Integrating Spatial Intelligence and Public Health Perspectives in Addressing Urban Air Pollution in Malaysia: A GIS-Based Environmental Assessment

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ABSTRACT

This study investigates the relationship between climate change and respiratory health in Cheras, Kuala Lumpur, a rapidly urbanising district facing growing environmental stress from pollution and temperature rise. Climate change, driven by both natural and anthropogenic factors, has intensified urban heat, altered rainfall patterns, and worsened air quality, threatening public health. Using a mixed-methods approach combining field observation, secondary data analysis, and Geographical Information Systems (GIS) mapping, this research examined the interaction between temperature, humidity, and fine particulate matter (PM2.5) with respiratory disease incidence. Data were obtained from the Malaysian Meteorological Department (MET Malaysia), World Air Quality Index (WAQI), and Cheras District Health Office. Results revealed a marked deterioration in air quality between 2021 and 2023, with PM2.5 concentrations rising from 54.68 µg/m³ to 65.34 µg/m³, shifting from "Unhealthy for Sensitive Groups" to "Unhealthy" levels. Although air pollution worsened, influenza cases dropped from 1,240 (2021) to 32 (2023), likely influenced by post-COVID-19 behavioural changes such as mask usage and hygiene awareness. It should be noted that the 2021 data represent full-year health records, whereas the 2023 data cover only a single epidemiological week. This mismatch limits direct comparability and trend interpretation across years. GIS spatial analysis confirmed that pollution hotspots corresponded with high-density traffic and industrial zones, validating a strong link between air quality and respiratory vulnerability. The findings underscore the urgent need for sustainable urban policies, including stricter emission controls, expansion of urban green zones, and integrated air-health monitoring systems. Ultimately, this study highlights how rapid urban development and inadequate environmental management accelerate respiratory health risks, calling for a shift toward long-term, data-driven climate resilience strategies in Malaysia's urban planning framework.

Keywords-Air pollution; Public health; GIS; PM2.5; Urban resilience; Malaysia

INTRODUCTION

Climate change is a major global challenge affecting multiple aspects of human life, including public health. Rising global temperatures, changing weather patterns, and increasing air pollution are particularly concerning in rapidly urbanizing areas such as Kuala Lumpur. As Malaysia's economic hub, the city faces serious environmental challenges, heatwaves, flash floods, and declining air quality which all contribute to worsening health outcomes.

Climate change refers to long-term alterations in elements such as temperature, rainfall, and wind patterns, caused by both natural and human activities (EPA, 2012). Natural causes include variations in Earth's orbit, solar radiation, and volcanic activity, while human activities such as industrialization, deforestation, and burning of fossil fuels accelerate the process (Aerts et al., 2018). Globally, climate change has triggered extreme weather events such as droughts, floods, hurricanes, and heatwaves like the deadly 2003 European heatwave that broke temperature records across Spain, France, and Germany (Botkin & Keller, 2005).

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One of the most affected areas of public health is respiratory health. Airborne pollutants such as PM2.5, greenhouse gases, and other harmful emissions from urban development and vehicle use have been linked to diseases such as asthma, bronchitis, and chronic obstructive pulmonary disease (COPD). In Kuala Lumpur, recurring haze episodes often caused by open burning in the region worsen air quality and respiratory risks. Studying this connection is essential to design effective mitigation and adaptation policies to protect public wellbeing.

Malaysia is already experiencing the consequences of climate change: rising temperatures, unpredictable rainfall, and more frequent extreme weather. In major urban centers like Kuala Lumpur, air pollution poses a serious threat to health, particularly in densely populated areas such as Cheras. As the nation's capital, Kuala Lumpur suffers from heavy traffic, industrial activities, and open burning all contributing to poor air quality. Climate change exacerbates this through increased temperatures and humidity, which facilitate the formation of ground-level ozone and fine particles (PM2.5, PM10) that irritate the respiratory system. Cheras, being one of the most populated urban districts, faces daily emissions from vehicles and industrial zones, releasing pollutants like carbon monoxide (CO) and nitrogen dioxide (NO_2). Seasonal haze episodes further worsen the situation, especially during dry periods.

