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FACTORS RELATED TO AIR POLLUTION AND IMPACTS ON RESPIRATORY HEALTH IN MALAYSIA

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Abstract

Introduction: Air pollution, driven by urbanization, industrial activities, and transboundary haze, poses a significant threat to public health in Malaysia. It contributes to respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and bronchitis. Although advancements in monitoring have improved data accuracy, challenges remain in addressing regional disparities and climate-related factors. This review aims to explore air quality monitoring, factors influencing pollution, and its impacts on respiratory health in Malaysia.
Objective: To identify the scope of air quality monitoring, factors contributing to air pollution, and the associated impacts on respiratory health in Malaysia.
Method: A scoping review methodology was employed, using databases such as ScienceDirect, Scopus, and Google Scholar. Studies were included if they were conducted in Malaysia, published in English within the last five years, and investigated the relationship between air pollution and respiratory diseases. Data extraction focused on pollutants, study settings, and key findings.
Results: The review included 19 studies. Key findings indicate that urbanization, vehicular emissions, and transboundary haze are primary contributors to air pollution. Pollutants such as PM10, PM2.5, and NO2 are significantly associated with respiratory diseases, particularly asthma and COPD. Monitoring data shows that urban areas face greater challenges, while transboundary pollution affects rural and suburban regions.
Conclusion: Air pollution remains a pressing issue in Malaysia, exacerbated by urbanization and transboundary haze. Strengthening air quality policies, enhancing monitoring systems, and promoting public awareness are crucial to reducing health risks. Future research should prioritize underrepresented regions, long-term health impacts, and the effectiveness of regulatory measures. Collaborative and region-specific interventions are essential to combat this multifaceted challenge.

Keywords: Air quality, air pollution, respiratory diseases, asthma, COPD

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INTRODUCTION

Air quality, a key environmental health indicator, varies globally due to industrial activities, traffic emissions, agriculture, and natural events. Urban areas, especially in developing countries, often face higher pollution levels from rapid industrialization and population growth, while rural areas may be affected by agriculture and natural dust and smoke (WHO, 2021). Air pollution significantly impacts global health, causing about 7 million premature deaths annually. Pollutants such as PM2.5, PM10, NO2, SO2, O3, and CO are linked to respiratory infections, heart disease, stroke, lung cancer, and COPD, with vulnerable groups like children, the elderly, and those with preexisting conditions being particularly at risk (WHO, 2021).

Extensive Air Pollution Index (API) monitoring can ideally be achieved by integrating new technologies such as ground-based smart sensors, satellite remote sensing systems, geospatial technologies, and computational advancements like machine learning, artificial intelligence, and the Internet of Things (IoT) (Singh et al., 2021). The Global Environment Monitoring System for Air (GEMS Air) under the United Nations promotes a coordinated framework to track air quality and forecast pollution events globally, emphasizing standardization and accessibility of data (UNEP).

The Department of Environment (DOE) Malaysia monitors air quality using a variety of advanced instruments installed in Continuous Air Quality Monitoring (CAQM) stations. These stations are equipped with analyzers for measuring particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO), and ozone (O3) (DOE Malaysia). The analyzers operate continuously, providing real-time data essential for assessing air quality and identifying pollution trends (DOE Malaysia). As of 2011, the DOE monitored the country's ambient air quality through a network of 52 continuous monitoring stations; by 2023, this network had significantly improved, expanding to include 65 automatic monitoring stations, 14 manual monitoring stations, and 3 mobile monitoring stations, reflecting a strengthened commitment to comprehensive air quality monitoring. (DOE Malaysia, 2011; 2023).

In 2017, chronic respiratory diseases (CRDs) impacted 544.9 million individuals globally, with chronic obstructive pulmonary disease (COPD) as the leading cause of mortality, resulting in 3.91 million deaths. Consequently, CRDs ranked as the third leading cause of death worldwide, with smoking and air pollution recognized as significant risk factors (Soriano et al., 2020). In Southeast Asia, recurrent haze episodes have adversely affected respiratory health, resulting in heightened hospitalizations for conditions such as bronchial asthma and COPD exacerbations. Healthcare utilization is notably elevated during haze periods compared to non-haze periods (Jaafar et al., 2021). In Malaysia, particulate matter (PM2.5) pollution was responsible for 9781 excess deaths in 2013, significantly affecting respiratory health, especially in relation to conditions such as COPD and asthma (Mazeli et al., 2023). The seasonal haze in Malaysia exacerbates respiratory issues, leading to increased outpatient visits and hospitalizations, which highlights the significant health challenges associated with air pollution (Jaafar et al., 2021).

Therefore, this scoping review aims to identify the provision of air quality monitoring, factors related to air pollution, and highlight the impacts of air pollution on respiratory health in Malaysia.

MATERIALS AND METHODS

Search Strategy

A detailed search approach was devised to identify appropriate studies for this scoping review. The search will include multiple electronic databases, such as ScienceDirect, Scopus, and Google Scholar. Articles from Google Scholar were cross-checked with respective authors' institutional affiliations or professional profiles. The search criteria will consist of a combination of keywords and terminologies pertaining to air quality, air pollution, and respiratory disorders in Malaysia. The following terms will be included in the search: "air pollution," "air quality, "Malaysia," "asthma", "COPD," "bronchitis," "lung cancer," and "respiratory diseases." The search terms were suitably combined using Boolean operators, namely "AND" and "OR". In addition, the reference lists of the included research will be examined to find any more relevant articles.

Inclusion and Exclusion Criteria

Inclusion criteria ensured the review included relevant papers: research conducted in Malaysia, published in English within the last five years, investigating the link between air pollution and respiratory disorders. Both observational studies and systematic reviews with empirical evidence were eligible. Exclusion criteria eliminated studies outside Malaysia, non-English publications, non-peer-reviewed works, and those lacking significant data on air pollution or respiratory disorders.

