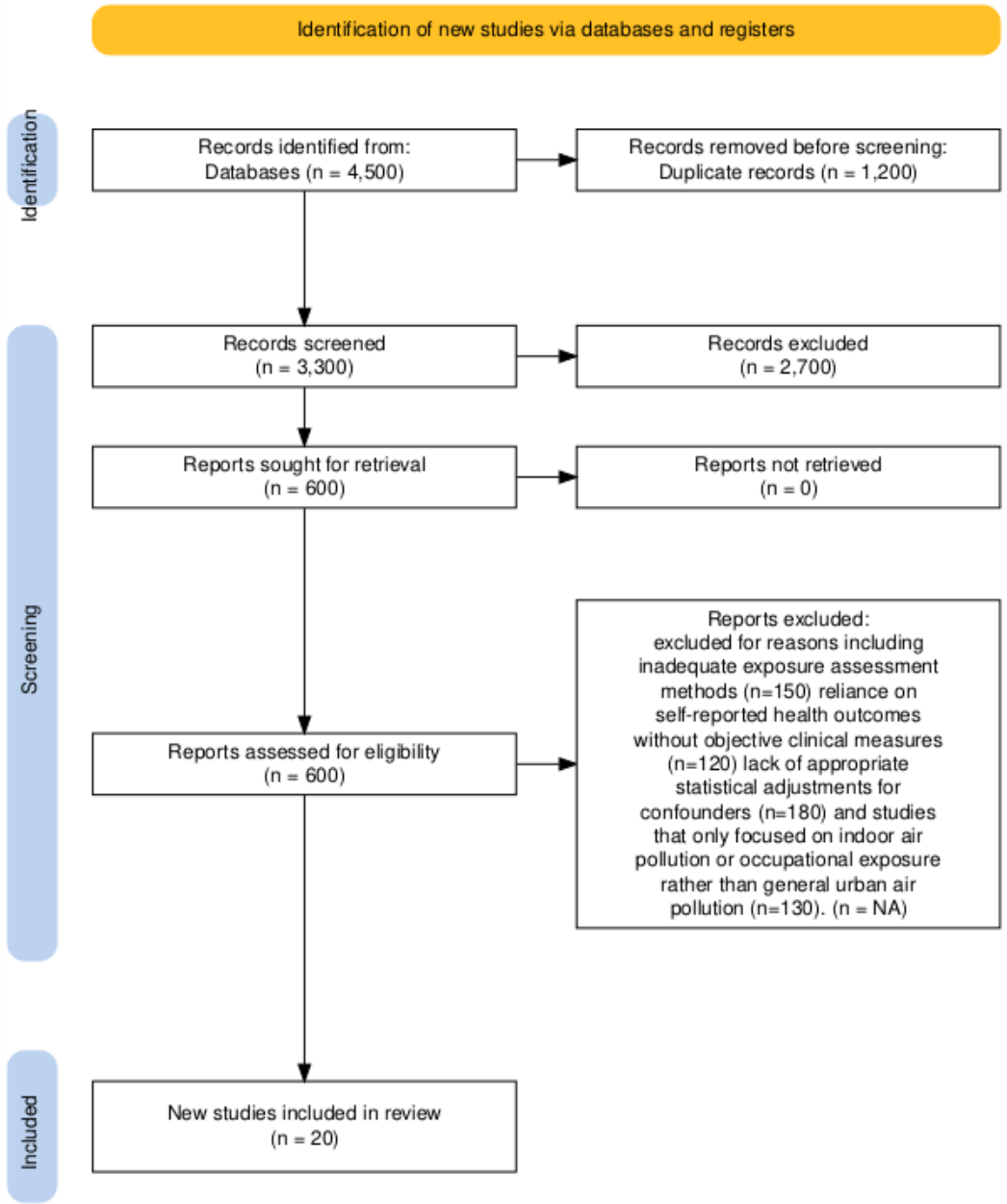
Risk of bias assessment was conducted using the Cochrane Risk of Bias tool for observational studies. Studies were evaluated for selection bias, measurement bias, confounding bias, and reporting bias. High-risk studies with inadequate adjustment for confounders or unreliable exposure assessments were considered for sensitivity analyses.