Research consistently shows a strong link between air pollution and respiratory diseases. For example, Brauer et al. (2002) found that children exposed to traffic-related air pollution in the Netherlands were more likely to suffer from coughing, wheezing, asthma, and impaired lung function. Similarly, residents of Cheras particularly children, the elderly, and those with pre-existing conditions are at higher risk due to sustained exposure to poor air quality and rising temperatures.

This study, therefore, aims to examine the relationship between climate change and respiratory health among Cheras residents, exploring how factors such as temperature, humidity, and air quality contribute to health outcomes and identifying possible mitigation and adaptation strategies.

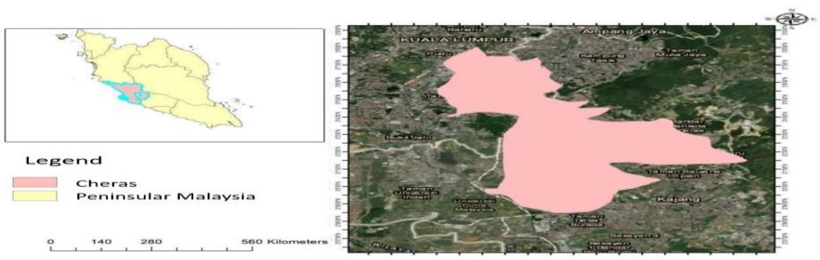
Kuala Lumpur, particularly Cheras, is increasingly exposed to extreme weather events, worsening air pollution, and temperature rise due to climate change. These conditions threaten public health, especially respiratory health. Urban congestion, industrial emissions, and open burning generate pollutants such as nitrogen dioxide (NO_2), carbon monoxide (CO) and hydrocarbons (Wjist et al., 1993), which lead to respiratory illnesses like asthma, influenza, bronchitis, and chronic respiratory diseases. Heatwaves also heighten the formation of ground-level ozone, which damages lung tissue and aggravates breathing problems particularly among vulnerable groups.

Despite growing evidence on the health impacts of climate change, there remains a lack of localised data in Malaysia linking climate variables (temperature, humidity, pollution) directly to respiratory health outcomes. This knowledge gap hinders effective policy development and mitigation planning.

Study Area

This study focuses on Cheras, Kuala Lumpur, a high-density metropolitan area facing severe air pollution due to rapid urbanization, industrial activities, and heavy traffic. The research will analyze environmental and health data to understand the local dynamics between climate variables and respiratory health, aiming to inform future urban and health policies for sustainable city management.

Figure 1: Study Area of Cheras, Kuala Lumpur, Malaysia



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This study was conducted in Kuala Lumpur, Malaysia's primary urban and economic hub, with a particular focus on the district of Cheras. As one of the city's fastest-growing areas, Cheras is densely populated and characterized by a tropical climate, with average daily temperatures ranging from 26°C to 33°C and consistently high humidity. The community is ethnically diverse, comprising mainly Malay, Chinese, and Indian residents. Its economy is driven by commerce, services, and small-scale industries, with major shopping centers such as Cheras Leisure Mall and Sunway Velocity serving as key commercial nodes. The area also offers essential public amenities, including schools, hospitals, and parks, which contribute to residents' quality of life. However, Cheras faces increasing environmental stress due to climate change impacts such as heatwaves, flash floods, and air pollution. Heavy traffic, industrial activities, and frequent open burning have led to poor air quality, while its topography comprising both hilly and low-lying zones at an elevation of about 74 meters tends to trap pollutants. Consequently, residents, especially children and the elderly, are highly vulnerable to respiratory illnesses, making Cheras an ideal location for studying the relationship between climate change and respiratory health.

METHODOLOGY

Data Collection Methods

Primary Data - Field Observation

Field observations were conducted at strategic locations in Cheras to record environmental factors related to air quality. The selected sites included residential areas near highways with heavy traffic, such as Bandar Tun Razak, located close to hospitals and schools, and Cheras Perdana, which has small industrial zones and open burning activities that may contribute to air pollution. Observations focused on traffic density, open burning activities, and the presence of industrial areas that potentially emit pollutants. These were carried out during peak traffic hours and under extreme weather conditions to ensure that the data reflected real environmental situations. Although no specific instruments such as particulate matter (PM2.5) or surface temperature sensors were used, the observations supported the secondary data analysis obtained from official agencies. Recorded data included the presence of smoke, odour, dust, and the frequency of open burning to assess the extent of air pollution and its possible effects on residents' health.

