AIR POLLUTION AND ITS EFFECT ON UPPER RESPIRATORY TRACT INFECTIONS: A SCOPING REVIEW FROM 2010 TO 2019

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Air pollution is a significant global health concern, linked to numerous severe health outcomes, particularly respiratory infections. However, the effects of air pollution components on upper respiratory tract infections (URTI) remain limited. This study aims to synthesize the impact of air pollution on URTI from 2010 to 2019 to provide a basis for effective public health interventions. A total of 23 studies were included in the analysis, with results showing that pollutants such as PM10, PM2.5, NO2, SO2, and O3 were closely linked to URTI, particularly in children. PM10 and PM10 were identified as having the greatest impact. These findings affirm the need for further research to develop effective pollution control measures, thereby reducing the burden of upper respiratory tract infections.

Keywords: Air pollution, upper respiratory tract infections, a scoping review, period 2010 - 2019.

I. INTRODUCTION

Air pollution is a significant global health concern that has been linked to a variety of adverse health outcomes. It consists of a mixture of harmful substances, including particulate matter (PM10 and PM2.5), nitrogen oxides (NOx), sulfur dioxide (SO2), and ozone (O3), which are released from sources such as industrial activities, vehicular emissions, agricultural practices, and natural phenomena like wildfires and volcanic eruptions. The World Health Organization (WHO) reports that 90% of the global population lives in areas where ambient air pollution surpasses current local regulation.[1] Exposure to ambient air pollutants is a well-established risk factor for several adverse respiratory outcomes.[2]

Acute respiratory infections among adults are common and represent a major source of disease burden.[3] The number of deaths among people above 70 years old rose from nearly 750,000 to 1.1 million annually between 2000 and 2016.[4] Upper respiratory tract infections (URTI), which include conditions such as acute rhinitis, pharyngitis, laryngitis, and sinusitis, are among the most common health issues influenced by air pollution. Upper respiratory tract infection is responsible for 81% of emergency room hospital outpatients for respiratory diseases in children aged 0 - 18 years.[5] These infections lead to significant morbidity and economic costs due to increased healthcare utilization and loss of productivity.

Most studies have focused on assessing the impact of air pollution on the lower respiratory

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system, while the upper respiratory tract is most exposed to air pollution. Evidence of the adverse effects of air pollution on lower respiratory tract illnesses is growing, there is limited knowledge about its impact on upper respiratory tract symptoms (URTS).[6] Despite these findings, there is a notable gap in comprehensive, region-specific studies that explore the full extent of air pollution's impact on URTS. This gap highlights the need for focused research to understand the local epidemiology and guide effective public health interventions. This study seeks to address the research question: What is the impact of air pollution on the incidence of upper respiratory tract infections? Therefore, the aim of this scoping review is: To synthesize the effect of air pollution on upper respiratory tract infections attributed in worldwide from 2010 to 2019.

II. OVERVIEWS

1. Materials and methods

Study design

This is an applied scoping review method.

Search methods for identification of studies

A systematic search strategy using the Population, Concept, and Context (PCC) framework will be employed to identify relevant studies published between January 2010 and June 2019. The population of interest includes humans, with a specific focus on vulnerable groups such as children, the elderly, and individuals with pre-existing respiratory conditions. The concept revolves around various types of air pollution, including particulate matter (PM10, PM2.5), nitrogen oxides (NOx), sulfur dioxide (SO2), and ozone (O3), and their association with URTIs such as acute rhinitis, pharyngitis, laryngitis, and sinusitis. The context spans a global scope, aiming to capture diverse geographical regions to understand variations in pollution levels and health outcomes.

The search was conducted across 3 databases, including PubMed, Google Scholar, and Web of Science using a combination of keywords and Boolean operators.

Keywords such as "air pollution," "particulate matter," "upper respiratory tract infections," "acute rhinitis," "pharyngitis," "laryngitis," "sinusitis," and related terms will be used in various combinations to refine the search results. Boolean operators like AND, OR, and NOT will help narrow or expand the search as needed. Example search strings include "humans AND air pollution AND upper respiratory tract infections AND global" and "children AND PM2.5 AND acute rhinitis AND regional variations". Medical Subject Headings (MeSH) terms such as "Air Pollution," "Particulate Matter," "Nitrogen Oxides," "Sulfur Dioxide," "Ozone," and "Respiratory Tract Infections" will be used.