Data Extraction and Synthesis

Data extraction will be performed using a standardized form to collect essential information such as study title, authors, publication year, study design, sample size, population characteristics, air quality parameters, reported respiratory outcomes, primary findings, and statistical significance. The data synthesis involved an analysis by the author of this article of the included studies, summarizing key findings on the associations between air pollution and respiratory diseases in Malaysia.

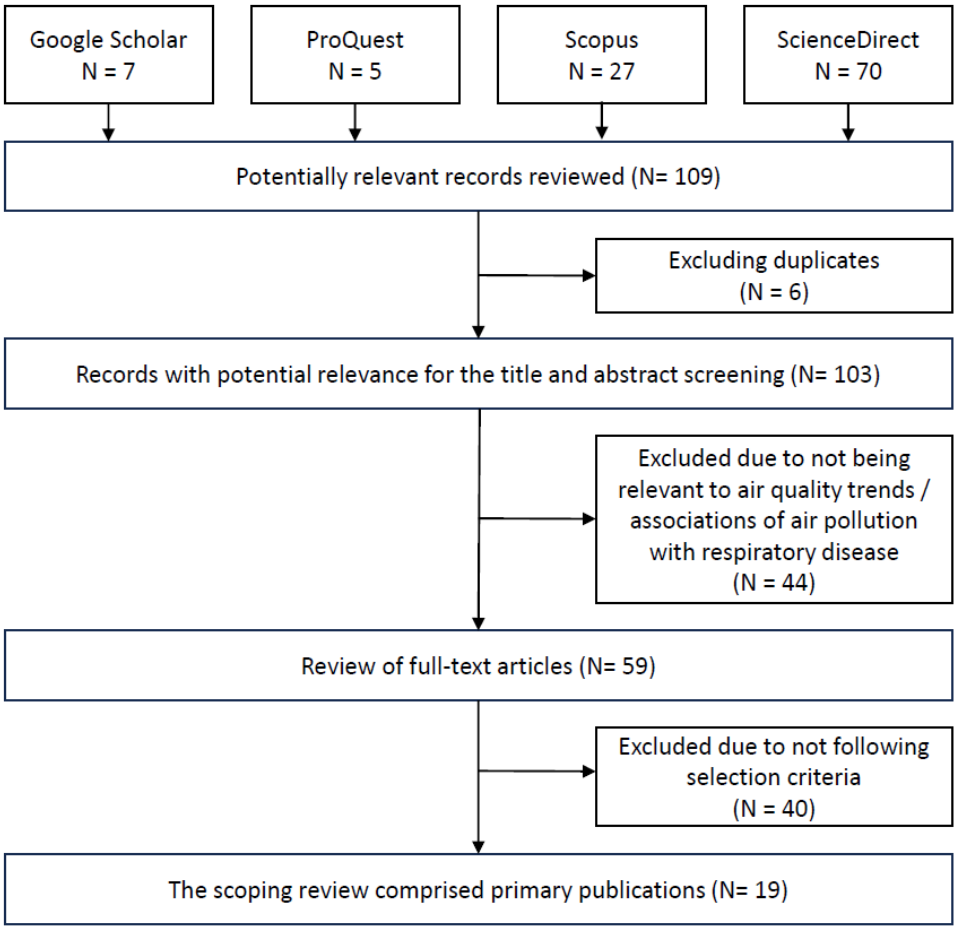

Figure 1: Systematic Selection of Records - Flow Diagram

RESULTS

The author initially conducted a search for pertinent publications that primarily focused on three key areas: abstract, findings, and discussion. The data collected from the selected studies were consolidated and analyzed using a charting technique that relies on a descriptive approach. The authors' names, publication year, research setting, study design, methodology, and any available study findings were recorded by adhering to this approach. The data from the articles was compiled and summarized using Microsoft Excel and Microsoft Word. The results sections of each article were examined to identify statements pertaining to the factors that exhibited associations with air quality and the incidence of respiratory disorders in Malaysia.

Table 3.1 : Summary of Selected Articles on Air Quality Across Different Regions in Malaysia (n = 9)

Author(s)	Title	Period of Study	Region	Objective of Study	Data Source	Pollutants and Other Parameters Measured	Key Findings
Abdul Halim et al., 2020	Spatial assessment of land use impact on air quality in mega urban regions, Malaysia	2000 - 2015	Kuala Lumpur Extended Mega Urban Region (covers the area from Bernam River Basin, south Perak to Linggi River Basin in Negeri Sembilan, extending to Melaka River Basin, Melaka. Area is about 11 982 km^2	Assess the impact of land use changes on air quality in a mega urban region in Malaysia	Continuous air quality monitoring stations managed by DOE in Tg Malim , Petaling Jaya, Klang, Shah Alam, Nilai, Seremban, Bandaraya Melaka, and Bukit Rambai	PM10, NO, NO2, NOx, CO, SO2	Land use changes (increase in built-up land, decrease in vegetation and water bodies) contributed to spatial expansion of air pollutants like NO, NO2, CO, and SO2.
Abdullah et al., 2020	Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus pandemic	March 2020 – April 2020	Malaysia	Examine changes in air pollutant levels during the Movement Control Order (MCO) in 2020	68 air quality monitoring stations managed by Department of Environment Malaysia	PM2.5	PM2.5 levels showed significant reductions (up to 58.4%) during the MCO, particularly in red zone areas with high COVID-19 cases.
Drahman et al., 2024	Twenty years of air pollutant index trend analysis in Kuching, Sarawak, Malaysia (2000–2019)	2000 - 2019	Kuching, Sarawak, Malaysia	Analyze API trends over 20 years in Kuching to assess long-term air quality fluctuations	Air pollutant index (API) for the monitoring station located at Medical Store Kuching, Sarawak	SO2, PM10, PM2.5, O3, NO2, CO	Elevated API readings were primarily due to transboundary haze from Indonesia; Fourier model predicted data well.