Secondary Data

Secondary data were essential in understanding the relationship between climate change and respiratory health in Kuala Lumpur. Two main datasets were used: climate data and health data, collected from the Malaysian Meteorological Department (MET Malaysia) and health institutions such as hospitals and public clinics.

Climate Data:

Climatic parameters such as temperature, humidity, rainfall, and concentrations of particulate matter (PM2.5, PM10) were gathered from agencies like the Meteorological Department and the World Air Quality Index (WAQI) website (https://waqi.info). These indicators are critical in assessing respiratory health impacts. High temperatures and low humidity increase respiratory risks, while fine particulate pollution is linked to asthma and chronic obstructive pulmonary disease (COPD). Data were collected daily across a two- to five-year period to identify trends in air quality and climate variability. Seasonal variations, such as haze during monsoon months caused by transboundary burning, were also analysed.

Health Data:

Health data were obtained from hospitals, clinics, and public health centres in Kuala Lumpur. They included records of respiratory diseases such as asthma, bronchitis, influenza, upper respiratory infections, and COPD, along with patient demographics (age, gender) and diagnosis information. These data were compared with climatic variables to explore correlations, for example, between higher PM2.5 concentrations and increased hospital admissions for influenza. The Weekly Epidemiological Bulletin (ME 35/2023) from the Cheras District Health Office under the Ministry of Health (MOH) provided official statistics on Influenza-Like Illness

(ILI), including total reported cases, consultation rates, and laboratory test results for respiratory infections such as Influenza A. This comprehensive dataset enabled the study to evaluate how air pollution and weather fluctuations affect urban respiratory health and to provide scientific evidence for public health interventions and environmental policy. However, while 2021 health data represent full-year records, the 2023 dataset covers only one epidemiological week. This temporal discrepancy was explicitly considered in the interpretation of findings to avoid overgeneralisation.

Data Analysis Methods

The study employed an integrated analytical approach combining statistical and geospatial methods to assess how climate parameters temperature, humidity, and Air Quality Index (AQI) influence respiratory disease incidence in Kuala Lumpur. Two main tools were utilised: Microsoft Excel for statistical analysis and Geographical Information System (GIS) for spatial mapping.

Microsoft Excel:

Excel served as the primary platform for managing and analysing raw data from hospitals, health agencies, and environmental monitoring stations. Patient records were organised by location, disease type, admission date, age, and gender. Climate data such as temperature, humidity, and PM2.5 concentration were also integrated. Descriptive analyses including mean, median, and frequency distributions were performed to identify initial trends in disease occurrence. Graphical tools such as bar charts, pie charts, and histograms provided visual insights prior to spatial mapping. Excel also facilitated data conversion into GIS-compatible formats (e.g. CSV) for further geospatial analysis.

GIS Mapping:

GIS mapping complemented the statistical findings by visualising high-risk zones for respiratory diseases. Health data were spatially overlaid with climate variables (temperature, humidity, PM2.5) to generate risk maps showing areas of elevated disease prevalence. For instance, urban zones with heavy traffic exhibited higher respiratory disease rates due to elevated particulate concentrations, while low-lying areas prone to flash floods showed increased respiratory infections linked to water and air pollution. GIS enabled identification of geographic patterns and environmental linkages, providing valuable tools for public health planning. High-risk zones could be prioritised for interventions such as free respiratory check-ups or air quality awareness campaigns. The maps also guided policymakers in enforcing emission control measures in critical areas, such as industrial or traffic-dense zones. In summary, this study's data collection and analysis framework combined field observation, climatic and health data, and statistical-GIS integration to provide a comprehensive understanding of how climate change impacts respiratory health in Cheras, Kuala Lumpur. This evidence-based approach supports targeted environmental and health policy development for Malaysia's urban populations.

RESULTS AND DISCUSSIONS

Summary of Field Observation and Findings in Cheras, Kuala Lumpur

The first objective of this study was to identify climate change patterns in Cheras, Kuala Lumpur, and assess their impact on local air quality. Cheras was chosen due to its rapid urbanisation, high population density, and extensive infrastructure development, all of which contribute to rising local temperatures and worsening air pollution. The study used indirect field observations, conducted in April 2025, to document visible environmental changes, focusing on traffic congestion, land use, and green space distribution. Data were collected through visual assessments and photography at several strategic sites, comparing shaded and open areas to determine differences in temperature and air quality.