Selection of studies and management

To remove duplicate studies, a thorough review of all collected references was conducted using Endnote X20 software. The initial screening involved reviewing titles and abstracts to exclude studies that do not meet the inclusion criteria, such as those focusing on lower respiratory tract infections, non-peer-reviewed articles, or studies conducted on animals. Full-text articles of potentially relevant studies were retrieved and assessed for eligibility against strict inclusion criteria, which require studies to be peer-reviewed, published within the specified timeframe, focused on human populations, and available in English. Two independent reviewers evaluated each full-text article to confirm its eligibility, and any disagreement was resolved through discussion or consultation with a third reviewer.

Data extraction and analysis

The information that was extracted included:

- Author Names.
- Publication Year.
- Study Design.
- Sample Size.
- Population Demographics.
- Exposure substances: PM2.5, PM10, NOx, SO2, O3.
- Exposure Assessment Methods.
- URTI Types (e.g., acute rhinitis, pharyngitis, laryngitis, sinusitis).
- Association Findings.

Research ethics

The review prioritized studies that reported obtaining informed consent from participants, ensuring that the rights and welfare of participants were respected. The data synthesis was conducted transparently and objectively, avoiding any bias that could arise from ethical conflicts.

2. Results

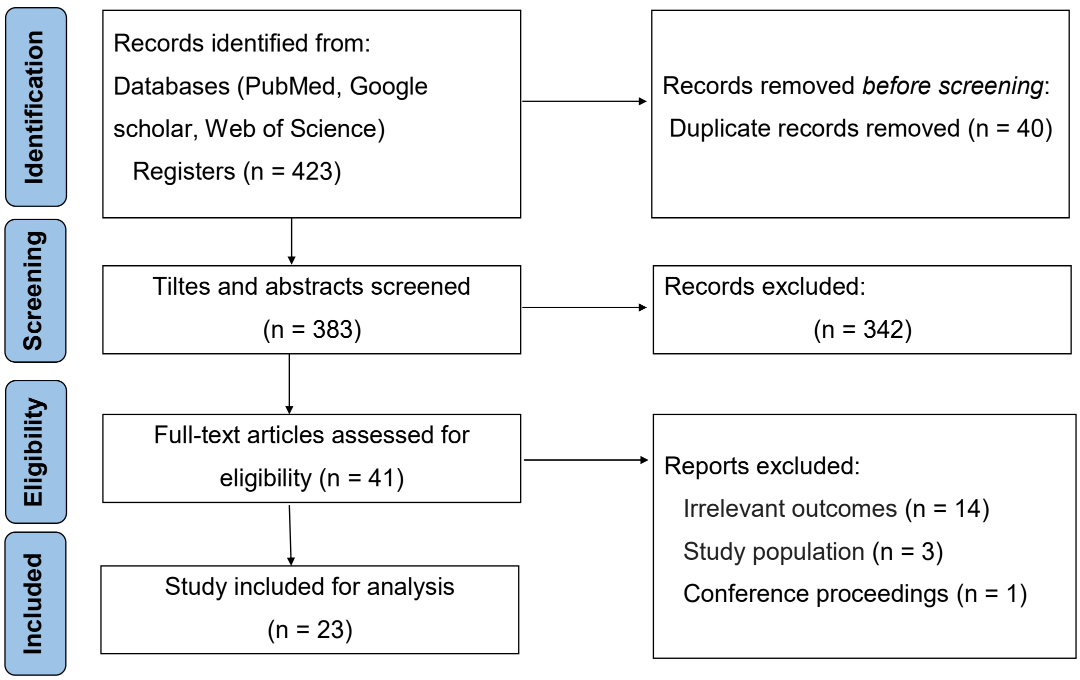

Figure 1. PRISMA Flow diagrams

Through the literature search for the study, the results were (n = 423) abstracts screened from databases (PubMed, Google Scholar, Web of Science). After eliminating duplicates (n = 40) and reviewing to eliminate further (n = 342) articles that did not meet the research objectives, research subjects, and research issues, (n = 41) full-text articles were further screened. The results (n = 20) were eliminated due to irrelevant outcomes (n = 14), study population (n = 3), and conference proceedings (n = 1). The remaining results (n = 23) were review articles eligible for synthesis and analysis of results.