Author(s)	Title	Period of Study	Region	Objective of Study	Data Source	Pollutants and Other Parameters Measured	Key Findings
Mohd Halim et al., 2022	Air quality status during the pandemic Covid-19 in urban and sub-urban areas in Malaysia	January 2020 – December 2020	Kangar (suburban), Cheras (urban)	Assess the impact of the COVID-19 pandemic on air quality in urban and suburban areas	Malaysian Air Pollutant Index website	Air Pollutant Index (API)	API showed reductions in urban areas during lockdown phases, while suburban areas showed minimal changes.
Lee et al., 2020	Evaluation of air quality in Sunway City, Selangor, Malaysia from a mobile monitoring campaign using air pollution micro-sensors	September 2018 – March 2019	Sunway City, Selangor, Malaysia	Evaluate air quality using a mobile monitoring campaign in a high-density urban area	Measurements collected via mobile monitoring campaign (using Aeroqual Series 500 portable monitoring sensors)	CO2, NO2	CO2 and NO2 concentrations varied significantly with traffic and meteorological conditions; urbanization contributed to pollutant levels.
Naidin et al., 2023	Decade-long analysis: Unravelling the spatio-temporal dynamics of PM10 concentrations in Malaysian Borneo	2006 - 2016	Malaysian Borneo (Sabah and Sarawak)	Study long-term PM10 trends and transboundary air pollution effects in Malaysian Borneo	Air quality monitoring station data from 13 monitoring sites in Borneo, provided by the DOE	PM10	Southern Malaysian Borneo recorded the highest PM10 levels; biomass burning and El Niño were significant contributors to high pollution.
Rahim et al., 2023	Variability of PM10 levels with gaseous pollutants and meteorological parameters during	1997, 2005, 2013, 2015	Klang, Melaka, Pasir Gudang, Petaling Jaya	Analyze variability of PM10 with gaseous pollutants and meteorological	Hourly dataset from Department of Environment Malaysia (PM10, gaseous pollutants, weather parameters)	NOx, SO2, NO2, O3, CO, PM10. Meteorological parameters such as wind speed, relative	PM10 showed strong correlations with CO and moderate correlations with SO2; haze episodes were strongly influenced by transboundary pollution from Sumatra.

Author(s)	Title	Period of Study	Region	Objective of Study	Data Source	Pollutants and Other Parameters Measured	Key Findings
	episodic haze events in Malaysia			parameters during haze episodes		temperature, humidity	
Sentian et al., 2019	Long-term air pollution trend analysis in Malaysia	1997 - 2015	Malaysia (20 monitoring stations)	Conduct long-term analysis of pollutant trends and identify pollution sources	Data from 20 air quality monitoring stations in Malaysia	CO, NOx, PM10	Transboundary pollution from Indonesia during the southwest monsoon was a key contributor to PM10 levels; urban areas had additional local emission sources.
Zheng et al., 2023	Assessing the impacts of climate variables on long-term air quality trends in Peninsular Malaysia	2000 - 2019	Peninsular Malaysia	Investigate the impacts of climate variables on long-term air quality trends	Ground-based observations from climate and air quality monitoring stations (2000–2019)	PM10, O3, CO, NO2, SO2. Meteorological data such as temperature, precipitation, relative humidity, wind speed, wind direction.	Air quality worsened with rising temperatures, with increases in PM10 and O3 concentrations linked to global warming.

Table 3.2 : Summary of Selected Articles on Associations between Air Pollution with Respiratory Disease (n = 10)

Author(s)	Title	Study Location	Study Design	Study Objective	Data Source/ Sample Size	Independent Variables	Dependent Variable (s)	Key Findings
Anuar et al., 2023	Impact of haze event on daily admission of respiratory system patients in Peninsular Malaysia	Peninsular Malaysia	Cross-sectional (Generalized linear lag model)	Evaluate the impact of haze on respiratory admissions	Dataset June – September in year 2019 from DOE and 92 hospitals under MOH	Air pollutant levels (SO2, NO2, CO, O3, PM10,P,2.5), meteorological data (wind direction, wind speed, relative humidity, ultraviolet radiation, temperature)	Daily hospital admissions for respiratory diseases	Significant correlation between PM10 concentration and average daily number of respiratory disease hospitalization. Variability on the daily admission rate of patients with respiratory diseases to hospitals during haze period.
Awang et al., 2020	Assessment of micronucleus frequency and respiratory health symptoms among traffic policemen exposed to BTEX and PM2.5 in Klang Valley, Malaysia	Klang Valley	Cross-sectional	Assess micronucleus frequency and respiratory symptoms among traffic policemen	160 traffic policemen; 149 office workers	BTEX, PM2.5 exposure levels	Micronucleus frequency; respiratory symptoms	Higher exposure to BTEX and PM2.5 is linked to elevated micronucleus frequency and increased respiratory symptoms.
Ibrahim et al., 2022	Children's exposure to air pollution in a natural gas industrial area and their risk of hospital admission for respiratory diseases	Bintulu	Time-series analysis (Distributed Lag Non-linear Model)	Assess children's hospital admission risk in a natural gas industrial area	Children's admission data (2010 -2019)	Air pollutant levels (PM10, PM2.5, SO2, NO2, O3, CO)	Children's hospital admission rates	Short-term exposure to PM2.5 and SO2 associated with hospital admissions for respiratory diseases in children.