The field observations revealed a clear contrast between built-up areas and open spaces. Highly developed zones with extensive paved surfaces roads, car parks, and high-rise buildings, recorded noticeably higher temperatures than open, less-developed areas. This pattern illustrates the urban heat island effect, where

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concrete and asphalt absorb solar radiation and release heat, increasing ambient temperatures. Heavy traffic during peak hours was observed as a major contributor to air pollution, with significant emissions of carbon dioxide (CO_2), nitrogen dioxide (NO_2), and fine particulate matter (PM2.5). The findings support the hypothesis that rapid development and dense traffic directly degrade air quality and elevate health risks.

Figure 2: Cheras area captured on 12th April 2025

Photographic documentation of Figure 2 from commercial and residential zones in Cheras captured scenes of intense traffic, compact infrastructure, and a lack of vegetation. Despite clear skies, the scarcity of trees and green spaces exacerbates heat retention and restricts natural ventilation, reinforcing the urban heat island phenomenon. The imbalance between physical development and ecological planning has created microclimatic shifts that heighten exposure to air pollutants, especially among vulnerable populations such as children and the elderly.

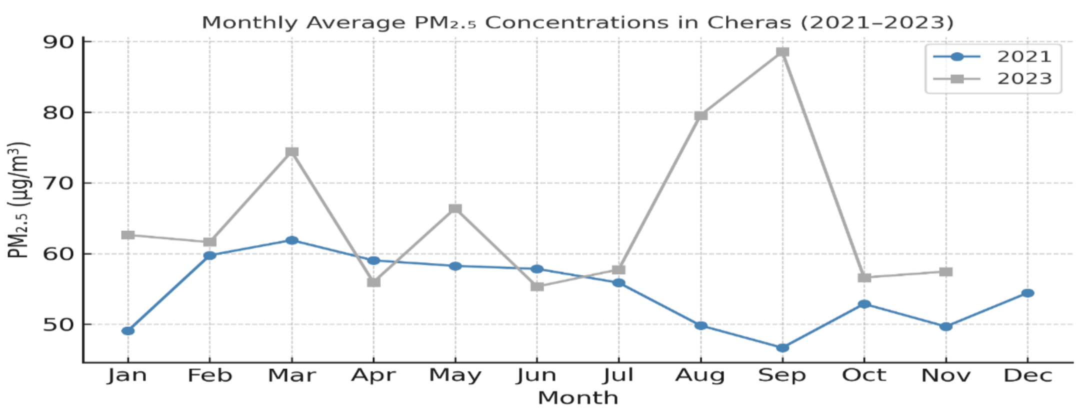
The analysis concludes that Cheras is experiencing a distinct microclimate transformation marked by increasing surface temperatures and declining air quality driven by land-use changes, reduced vegetation, and vehicular emissions. These localised climatic shifts contribute not only to discomfort and health problems, including respiratory illnesses, but also to broader patterns of environmental degradation. Sustainable urban planning measures, such as improved traffic management, expansion of green infrastructure, and stricter control of vehicle emissions, are therefore crucial to mitigating ongoing air pollution and preserving public health in rapidly urbanising districts like Cheras.

Secondary Data Analysis of Climate Change and Air Quality in Cheras

This section analyses secondary climate and air quality data in Cheras, focusing on comparative trends between 2021 and 2023. The data, obtained from the Air Quality Index (AQI) website and meteorological sources, demonstrate how environmental changes and post-pandemic human activity have influenced air conditions and potential health risks in Kuala Lumpur's urban landscape.

Comparison of Air Quality Index (AQI)

Figure 3: Monthly average PM2.5 concentrations in Cheras for 2021–2023, illustrating seasonal variability and post-pandemic rebound effects.