Table 1 shows studies from 2010 - 2019, the number of studies increased gradually from 2010 - 2015 and tended to stabilize from 2016 - 2019. Asia had the highest proportion of studies (52.2%), Europe (17.3%), and America (30.5%). In particular, China accounted for 58.3% of the

Asian region. 43.7% of the study designs were time series studies, 34.7% were cross-sectional studies, 13.0% were cohort studies, and 8.6% were multi-site time-stratified case-crossover studies. The majority of the study age group was children under 15 years old (11/23 (47.8%) of the studies). The study sample size also varied by region of each country.

Table 1. General characteristics of the studies

No	Author(s), Year	Country/ Region	Study design	Sample size	Age/ Age group
1	M. Simoni, 2010[6]	Europe	Cross-sectional	654	10
2	Marcos Abdo Arbex, 2011[7]	Brazil	Time series study	137,530	All
3	Ana C. Amarillo, 2012[8]	Argentina	Cross-sectional	81,569	All
4	Yu-Kai Lin, 2013[9]	Taiwan	Cross-sectional	39,766	0 - 14
5	Lyndsey A. Darrow, 2014[10]	America	Time series study	359,246	0 - 4
6	Elaina A. MacIntyre, 2014[11]	Europe	Cross-sectional	16,059	0 - 3
7	Wilson W S Tam, 2014[12]	Hong Kong	Time series study	817,240	All
8	Francine Heloisa Nicolussi, 2014[13]	Brazil	Cross-sectional	139	6 - 7
9	Hwa-Lung Yu, 2015[14]	Taiwan	Cross-sectional	NA	6 - 14
10	Young Hoon Joo, 2015[15]	Korea	Cross-sectional	21,116	≥ 19
11	Yonglin Liu, 2015[16]	China	Cross-sectional	15,323	All
12	William J. Shaughnessy, 2015[17]	America	Time series study	NA	0 - 18
13	Matthew J Strickland, 2016[18]	America	Multi-site time-stratified case-crossover	414,556	All
14	Brian J. Malig, 2016[19]	America	Multi-site time-stratified case-crossover	86,678	All

No	Author(s), Year	Country/ Region	Study design	Sample size	Age/ Age group
15	Tzu-Ying Chiang, 2016[20]	Taiwan	Time series study	587	11 - 14
16	Pei-Wen Zheng, 2017[21]	China	Time series study	407,028	0 - 14
17	Xiaolin Xia, 2017[22]	China	Time series study	11,994	All
18	Kristina Trnjar, 2017[23]	Croatia	Time series study	5868	All
19	Y R Li, 2018[24]	China	Time series study	310,421	0 - 14
20	Dan Norbäck, 2018[25]	China	Cohort study	39,782	3 - 6
21	Emilie Burte, 2018[26]	Europe	Cohort study	1533	≥ 18
22	Daitao Zhang, 2019[27]	China	Time series study	17,288,666	All
23	Jinyue Liu, 2019[28]	China	Cohort study	40,172	All

All: All ages

Table 2. Impact of pollutants on URTI

Author(s), Year	Pollutants measured	URTI	Association Findings
M. Simoni, 2010[6]	PM10	rhinitis	Schoolchildren exposed to PM10 > 50 mg/m^3 showed a significantly higher risk for rhinitis (Crude OR = 1.17 (0.76 -1.82), not significant
Marcos Abdo Arbex, 2011[7]	PM10, SO2, NO2	J00–J06	An interquartile range increase in PM10 concentration (28.26 g/m^3) led to increases in URTI ER visits. It was observed a three-day cumulative effect (from lag0 to lag2) of 8.9% (95% CI: 5.7 - 12.0)
Ana C. Amarillo, 2012[8]	PM10	J00–J06	There is a percentage increase (1.91%, 95% CI: 1.48 - 2.35) in the risk of upper (URI) infections for every 10 mg/m^3 increase in particles (PM10).
Yu-Kai Lin, 2013[9]	NO2, O3, PM2.5	J00–J06	Cumulative 6-day RRs were 1.25 (95% CI: 1.21 - 1.29) for NO2, 1.04 (95% CI: 1.01 - 1.06) for O3, and 1.00 (95% CI: 0.98 - 1.03) for PM2.5 at the 95th percentile