Author(s)	Title	Study Location	Study Design	Study Objective	Data Source/ Sample Size	Independent Variables	Dependent Variable (s)	Key Findings
Jaafar et al., 2021	The impact of haze on healthcare utilizations for acute respiratory diseases: Evidence from Malaysia	Selangor (Petaling, Klang, Kuala Selangor, Kuala Langat)	Cross-sectional	Investigate haze's impact on acute respiratory healthcare utilization	Haze/non-haze data (from CAQM DOE) and healthcare utilization records (public hospital and health clinics) in year 2012 – 2015.	Haze episodes	Healthcare utilization for respiratory diseases	Haze episodes significantly increase healthcare utilization for acute respiratory diseases.
Khamal et al., 2019	Indoor particulate matters, microbial count assessments, and wheezing symptoms among toddlers in urban daycare centers in the district of Seremban, Malaysia	Seremban	Cross-sectional	Analyze indoor air quality and wheezing symptoms among toddlers in daycare	10 daycare centers; toddlers aged 1-4 years	Indoor air quality (PM2.5, PM10, CO2, total bacterial count, total fungal count)	Wheezing symptoms in toddlers	Indoor air quality exceeding standards and increased levels indoor air pollutants is associated to a higher prevalence of wheezing symptoms in toddlers.
Morrissey et al., 2021	The effects of air quality on hospital admissions for chronic respiratory diseases in Petaling Jaya, Malaysia, 2013 - 2015	Petaling Jaya	Time-series analysis (Distributed Lag Model)	Examine air quality effects on chronic respiratory admissions	Hospital admissions data (2013 - 2015)	Air Quality Index (API) changes	Hospital admissions for chronic respiratory diseases	A 10 $\mu g/m^3$ increase in API significantly raises hospital admissions for chronic respiratory conditions.
Norback et al., 2021	Asthma symptoms and respiratory infections in Malaysian students: Associations with	Johor Bahru	Cross-sectional	Identify chemical exposure links to asthma and respiratory issues	462 junior high students	Chemical exposure at home and school	Asthma symptoms and respiratory infections	Para-dichlorobenzene exposure at schools is associated with increased asthma

Author(s)	Title	Study Location	Study Design	Study Objective	Data Source/ Sample Size	Independent Variables	Dependent Variable (s)	Key Findings
	ethnicity and chemical exposure at home and school							and respiratory infections.
Shafie et al., 2022	Influence of urban air pollution on the population in the Klang Valley, Malaysia: A spatial approach	Klang Valley	Spatial Analysis	Examine urban air pollution's spatial risks on public health	Population density (Census of Population and Housing Malaysia), PM10 data (DOE) and health data from Klang Valley	Urban air pollution levels (PM10)	Chronic bronchitis risk (AirQ+ model)	High PM10 levels in Klang Valley correlate with increased chronic bronchitis risk among adults.
Sofwan et al., 2021	Risks of exposure to ambient air pollutants on the admission of respiratory and cardiovascular diseases in Kuala Lumpur	Kuala Lumpur	Time-series analysis (Distributed Lag Non-linear Model)	Assess air pollutants' risks on respiratory and cardiovascular health	Hospitalization data from Hospital Canselor Tunku Muhriz UKM, Hospital Kuala Lumpur, and MOH; pollutant concentrations from CAQMs in Batu Muda, Petaling Jaya, and Cheras	Ambient air pollutants (PM10, CO, NO2, SO2), meteorological variables (ambient temperature, relative humidity)	Respiratory and cardiovascular admissions	Significant associations found between air pollutants and hospital admissions for respiratory and cardiovascular diseases.
Tajudin et al., 2019	Risk of concentrations of major air pollutants on the prevalence of cardiovascular and respiratory diseases in urbanized area of	Kuala Lumpur	Time-series Analysis (Generalized Additive Model)	Evaluate air pollutants' impact on cardiovascular and respiratory disease prevalence	Hospitalization data from HCTM; and data from DOE's CAQM at Bandar Tun Razak (2010 - 2014)	Concentrations of air pollutants (SO2, NO2, PM10, CO, O3), meteorological variables (temperature, relative humidity)	Prevalence of cardiovascular and respiratory diseases	Delayed effects of NO2 and SO2 on hospitalizations for respiratory and cardiovascular conditions were observed.

Author(s)	Title	Study Location	Study Design	Study Objective	Data Source/ Sample Size	Independent Variables	Dependent Variable (s)	Key Findings
	Kuala Lumpur, Malaysia							

Table 3.3 : Descriptive Results Summary (n = 19)

Type of Study	**n**
Cross-sectional	10
Longitudinal cohort	1
Longitudinal ecological	3
Time series analysis	4
Spatial analysis	1
Location/Setting	
Nationwide	4
Selangor	4
Kuala Lumpur	3
Negeri Sembilan	1
Sabah / Sarawak	3
Various locations (Peninsular Malaysia)	4
Year of Publication	
2019	3
2020	4
2021	4
2022	3
2023	4
2024	1

DISCUSSION

Measurement of air quality across Malaysia

Air quality in urban regions like the Kuala Lumpur Extended Mega Urban Region (KLEMUR) has been well-captured, showing significant correlations between land use changes and pollutants such as PM10, NO, NO2, and CO, which are heavily influenced by vehicular and industrial emissions (Abdul Halim et al., 2020). The COVID-19 Movement Control Order (MCO) provided a unique opportunity to observe reductions in PM2.5 levels across Malaysia, with decreases of up to 58.4%, demonstrating the responsiveness of monitoring systems during specific events (Abdullah et al., 2020). In Kuching, Sarawak, long-term Air Pollutant Index (API) trend analyses over 20 years have been conducted, employing sophisticated models to compensate for missing data, suggesting a robust capability to track air quality fluctuations and seasonal transboundary pollution (Drahman et al., 2024). Similarly, monitoring in suburban and urban areas like Kangar and Cheras revealed notable differences in API changes during the MCO, emphasizing variability in monitoring precision between urban and suburban zones (Mohd Halim et al., 2022).