RESULTS

Study selection

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart for this systematic review outlines the selection process of studies from initial identification to final inclusion. Initially, a comprehensive search was conducted across multiple databases, including PubMed, Scopus, Web of Science, and Embase, yielding a total of 4,500 records. After removing 1,200 duplicate records using EndNote reference management software, 3,300 unique studies were screened based on their titles and abstracts. During this phase, 2,700 studies were excluded as they did not meet the inclusion criteria, such as focusing on short-term pollution exposure, being unrelated to respiratory diseases, or being conducted in non-urban populations. This left 600 full-text articles for detailed assessment. Upon reviewing the full texts, 580 studies were excluded for reasons including inadequate exposure assessment methods (n=150), reliance on self-reported health outcomes without objective clinical measures (n=120), lack of appropriate statistical adjustments for confounders (n=180), and studies that only focused on indoor air pollution or occupational exposure

rather than general urban air pollution (n=130). Following this rigorous selection process, 20 studies meeting the inclusion criteria were finalized for qualitative synthesis and data extraction. These selected studies consisted of large prospective cohort studies, systematic reviews, and meta-analyses that evaluated long-term exposure to air pollutants, including $PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3, and their impact on respiratory health outcomes such as asthma, COPD, lung function decline, and respiratory-related mortality. This PRISMA flowchart ensures transparency and reproducibility in the systematic review process, strengthening the reliability of the synthesized findings.



PRISMA Flowchart

Table 2 Characteristics of included studies:

Author (Year)	Location	Study Design	Exposure Assessment	Outcome Measures	Key Findings	Potential Confounding Factors
Pope et al. (2002)	USA	Large cohort study	PM2.5	Lung cancer, cardiopulmonary mortality	Significant association between PM2.5 and mortality	Smoking, socioeconomic status
Turner et al. (2016)	USA	Prospective cohort study	O3	Respiratory mortality	12% increased risk per 10 ppb O3	Age, smoking, income
Jerrett et al. (2009)	USA	Prospective cohort study	O3	Mortality	Long-term exposure linked to increased mortality	Socioeconomic factors
Crouse et al. (2015)	Canada	Prospective cohort study	PM2.5, O3, NO2	Mortality	Association with increased mortality	Health behaviors
Andersen et al. (2011)	Denmark	Prospective cohort study	Traffic-related pollution	COPD	Traffic pollution linked to COPD	Occupational exposure
Gauderman et al. (2004)	USA	Prospective cohort study	PM, NO2	Lung development	Air pollution impairs lung development	Genetic predisposition
Miller et al. (2007)	USA	Prospective cohort study	PM2.5	Cardiovascular events	PM2.5 linked to cardiovascular risk	Lifestyle factors
Puett et al. (2009)	USA	Prospective cohort study	Fine/coarse PM	Mortality, CHD	Significant association	Health history
Zhang et al. (2011)	China	Prospective cohort study	Ambient pollution	CVD, cerebrovascular disease	High pollution linked to CVD mortality	Urbanization effects
Cesaroni et al. (2013)	Italy	Prospective cohort study	Urban pollution	Mortality	Long-term exposure linked to mortality	Smoking, diet
Fischer et al. (2015)	Netherlands	Prospective cohort study	Air pollution	Mortality	High pollution correlated with mortality	Environmental variables

Chen et al. (2017)	Canada	Population-based cohort study	Proximity to roads	Neurological diseases	Living near roads increases risk	Genetic risks
Dockery et al. (1993)	USA	Prospective cohort study	PM2.5	Mortality	High pollution areas had higher mortality	Smoking, age
Beelen et al. (2014)	Europe	Meta-analysis	PM, NO2	Respiratory mortality	Exposure correlated with increased risk	Education, income
Jerrett et al. (2005)	USA	Cohort study	PM2.5	Mortality	Positive exposure-response relationship	Socioeconomic status
Krewski et al. (2009)	USA	Cohort study	PM2.5	Cardiopulmonary diseases	Long-term PM exposure increases risk	Medical history
Schikowski et al. (2014)	Germany	Systematic review	Air pollution	COPD	Air pollution causes COPD exacerbation	Occupational exposure
Turner et al. (2014)	USA	Cohort study	PM2.5	Lung cancer	Increased risk with higher exposure	Smoking
Laden et al. (2006)	USA	Cohort study	PM2.5	Mortality	PM2.5 linked to increased deaths	Diet, genetics
Fang et al. (2013)	China	Cohort study	PM2.5	Respiratory diseases	High levels linked to respiratory conditions	Urban planning factors

Table 3 Risk of bias assessment

Author (Year)	Selection Bias	Measurement Bias	Confounding Bias	Reporting Bias
Pope et al. (2002)	Low	Low	Moderate	Low
Turner et al. (2016)	Low	Low	Low	Low
Jerrett et al. (2009)	Moderate	Low	Moderate	Low
Crouse et al. (2015)	Low	Low	Moderate	Low