Author(s), Year	Pollutants measured	URTI	Association Findings
Lyndsey A. Darrow, 2014[10]	NO_2, $PM_{2.5}$, PM_{10}, $PM_{2.5-10}$ (coarse PM)	Laryngitis, otitis media	For otitis media and laryngitis, results were generally null across all analyses except for NO_2 and otitis media (OR = 1.09; 95% CI: 1.02 - 1.16 per 10 μg/m³).
Elaina A. MacIntyre, 2014[11]	PM_{10}, O_3, SO_2, NO_2	J00–J06	The summary relative risks (with 95% confidence intervals) from all GOPC for NO_2, PM_{10}, O_3, and SO_2 were 1.005 (1.002 - 1.009), 1.010 (1.006 - 1.013), 1.009 (1.006 - 1.012) and 1.004 (1.000 - 1.008) respectively, per 10 μg/m³ increase in the concentration of each air pollutant.
Wilson W S Tam, 2014[12]	PM_{10}, O_3, NO_2	Rhinitis	There was a strong positive correlation between rhinitis symptoms and PM_{10} and NO_2 (r = 0.89 and 0.88).
Francine Heloisa Nicolussi, 2014[13]	$PM_{2.5}$, PM_{10}, NO_x, O_3	J00-J06	3-day moving average concentrations of ozone, nitrogen dioxide, were associated with ED visits for URI. O_3 associations were strongest and were observed at low (cold-season) concentrations; a 1–interquartile range increase predicted a 4% increase (95% confidence interval: 2%, 6%) in visits for URI
Hwa-Lung Yu, 2015[14]	$PM_{2.5}$, NO_x, O_3, cPM	J00-J06	For preschool children, a high $PM_{2.5}$ concentration (93.44 μg/m³) caused the RR percentage of clinic visits to greatly increase from 7.50% to 42.11% when $PM_{2.5}$ concentrations reached 100.33 μg/m³
Young Hoon Joo, 2015[15]	PM_{10}, SO_2, NO_2, O_3	Laryngitis	Elevated PM_{10} exposures could be associated with increased risk of Laryngitis (OR = 1.378; 95% CI: 1.006 -1.886, p = 0.0457). No correlation was detected between prevalence of Laryngitis and SO_2 (p = 0.2938), O_3 (p = 0.1182), NO_2 (p = 0.2943).
Yonglin Liu, 2015[16]	PM_{10}, SO_2, NO_2	J00-J06	PM_{10} alone and in combination with SO_2 and NO_2, into the model, but yet did not observe any significant correlation between PM_{10} and number of respiratory tract infection hospitalizations in children.

Author(s), Year	Pollutants measured	URTI	Association Findings
William J. Shaughnessy, 2015[17]	PM10	J00–J06	The analysis estimates a 0.6% increase in the weekly rate of emergency room visits for upper respiratory infections for every 10 μg/m^3 increase in the weekly-averaged PM10 concentration above the mean.
Matthew J Strickland, 2016[18]	PM2.5	J00–J06	For a 10 μg/m^3 increase in lag 0 PM2.5 concentration, there was a positive association with upper respiratory tract infections (OR = 1.015; 95% CI: 1.008 - 1.022). Associations for a 10 μg/m^3 increase in lag 1 PM2.5 concentration with upper respiratory tract infections (OR = 1.011; 95% CI: 1.004 - 1.018)
Brian J. Malig, 2016[19]	SO2, NO2, O3	J00–J06	Multiple O3 lags showed associations with URTI (ERlag03 = 2.5%, 95% CI: 0.4 - 4.6).
Tzu-Ying Chiang, 2016[20]	SO2	Rhinitis	The hazard ratios between exposure groups were 3.05, 2.74, and 1.93 for allergic rhinitis with significant difference in three periods: 1999 - 2002, 1999 - 2006, and 1999 - 2010.
Pei-Wen Zheng, 2017[21]	PM10, PM2.5, SO2, NO2	J00–J06	The effect estimates for acute upper respiratory infections tended to be higher (PM2.5 ER = 3.46, 95% CI: 2.18 - 4.76; PM10 ER = 2.81, 95% CI: 1.93 - 3.69; NO2 ER = 11.27, 95% CI: 8.70 - 13.89; SO2 ER = 15.17, 95% CI: 11.29 - 19.19).
Xiaolin Xia, 2017[22]	PM10, PM2.5, SO2, NO2	J00–J06	Acute upper respiratory infection hospitalizations were significantly increased by 13.5% (95% CI: 5.6 - 22) and 20.6% (95% CI: 5.6 - 37.7) per 10 μg/m^3 increases beyond the threshold in PM10 and PM2.5 respectively. No significant association was detected between SO2 and either acute respiratory infection.
Kristina Trnjar, 2017[23]	PM10, NO2, O3	J00–J06	The occurrence of respiratory diseases showed positive Spearman's correlation with the values of PM10 (days 0-3, r = 0.10 to 0.13) and NO2 concentrations (day 0, r = 0.11), and negative correlation with the values of O3 concentrations (days 0-3, r = -0.21 to -0.22) ($p < 0.05$ all).