Advanced monitoring techniques, such as mobile sensors with GPS, have been employed in Sunway City to provide comprehensive spatial data on pollutants like CO2 and NO2, addressing limitations of fixed monitoring stations and enhancing localized data collection (Lee et al., 2020). Long-term analyses at multiple monitoring stations across Malaysia have revealed decreasing trends in pollutants like PM10, while transboundary haze remains a persistent issue, indicating that monitoring captures both local and regional pollution sources (Sentian et al., 2019). Climate-driven changes have also influenced air quality trends, with significant increases in pollutants like PM10 and O3 linked to warming temperatures, demonstrating the evolving challenge of air pollution measurement under climate change scenarios (Zheng et al., 2023).

The fixed monitoring stations, while useful, often lack sufficient spatial coverage, especially in high-density urban areas and suburban or rural regions, leading to gaps in capturing localized variations (Lee et al., 2020; Mohd Halim et al., 2022). The monitoring system struggles to address the impact of transboundary pollution, particularly from biomass burning in neighboring Indonesia, which remains a persistent challenge during seasonal haze episodes (Naidin et al., 2023; Rahim et al., 2023). Data gaps in long-term pollutant trends, such as PM10, often require advanced models for accurate prediction, highlighting limitations in consistent data collection (Drahman et al., 2024). Additionally, the system has yet to fully integrate climate variables, such as rising temperatures and changing precipitation patterns, which significantly influence pollutant trends under evolving environmental conditions (Zheng et al., 2023).

Urbanization-related changes, including increased built-up areas and reduced vegetation, are also not adequately reflected in current assessments, despite their clear role in exacerbating pollution levels (Abdul Halim et al., 2020). While the COVID-19 Movement Control Order demonstrated the adaptability of the monitoring network in capturing pollutant reductions, the system needs to further enhance its responsiveness and real-time capabilities (Abdullah et al., 2020).

Air quality trend in Malaysia

Air quality trends in Malaysia vary significantly between urban and suburban or rural areas due to differences in pollutant sources, urbanization, and the influence of transboundary pollution. In urban areas, the Kuala Lumpur Extended Mega Urban Region (KLEMUR) from 2000 to 2015 saw increasing concentrations of pollutants such as PM10, NO, NO2, and CO, driven by rapid urbanization and changes in land use. These trends reflect the growing contribution of vehicular and industrial emissions in densely populated regions (Abdul Halim et al., 2020). Similarly, a six-month study in Sunway City, Selangor, from September 2018 to March 2019, revealed that traffic-related pollutants like NO2 and CO2 were dominant, highlighting the localized effects of urban activities on air quality (Lee et al., 2020).

Nationwide, urban areas experienced significant improvements in air quality during the COVID-19 Movement Control Order (MCO) in 2020, with PM2.5 levels reducing by up to 58.4%. This reduction demonstrated the immediate impact of decreased vehicular and industrial activities during lockdowns (Abdullah et al., 2020). However, haze events in urban areas during specific years—1997, 2005, 2013, and 2015—showcased the persistent challenge of transboundary pollution, as PM10 levels consistently exceeded recommended guidelines. Strong correlations were observed between PM10 and CO levels during these episodes, with urban centers bearing significant impacts (Rahim et al., 2023). Additionally, from 2000 to 2019, urban areas in Peninsular Malaysia recorded increasing levels of PM10 (+16.4%) and O3 (+39.5%), trends

closely linked to warming temperatures and urbanization, underscoring the influence of climate change on air quality (Zheng et al., 2023).

In contrast, suburban and rural areas display different air quality dynamics. During the COVID-19 MCO, suburban Kangar showed smaller reductions in API compared to urban Cheras, reflecting lower baseline emissions in less industrialized and densely populated regions (Mohd Halim et al., 2022). In Malaysian Borneo (Sabah and Sarawak), from 2006 to 2016, PM10 levels varied across regions: urbanized areas like Miri and Limbang experienced increases, while rural areas such as Kuching and Bintulu saw significant decreases. This variability highlights the complex interaction of local emissions and transboundary pollution from biomass burning in neighboring countries (Naidin et al., 2023).

Kuching, Sarawak, provides a particularly illustrative case of long-term trends in a suburban setting. Between 2000 and 2019, the Air Pollutant Index (API) showed periodic increases during transboundary haze episodes, driven by regional biomass burning. These events significantly affected rural and suburban regions, demonstrating their vulnerability to external pollution sources (Drahman et al., 2024). Nationwide monitoring from 1997 to 2015 revealed that while PM10 levels generally decreased across most of the 20 monitoring stations, suburban and rural areas were disproportionately affected by seasonal transboundary haze, whereas urban regions faced additional pressures from local emissions (Sentian et al., 2019).

Factors Related to Air Pollution in Malaysia

In Malaysia, air pollution is affected by a variety of human activities, natural events, and climatic conditions. Urbanization and changes in land use, including the expansion of built-up areas and the decrease in vegetation, are important factors in regions such as KLEMUR. These changes have led to an increase in pollutants like PM10 and NO2, primarily due to emissions from industrial activities and vehicles (Abdul Halim et al., 2020). In high-density urban areas such as Sunway City, vehicular emissions, especially CO2 and NO2, are predominant. This issue is further intensified by the increasing population and dependence on private transportation (Lee et al., 2020). Industrial activities significantly impact air quality, especially in urban and industrialized areas, where emissions of PM10 and SO2 are major contributors to its deterioration (Zheng et al., 2023). Seasonal haze episodes, frequently caused by transboundary biomass burning from neighboring Indonesia, increase pollution levels, leading to periodic spikes in PM10 concentrations in areas such as Malaysian Borneo and urban centers throughout Peninsular Malaysia (Naidin et al., 2023; Rahim et al., 2023; Sentian et al., 2019).