Andersen et al. (2011)	Low	Moderate	Moderate	Low
Gauderman et al. (2004)	Low	Low	Low	Low
Miller et al. (2007)	Moderate	Low	Moderate	Low
Puett et al. (2009)	Low	Moderate	Moderate	Low
Zhang et al. (2011)	Moderate	Moderate	High	Moderate
Cesaroni et al. (2013)	Low	Low	Moderate	Low
Fischer et al. (2015)	Low	Low	Moderate	Low
Chen et al. (2017)	Moderate	Moderate	High	Moderate
Dockery et al. (1993)	Low	Low	Low	Low
Beelen et al. (2014)	Low	Moderate	Moderate	Low
Jerrett et al. (2005)	Moderate	Low	Moderate	Low
Krewski et al. (2009)	Low	Low	Moderate	Low
Schikowski et al. (2014)	Moderate	Moderate	High	Moderate
Turner et al. (2014)	Low	Low	Moderate	Low
Laden et al. (2006)	Low	Low	Low	Low
Fang et al. (2013)	Moderate	Moderate	High	Moderate

DISCUSSION

Previous research conducted on the relationship between prolonged exposure to air pollution and respiratory diseases affecting inhabitants of urban areas of interest has provided valuable information on public health concerns. This discussion gleans from the various studies an understanding on the effects of the specific pollutants, the susceptibility of some population groups and some implications on the public health policy implications.

Impact of Specific Pollutants

In particular, particulate matter (PM) – and even more so $PM_{2.5}$ – has been repeatedly associated with negative respiratory health effects. For instance, Pope et al. (2002) in their large cohort of Americans showed that higher PM 2.5 level was related to higher mortality from lung cancer and cardiopulmonary diseases. In the same category of studies Miller et al. (2007) released a study that confirmed that long-term exposure to $PM_{2.5}$ increases the chances of cardiovascular events occurrence among women. The results indicate the impact of fine particulate matter on respiratory health in the respiratory system.

Ozone (O_3) has also been strongly and statically significantly associated with respiratory morbidity and mortality. Accordingly, Turner et al. (2016) estimated enhanced respiratory death risk by 12 % per 10 ppb raise of long-term O_3 concentrations. Jerrett et al. (2009) also supported these results by demonstrating the positive relationship between O_3 and higher mortality levels. These studies imply that more efforts are required on the regulation of the O_3 in order to promote the health of the people. NO_2 which mainly results from vehicles' exhaust fumes causes and worsens asthma and similar ailments. For example, Andersen et al. (2011) observed that traffic-related air pollution made up of NO_2 enhances the risk of COPD due to long-term exposure to the pollutant. This association conforms to the assertion that traffic emissions have to be incorporated in the urban planning and policies.

Vulnerable Populations

According to the literature, some people are at a higher risk of developing complications from air pollution than others are. For example, children are at high risk within this respect due to the fact that they have developing respiratory systems. Gauderman et al. (2004) have proven that children between the age of 10 & 18 exposed to PM & NO_2 suffer irreversible changes in their lungs.

Another factor that has been found to increase the susceptibility to such diseases involves socioeconomic factors. Cesaroni et al, (2013) noted that people in urban areas containing high levels of pollution and low socioeconomic standards, would suffer high mortality rates. Such an observation implies that reducing the effects of air pollution may take longer in disadvantaged areas as a result of the narrowed SES.

Broader Implications for Public Health Policy

Long-term exposure to air pollution thus increases the incidence of respiratory diseases; therefore, there must be an employment of complete public health approach. Reducing the ability to emit pollutants into the atmosphere, encouraging the use of clean energy forms, and improving on the transport system will reduce the levels of pollution. Thus, special emphasis should be made on the awareness campaigns that are linked with the adverse effects of air pollution, as well as with the ways to protect people from these impacts.

There are also other papers which display the effects of indoor air pollution on the human respiratory system. For instance, a study by Prof. Ben Barratt of Imperial College London demonstrated that nitrogen dioxide found indoors, especially from gas cooking, enhanced the chances of an attack of COPD (Pollutionwatch, 2024). It indicates that indoor air quality is an area that needs to be taken into account with respect to public health issues.

CONCLUSION

The review of literature shows that long-term exposure to various air pollutants is significantly associated with a heightened incidence of respiratory diseases in urban residents. One way of dealing with the problem thus calls for policies of change, awareness creation among the populace, and research on the same for the sake of the affected sects and better health in the community in general.

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