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The average annual PM2.5 concentration in Cheras increased markedly between 2021 and 2023, as shown by AQI readings in Figure 3. In 2021, the PM2.5 average stood at 54.68 µg/m³, categorised as "Unhealthy for Sensitive Groups." However, by 2023, the concentration rose to 65.34 µg/m³, placing it in the "Unhealthy" category. This escalation of nearly 10.66 µg/m³ within two years signifies a substantial decline in air quality. The deterioration is likely due to intensified urban activities following the COVID-19 recovery phase, including increased traffic flow, rapid infrastructure expansion, and hotter, drier microclimatic conditions that concentrate fine particulate matter. Prolonged exposure to PM2.5 is medically linked to respiratory illnesses such as asthma, bronchitis, and upper respiratory tract infections, particularly in densely populated zones like Cheras where vehicular emissions dominate the urban environment.

Annual Maximum Temperature Trends

The average annual maximum temperature showed a marginal decrease, from 32.12°C in 2021 to 32.09°C in 2023, a statistically insignificant difference of 0.03°C. Despite the slight variation, the consistently high temperatures above 32°C confirm the persistence of intense urban heat in Cheras.

High ambient temperatures accelerate photochemical reactions that generate ground-level ozone and enhance the suspension of pollutants such as PM2.5. This interaction between heat and pollution heightens respiratory risks. The minimal dip in 2023 temperatures may partially reflect the indirect effects of the COVID-19 pandemic, when industrial and transportation activities were drastically curtailed in 2021. Nevertheless, the return of full economic activity in 2023 restored the stable pattern of elevated temperatures, reinforcing the relationship between human mobility, urban heat dynamics, and pollution levels.

Annual Minimum Temperature Trends

Similarly, the average minimum temperature recorded a negligible decline from 23.71°C in 2021 to 23.67°C in 2023 (a 0.04°C difference). Though statistically insignificant, this sustained nighttime warmth above 23°C indicates continuous urban heat island (UHI) effects. Elevated nighttime temperatures hinder the natural cooling cycle essential for human physiological recovery, disproportionately affecting the elderly and individuals with respiratory conditions.

During 2021's lockdowns, reduced vehicular and industrial emissions may have temporarily alleviated urban heat accumulation. However, as commercial and social activities resumed, minimum temperatures stabilised at high levels, underscoring persistent anthropogenic heat retention and its potential impact on thermal comfort and respiratory well-being.

Annual Average Humidity

Average humidity in Cheras decreased slightly from 80.05% (2021) to 79.97% (2023), a marginal 0.08% drop. While statistically minor, these values indicate consistently high humidity, a typical characteristic of Malaysia's equatorial climate. Sustained humidity above 79% can influence thermal discomfort and exacerbate respiratory stress. High moisture content in the air reduces the body's ability to cool through perspiration, intensifying heat stress among urban populations.

Furthermore, prolonged humidity fosters microbial growth mould, bacteria, and allergens that worsen indoor air quality and trigger respiratory ailments such as asthma and influenza. The minor variation in humidity may also relate to broader climatic and anthropogenic shifts, including rainfall fluctuations and post-pandemic increases in human activity. The Movement Control Order (MCO) in 2021 had temporarily suppressed emissions and vapour release, while renewed economic operations in 2023 likely restored atmospheric moisture to pre-pandemic equilibrium.

The combined data suggest that while temperature and humidity fluctuations in Cheras between 2021 and 2023 were minimal, air pollution indicators particularly PM2.5 showed a marked deterioration, signalling worsening environmental and health conditions. Elevated PM2.5 levels and persistent heat contribute synergistically to respiratory health risks, aggravating conditions such as asthma and COPD. The findings underscore the role of

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urbanisation, motorisation, and limited green infrastructure in shaping Cheras' microclimate. The city's consistent exposure to high temperature, humidity, and particulate concentrations highlights the urgency for sustainable interventions. Measures such as improved air quality monitoring, stricter vehicle emission control, urban tree planting, and sustainable land-use planning are critical to mitigating air pollution and protecting public health in Kuala Lumpur's rapidly urbanising districts.