Climatic factors exacerbate air pollution, as phenomena such as El Niño and the southwest monsoon influence the dispersion and concentration of pollutants, especially during haze events (Naidin et al., 2023; Sentian et al., 2019). Increased temperatures and altered precipitation patterns have been associated with higher levels of pollutants such as PM10 and O3, illustrating the relationship between climate change and air quality (Zheng et al., 2023). The insufficient enforcement of environmental regulations during periods of peak pollution, along with inadequate proactive policies, worsens the situation, especially during transboundary haze events (Rahim et al., 2023).

Table 3.4 Factors Related to Air Pollution in Malaysia

	Factors	Studies
1.	Urbanization, Land Use Changes	Abdul Halim et al., 2020
2.	Vehicular Emissions	Lee et al., 2020
3.	Industrial Activities	Zheng et al., 2023
4.	Biomass Burning, Transboundary Pollution	Naidin et al., 2023; Rahim et al., 2023; Sentian et al., 2019;
5.	Seasonal and Climatic Influences	Naidin et al., 2023; Sentian et al., 2019; Zheng et al., 2023
6.	Reduced Environmental Regulations During Peak Pollution Events	Rahim et al., 2023
7.	Population Growth	Lee et al., 2020; Abdul Halim et al., 2020

Impacts of air pollution to respiratory health

Indoor air quality refers to the quality of air within buildings, influenced by factors like temperature, humidity, ventilation, and pollutants such as VOCs and particulate matter (Bhattacharya, Sridevi, & Pitchiah, 2012), while outdoor air quality pertains to air quality in external environments, affected by sources like transportation and industry, with significant health impacts including respiratory and cardiovascular risks (Turner et al., 2020).

Poor indoor air quality, particularly in urban environments, contributes to respiratory issues, especially among vulnerable populations. For example, Khamal et al. (2019) found that high levels of PM2.5, PM10, and microbial counts in daycare centers were associated with increased wheezing symptoms among toddlers. Similarly, Norbäck et al. (2021) highlighted that indoor chemical emissions, such as para-dichlorobenzene in classrooms and homes, increased asthma and respiratory infections among Malaysian students. While indoor air pollution is often linked to chemical emissions from cleaning products, furniture, and paints, these sources can be mitigated with interventions like improved ventilation and reduced use of harmful products (Khamal et al., 2019; Norbäck et al., 2021).

In contrast, outdoor air quality is predominantly affected by broader environmental factors such as traffic emissions, industrial activities, and haze events, posing systemic challenges to respiratory health. Shafie et al. (2022) observed that outdoor PM10 levels in the Klang Valley significantly exceeded WHO guidelines, leading to an increased risk of chronic bronchitis. Similarly, Ibrahim et al. (2022) linked short-term exposure to outdoor pollutants, such as PM2.5 and SO2 in a natural gas industrial area, to higher hospital admissions for respiratory diseases in children. Additionally, Tajudin et al. (2019) highlighted that pollutants like NO2 and SO2 contributed to both immediate and delayed effects on respiratory and cardiovascular health in urbanized Kuala Lumpur. These findings underscore the need for systemic interventions, such as stricter emission controls and urban planning strategies, to mitigate outdoor air pollution and its health impacts (Shafie et al., 2022; Ibrahim et al., 2022; Tajudin et al., 2019).

Recommendations

Enhancing air quality and mitigating respiratory health risks in Malaysia necessitate a thorough strategy involving various sectors. Policy and governance should prioritize enhancing regional collaboration to address transboundary haze and implement stricter regulations on vehicular and industrial emissions (Drahman et al., 2024; Lee et al., 2020). Incorporating climate change mitigation into air quality policies and maintaining low-emission practices established during the COVID-19 movement control order can lead to a further decrease in pollutants (Zheng et al., 2023; Abdullah et al., 2020). Urban and regional planning should focus on sustainable land use, the development of green spaces, and the enhancement of public transportation infrastructure to mitigate the effects of urbanization and decrease traffic-related emissions (Abdul Halim et al., 2020). Stricter emission regulations aimed at industrial and vehicular pollutants are essential for improving outdoor air quality, especially in urban areas like Kuala Lumpur and the Klang Valley (Tajudin et al., 2019; Shafie et al., 2022). Advancing low-carbon energy sources and cleaner transportation alternatives is crucial for achieving sustained reductions in outdoor pollution (Shafie et al., 2022). Strategies for urban planning, such as the establishment of pollution-free zones and the reduction of residential exposure to industrial emissions, are essential (Ibrahim et al., 2022; Shafie et al., 2022).

Minimizing the use of volatile organic compounds (VOCs) in household and school products is essential to reduce risks associated with chemical exposure (Norbäck et al., 2021). Stricter indoor air quality standards can enhance protection for vulnerable populations, especially children, against harmful exposure (Khamal et al., 2019). Enhancing ventilation systems in daycare centers, schools, and homes can substantially decrease the buildup of pollutants, including PM2.5, PM10, and microbial counts (Khamal et al., 2019). Safe indoor practices, including the use of non-toxic cleaning products and the maintenance of adequate airflow, can strengthen individual initiatives aimed at improving indoor air quality (Norbäck et al., 2021). Public awareness campaigns can inform communities about the health risks associated with outdoor pollution and the preventative measures that can be taken, such as minimizing exposure during haze events (Jaafar et al., 2021; Ibrahim et al., 2022).