Author(s), Year	Pollutants measured	URTI	Association Findings
Y R Li, 2018[24]	PM10, PM2.5, SO2, NO2, O3	J00–J06	Per 10 μg/m^3 increasing in concentrations of PM10 at lag3, PM2.5, SO2, NO2 and at lag06 were associated with an increase of Excess risk (ER) with 0.15% (95% CI: 0.07% ~ 0.23%), 0.38% (95% CI: 0.17% ~ 0.60%), 2.92% (95% CI: 1.88% ~ 3.97%), 4.47% (95% CI: 3.69% ~ 5.25%) and 0.05% (95% CI: 0.02% ~ 0.08%)
Dan Norbäck, 2018[25]	PM10, NO2, SO2	Rhinitis	Rhinitis was associated with PM10 (OR = 1.06, 95% CI: 0.96 - 1.18), NO2 (OR = 1.20, 95% CI: 1.09 - 1.32 per 10 μg/m^3)
Emilie Burte, 2018[26]	PM2.5, NO2	Rhinitis	No association between long-term air pollution exposure and incidence of rhinitis was found (adjusted IRR (aIRR) for an increase of 10 μg/m^3 of NO2: 1.00 [0.91 - 1.09] for an increase of 5 μg/m^3 of PM2.5: 0.88 [0.73 - 1.04]).
Daitao Zhang, 2019[27]	PM2.5	J00–J06	10 μg/m^3 increase in PM2.5 concentration was associated with a 0.84% (95% CI: 0.05 - 1.64%) increase in hospital admissions for URTI at lag 0 - 3 days, but there were no significant associations with emergency room or outpatient visits.
Jinyue Liu, 2019[28]	PM1, PM2.5	J00–J06	Neither PM1 nor PM2.5 has any effect on upper respiratory tract infections

**URTI: Upper respiratory tract infection; J00-J06: nasopharyngitis, sinusitis, pharyngitis, tonsillitis, laryngitis, tracheitis*

During the study period from 2010-2019, the pollutants measured were mainly PM2.5, PM10, NO2, SO2, O3. Most studies measured a combination of pollutants, (n = 6) studied each individual substance with the risk of upper respiratory tract infections (mainly PM2.5, PM10). There were (n = 16) studies that combined all upper respiratory tract infections from J00-J06, rhinitis (n = 5) and laryngitis (n = 2). There was a positive association between upper respiratory tract infections (J00-J06) and increased PM10 (n = 8), PM2.5 (n = 7), NO2 (n = 5), O3 (n = 4), SO2 (n = 4);[7-9,11,13-15,17-24,27,28] There was a positive association between rhinitis and PM10 (n = 3), NO2 (n = 3);[6,12,25,26] There was a positive association between laryngitis and PM10 (n = 1), NO2 (n = 1).[15] There was no association between upper respiratory tract infections (J00-J06) and PM10 (n = 1), PM2.5 (n = 1);[16,28] There was no association between laryngitis and NO2 (n = 1), O3 (n = 1), SO2 (n = 1).[15]

3. Discussion

A review of 23 studies from 2010 to 2019 shows a significant increase in research from 2010 to 2015, with a steady trend from 2016 to

2019. This reflects a growing interest in studying the impact of air pollutants on respiratory health, particularly in the context of globalization and the rapid growth of urban populations. Regionally, Asia had the highest proportion of studies (52.2%), with China accounting for 58.3% of studies in the region. This is understandable, as severe air pollution affects densely populated and rapidly industrializing areas like China, where air pollution is estimated to cause around 2 million deaths annually.[21] Notably, fine particulate matter pollution from PM10 and PM2.5 has rapidly and alarmingly increased in China. Europe and the Americas had lower proportions of studies, reflecting differences in environmental and social conditions.