Air Quality and Respiratory Health in Cheras, Kuala Lumpur

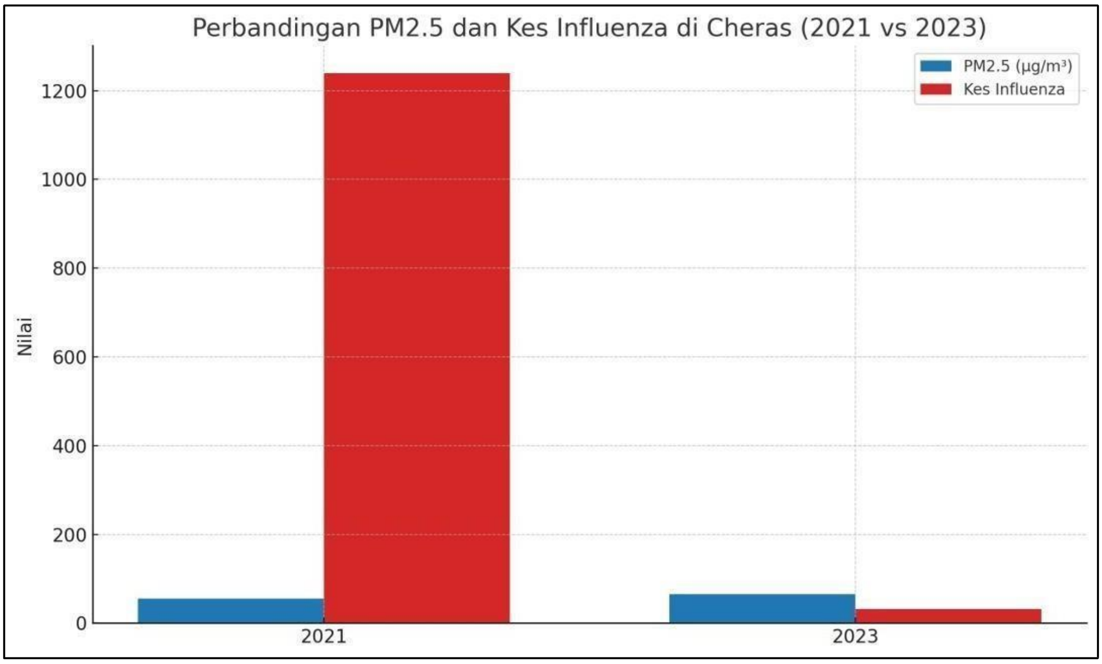
Air quality plays a critical role in determining the respiratory health of urban populations. High concentrations of fine particulate matter (PM2.5) particles smaller than 2.5 micrometres are known to aggravate respiratory illnesses such as influenza, asthma, and bronchitis. Comparative data from 2021 and 2023 in Cheras highlight variations in both air pollution and influenza cases, offering insights into how pollution levels correspond with health outcomes.

Table 1: Comparison of PM2.5 Concentrations and Influenza Cases in Cheras (2021–2023)

Year	Average PM2.5 (μg/m³)	Influenza Cases
2021	54.68	1240.0
2023	65.34	32.0

According to the data, the average PM2.5 concentration rose from 54.68 μg/m³ in 2021 to 65.34 μg/m³ in 2023, indicating a significant deterioration in air quality. Both readings fall within the "unhealthy for sensitive groups" range based on World Health Organization (WHO, 2016) standards, suggesting potential risks to vulnerable populations such as children, the elderly, and individuals with pre-existing respiratory conditions. This rise in pollution likely reflects increased post-pandemic urban activity, including higher traffic volume, industrial emissions, and construction.

Figure 4: Comparison of PM2.5 Readings with Influenza Cases in Cheras



However, the number of recorded influenza cases showed an unexpected trend: 1,240 cases in 2021 compared to only 32 cases in 2023. While the air quality worsened, influenza incidence sharply declined. This apparent contradiction diverges from findings by Dominici et al. (2006) and Gulliver et al. (2018), which reported a positive correlation between PM2.5 levels and respiratory illness rates.