Policymakers ought to utilize localized research findings to develop region-specific solutions that tackle challenges such as haze episodes and industrial emissions (Anuar et al., 2023; Ibrahim et al., 2022; Jaafar et al., 2021). Enhancements in monitoring and data collection are essential, particularly through the expansion of localized air quality stations and mobile monitoring campaigns to improve spatial data coverage (Lee et al., 2020; Mohd Halim et al., 2022). Monitoring and enforcing compliance with indoor air quality guidelines offer a systematic approach to protecting respiratory health (Khamal et al., 2019; Norbäck et al., 2021). Health surveillance systems must be established to monitor trends in air quality and to inform timely interventions (Khamal et al., 2019; Shafie et al., 2022).

Predictive modeling and climate forecasting tools can assist in anticipating and managing future challenges related to air quality (Zheng et al., 2023). Public health interventions, including early warning systems for haze and awareness campaigns, are crucial for mitigating health risks (Rahim et al., 2023). It is essential to address industrial emissions and establish inter-country agreements on transboundary pollution, in addition to implementing strategies for adapting to climate-related risks (Naidin et al., 2023; Rahim et al., 2023).

Collectively, these measures can establish a comprehensive framework for effectively addressing Malaysia's air quality and respiratory health challenges.

CONCLUSION

The results of this scoping review highlight the various issues that air pollution presents and how seriously it affects respiratory health in Malaysia. Despite significant advancements in air quality monitoring and the identification of major sources of pollution, more effective and region-specific actions are still urgently required. In order to lessen the effects of urbanization, transboundary haze, and climate change, comprehensive, multi-sectoral policies are required. To protect health outcomes, air quality regulations must be strengthened, climate adaption strategies must be incorporated, and public awareness must be raised. To provide a comprehensive strategy to reducing air pollution, future research should concentrate on underrepresented areas, long-term health implications, and the efficacy of current regulations. Malaysia can effectively tackle air pollution and its detrimental health effects by exploiting technological developments in monitoring and promoting regional cooperation.

REFERENCES

Department of Environment. (2023). Air Quality Monitoring and Assessment. Ministry of Environment and Water. Retrieved from *https://www.doe.gov.my/en/utama-english/*

Department of Environment Malaysia. (2011). Malaysia Environmental Quality Report 2011. Ministry of Natural Resources and Environment. Retrieved from https://www.doe.gov.my

Department of Environment Malaysia. (2023). Laporan Kualiti Alam Sekeliling 2023 [Environmental Quality Report 2023]. Ministry of Natural Resources and Environmental Sustainability. Retrieved from https://www.doe.gov.my

Department of Environment Malaysia. (n.d.). Air quality monitoring station in Malaysia. Retrieved from https://www.doe.gov.my/en/air-quality-monitoring-station-in-malaysia/

Environmental Quality Act 1974. (1974). Laws of Malaysia. Retrieved from *https://www.doe.gov.my/wp-content/uploads/2021/07/Environmental_Quality_Act_1974_-_ACT_127.pdf*

Environmental Quality (Clean Air) Regulations 2014. (2014). Laws of Malaysia. Retrieved from *https://www.doe.gov.my/en/environmental-quality-clean-air-regulations-2014/*

United Nations Environment Programme (UNEP). (n.d.). GEMS Air work packages. Retrieved from https://www.unep.org/explore-topics/air/what-we-do/monitoring-air-quality/gems-air-work-packages

World Health Organization. (2021). Air pollution. Retrieved from https://www.who.int/health-topics/air-pollution

Abdul Halim, N. D., Latif, M. T., Mohamed, A. F., Abdul Maulud, K. N., Idrus, S., Azhari, A., ... & Md Sofwan, N. (2020). Spatial assessment of land use impact on air quality in mega urban regions, Malaysia. Sustainable Cities and Society, 63, 102436. https://doi.org/10.1016/j.scs.2020.102436

Abdullah, S., Abu Mansor, A., Mohd Napi, N. N. L., Wan Mansor, W. N. D., Ahmed, A. N., Ismail, M., & Ahmad Ramly, Z. T. (2020). Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic. Science of the Total Environment, 729, 139022. https://doi.org/10.1016/j.scitotenv.2020.139022

Anuar, N. A. K., Samsudin, H. B., & Majid, N. (2023). Impact of haze event on daily admission of respiratory system patients in Peninsular Malaysia. Sains Malaysiana, 52(10), 2985–2997. https://doi.org/10.17576/jsm-2023-5210-19

Awang, M. F., Jalaludin, J., & Abu Bakar, S. (2020). Assessment of micronucleus frequency and respiratory health symptoms among traffic policemen exposed to BTEX and PM2.5 in Klang Valley, Malaysia. Jurnal Teknologi, 82(4), 71–80. https://doi.org/10.11113/jt.v82.14493

Bhattacharya, S., Sridevi, S., & Pitchiah, R. (2012). Indoor air quality monitoring using wireless sensor network. 2012 Sixth International Conference on Sensing Technology (ICST). https://doi.org/10.1109/ICSENST.2012.6461713

Drahman, S. H., Maseri, H., Nap, M. C., & Hossen, Z. B. (2024). Twenty years of air pollutant index trend analysis in Kuching, Sarawak, Malaysia (2000–2019). Sains Malaysiana, 53(3), 623-633. http://doi.org/10.17576/jsm-2024-5303-11

Ibrahim, M. F., Hod, R., Ahmad Tajudin, M. A. B., Wan Mahiyuddin, W. R., Mohammed Nawi, A., & Sahani, M. (2022). Children's exposure to air pollution in a natural gas industrial area and their risk of hospital admission for respiratory diseases. Environmental Research, 210, 112966. https://doi.org/10.1016/j.envres.2022.112966