The high rate of research in Asia indicates that the region is facing serious challenges related to air pollution and disease, highlighting the need for further studies to identify effective control measures. The time-series study design was the most commonly used (43.7%), as it is an effective method for assessing both the short-term and long-term impacts of air pollution on upper respiratory diseases. Notably the multi-site time-stratified case-crossover study (8.6%), though less common, can provide deeper insights into the causal relationship between pollution exposure and respiratory diseases. A significant finding of the studies is the focus on the under-15 age group, accounting for 47.8%. Respiratory infections are a leading cause of illness in children globally. While the underlying causes are not fully understood, exposure to pollutants is closely linked to upper respiratory infections. Children may be more vulnerable to the health impacts of ambient air pollution due to higher breathing rates, narrower airways, developing lungs and immune systems, and frequent exposure to outdoor air.[10]

Among the pollutants PM10, PM2.5, NO2, SO2, and O3 are the most commonly studied, reflecting the focus on particulate matter and toxic gases present in the air. Studies typically use a 10 μg/m^3 increase to assess the association between exposure to air pollutants and upper respiratory diseases. PM10, PM2.5 has been shown to be the pollutant most strongly associated with upper respiratory tract infections (J00-J06), as well as with rhinitis and laryngitis. The analysis estimated that the weekly hospitalization rate due to upper respiratory tract infections would increase by 0.6% - 1.91%, with a significant rise of up to 13.5% (95% CI: 5.6 - 22) for every 10 μg/m^3 increase in PM10 levels exceeding the permissible limit.[8,17,22] It was estimated that a 10 μg/m^3 increase in PM2.5 concentration is associated with a 0.84% increase (95% CI: 0.05 - 1.64%) in hospital admissions due to URTI.[27] PM10 has a positive correlation with URTI, with r values ranging from 0.10 - 0.13, and a very strong correlation with rhinitis, with an r = 0.89.[12,23] Schoolchildren exposed to PM10 > 50 mg/m^3 showed a significantly higher risk for rhinitis.[6] PM typically consists of carbon particles surrounded by reactive metals and organic chemicals, which exert their effects by inducing oxidative stress. Oxidative stress involves the generation of free radicals that can damage DNA and plasma membranes and lead to inflammation through the activation of transcription factors involved in inflammatory pathways.[1]

NO2, SO2, and O3 are all associated with upper respiratory tract infections. Outdoor NO2 exposure was associated with increased hospital visits for upper respiratory tract infections in children and adolescents, with RRs ranging from 1.005 (95% CI: 1.002 - 1.009) to 1.25 (95% CI: 1.21 - 1.29) for NO2 per 10 μg/m^3 unit increase in NO2.[9,11] NO2 was associated with rhinitis (OR = 1.20, 95% CI: 1.09 - 1.32 per 10 μg/m^3).[25] There are fewer studies on the association between SO2 and URTI, studies estimating the impact of SO2 on acute upper respiratory tract infections (ER from 2.92% (95% CI: 1.88% ~ 3.97%) to 15.17% (95% CI: 11.29% - 19.19%)), Xiaolin Xia (2017) found no significant association between SO2 and acute respiratory tract infections.[22] SO2 was also associated with rhinitis in an independent pollutant study by Tzu-Ying Chiang, 2016.[20] Studies on the association between O3 and URTI, studies estimating the impact of O3 on acute upper respiratory tract infections (ERlag03 = 2.5%, 95% CI: 0.4 - 4.6).[19] O3 associations were strongest and were observed at low (cold-season) concentrations.[13] The positive associations between upper respiratory tract infections (J00-J06) and pollutants such as PM10, PM2.5, NO2, O3, and SO2 are understandable, as these substances can irritate the respiratory tract mucosa, causing inflammation and increasing the risk of infection. Similarly, rhinitis and laryngitis were also positively associated with pollutants, although the strength of the association varied among substances. However, the lack of a clear association between certain pollutants such as O3 and SO2 with upper respiratory tract infections may be due to differences in environmental conditions, characteristics of the study population, or duration of exposure. This suggests the need for more geographically diverse studies with larger sample sizes to better understand the relationship between air pollution and respiratory health.

III. CONCLUSION

Studies from 2010 to 2019 demonstrate increasing interest in the impact of air pollution on respiratory health, particularly in rapidly industrializing regions like China. Pollutants such as PM10, PM2.5, NO2, SO2, and O3 have been shown to be closely linked to upper respiratory tract infections (URTI), especially in children. PM10 and PM2.5 have the most significant effects, causing inflammation and oxidative stress. Although there are some differences in study conditions, the findings highlight the need for further research to identify more effective pollution control measures.

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