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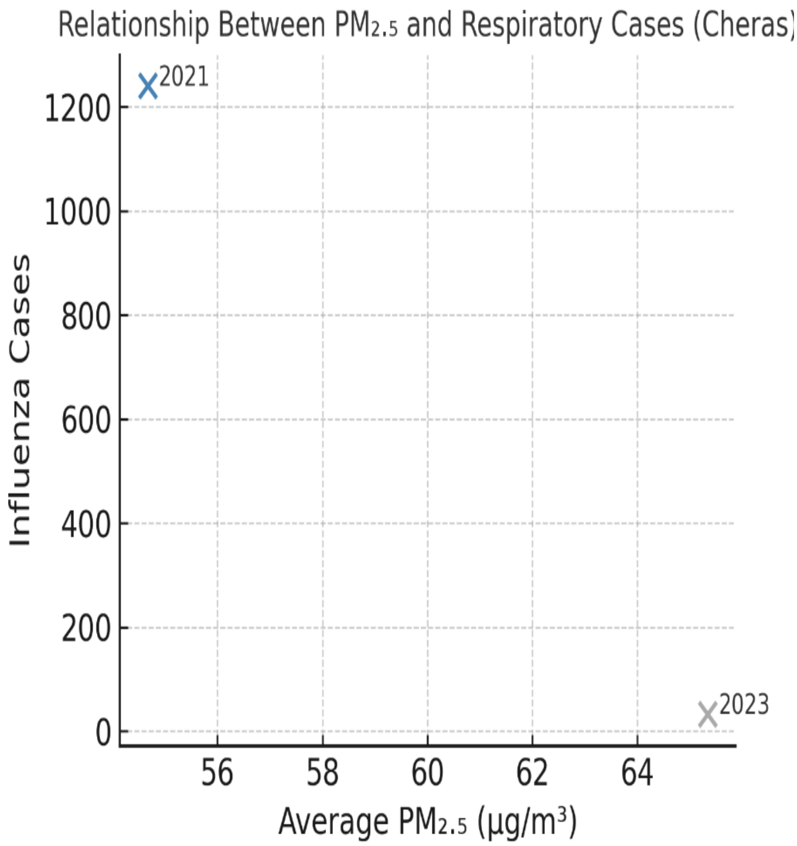
Figure 5: Relationship between PM2.5 levels and influenza cases in Cheras (2021 vs 2023).



Several contextual factors may explain this discrepancy. The data for 2021 represent a full-year total, while the 2023 data cover only one epidemiological week (ME35/2023), creating a reporting imbalance. Moreover, public health interventions during the post-COVID-19 period including widespread mask use, social distancing, and heightened hygiene practices likely reduced the spread of airborne diseases. The behavioural changes that persisted after the pandemic contributed to lower infection rates despite higher pollution levels.

In conclusion, while air pollution in Cheras worsened between 2021 and 2023, respiratory illness incidence did not increase correspondingly, suggesting that human behaviour, preventive measures, and data collection scope play pivotal roles in interpreting environmental health trends. To establish a more accurate relationship between air pollution and respiratory diseases, future research should employ consistent longitudinal datasets, incorporating weekly or monthly records across multiple years. This approach would clarify the long-term health impacts of PM2.5 exposure in Malaysia's urban environments and guide more targeted public health and environmental policies.

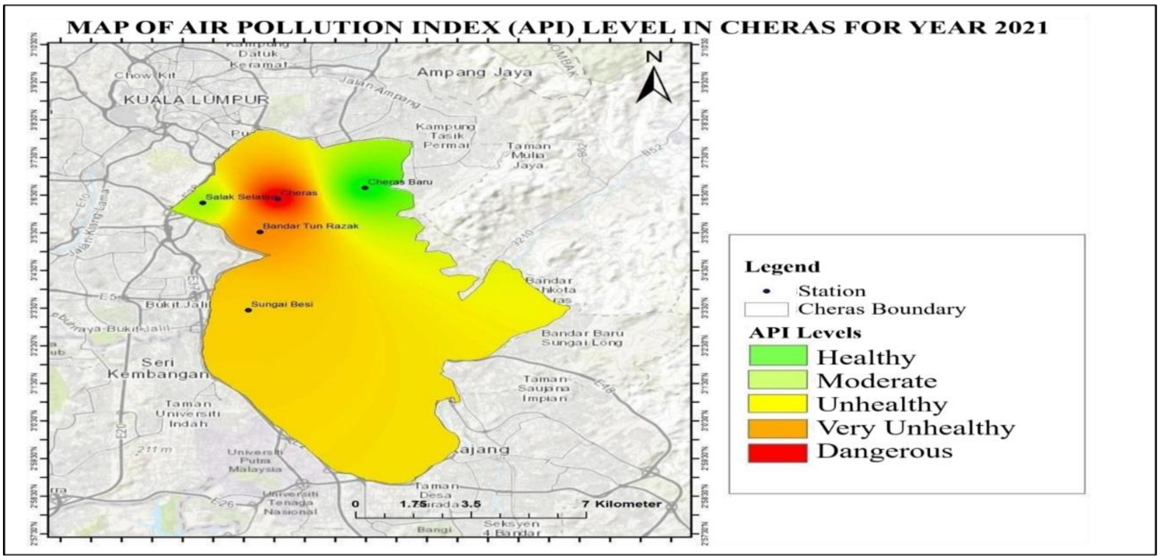
Spatial Analysis of the Relationship Between Air Quality and Respiratory Illness in Cheras