Jaafar, H., Azzeri, A., Isahak, M., & Dahlui, M. (2021). The impact of haze on healthcare utilizations for acute respiratory diseases: Evidence from Malaysia. Frontiers in Ecology and Evolution, 9, 764300. https://doi.org/10.3389/fevo.2021.764300

Khamal, R., Isa, Z. M., Sutan, R., Noraini, N. M. R., & Ghazi, H. F. (2019). Indoor particulate matters, microbial count assessments, and wheezing symptoms among toddlers in urban daycare centers in the district of Seremban, Malaysia. Annals of Global Health, 85(1), 15. https://doi.org/10.5334/aogh.2425

Lee, C. C., Tran, M. V., Choo, C. W., Tan, C. P., & Chiew, Y. S. (2020). Evaluation of air quality in Sunway City, Selangor, Malaysia from a mobile monitoring campaign using air pollution micro-sensors. Environmental Pollution, 265, 115058. https://doi.org/10.1016/j.envpol.2020.115058

Mazeli, M. I., Pahrol, M. A., Abdul Shakor, A. S., Kanniah, K., & Omar, M. (2023). Cardiovascular, respiratory, and all-cause (natural) health endpoint estimation using a spatial approach in Malaysia. The Science of the Total Environment, 162130. https://doi.org/10.2139/ssrn.4306133

Mohd Halim, N. F., Zahid, M. A., Salleh, M. Z. M., & Abu Bakar, A. A. (2022). Air quality status during the pandemic Covid-19 in urban and sub-urban areas in Malaysia. IOP Conference Series: Earth and Environmental Science, 1019, 012044. https://doi.org/10.1088/1755-1315/1019/1/012044

Morrissey, K., Chung, I., Morse, A., Parthasarath, S., Roebuck, M. M., Tan, M. P., et al. (2021). The effects of air quality on hospital admissions for chronic respiratory diseases in Petaling Jaya, Malaysia, 2013–2015. Atmosphere, 12(8), 1060. https://doi.org/10.3390/atmos12081060

Naidin, S., Sentian, J., Fazliatul Adnan, F. A., Herman, F., & Mohd Hashim, S. R. (2023). Decade-long analysis: Unravelling the spatio-temporal dynamics of PM10 concentrations in

Malaysian Borneo. Aerosol and Air Quality Research, 24(2), 230176. https://doi.org/10.4209/aaqr.230176

Norbäck, D., Hashim, Z., Ali, F., & Hashim, J. H. (2021). Asthma symptoms and respiratory infections in Malaysian students: Associations with ethnicity and chemical exposure at home and school. Environmental Research, 197, 111061. https://doi.org/10.1016/j.envres.2021.111061

Rahim, N. A. A., Noor, N. M., Jafri, I. A. M., Ul-Saufie, A. Z., Ramli, N., Abu Seman, N. A., ... & Victor, S. A. (2023). Variability of PM10 levels with gaseous pollutants and meteorological parameters during episodic haze events in Malaysia: Domestic or solely transboundary factor? Heliyon, 9, e17472. https://doi.org/10.1016/j.heliyon.2023.e17472

Sentian, J., Herman, F., Yit Yih, C., & Chang Hian Wui, J. (2019). Long-term air pollution trend analysis in Malaysia. International Journal of Environmental Impacts, 2(4), 309–324. https://doi.org/10.2495/EI-V2-N4-309-324

Shafie, S. H. M., Mahmud, M., Mohamad, S., Rameli, N. L. F., Abdullah, R., & Mohamed, A. F. (2022). Influence of urban air pollution on the population in the Klang Valley, Malaysia: A spatial approach. Ecological Processes, 11, 3. https://doi.org/10.1186/s13717-021-00342-0

Singh, D., Dahiya, M., Kumar, R., & Nanda, C. (2021). Sensors and systems for air quality assessment monitoring and management: A review. Journal of Environmental Management, 289, 112510. https://doi.org/10.1016/j.jenvman.2021.112510

Sofwan, N. M., Mahiyuddin, W. R. W., Latif, M. T., Ayub, N. A., Mohd Yatim, A. N., Ahmad Mohtar, A. A., et al. (2021). Risks of exposure to ambient air pollutants on the admission of respiratory and cardiovascular diseases in Kuala Lumpur. Sustainable Cities and Society, 75, 103390. https://doi.org/10.1016/j.scs.2021.103390

Soriano, J. B., Kendrick, P. J., Paulson, K. R., Gupta, V., Abrams, E. M., Adedoyin, R. A., ... Vos, T. (2020). Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. The Lancet. Respiratory Medicine, 8(6), 585-596. https://doi.org/10.1016/S2213-2600(20)30105-3

Tajudin, M. A. B. A., Khan, M. F., Mahiyuddin, W. R. W., Hod, R., Latif, M. T., Hamid, A. H., & Sahani, M. (2019). Risk of concentrations of major air pollutants on the prevalence of cardiovascular and respiratory diseases in urbanized area of Kuala Lumpur, Malaysia. Ecotoxicology and Environmental Safety, 171, 290–300. https://doi.org/10.1016/j.ecoenv.2018.12.057

Turner, M., Andersen, Z., Baccarelli, A., Diver, W. R., Gapstur, S., Pope, C., Prada, D., Samet, J., Thurston, G., & Cohen, A. (2020). Outdoor air pollution and cancer: An overview of the current evidence and public health recommendations. CA: A Cancer Journal for Clinicians, 70(6), 460–479. https://doi.org/10.3322/caac.21632

Zheng, Y., Ooi, M. C. G., Juneng, L., Wee, H. B., Latif, M. T., Mohd Nadzir, M. S., ... & Tangang, F. (2023). Assessing the impacts of climate variables on long-term air quality trends in Peninsular Malaysia. Science of the Total Environment, 901, 166430. https://doi.org/10.1016/j.scitotenv.2023.166430