To better understand the connection between air quality and respiratory health, spatial analysis maps of the Air Pollution Index (API) were developed for Cheras using data from 2021 and 2023. These maps visualised how pollution levels varied across different monitoring stations and how changes in human activity influenced environmental and health outcomes.

Air Pollution Index (API) Map - 2021

In 2021, air quality across Cheras was relatively moderate. Data collected from five monitoring stations which are Cheras, Cheras Baru, Sungai Besi, Salak Selatan, and Bandar Tun Razak, showed API readings between 68 and 75, classified as “Moderate.” The highest value (75) was recorded in Cheras, while Cheras Baru registered the lowest (68).

Figure 6: Map of Air Pollution Index (API) Levels in Cheras, Kuala Lumpur for the Year 2021

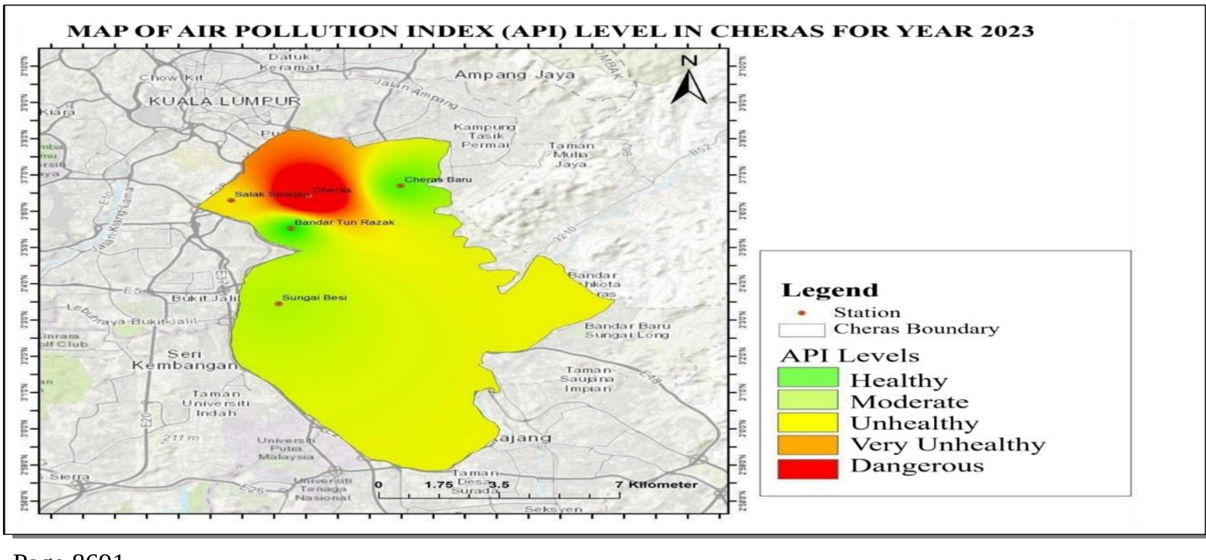


This relatively clean air quality coincided with the COVID-19 pandemic lockdown (Movement Control Order - MCO), during which Malaysia imposed strict restrictions on mobility, industrial operations, and non-essential economic sectors. The drastic reduction in vehicular traffic and factory emissions resulted in a notable decline in urban air pollutants such as PM2.5, PM10, CO, NO_2, SO_2, and O_3. Research by Kanniah et al. (2020) confirmed significant reductions in nitrogen dioxide and particulate matter concentrations in Malaysia's urban centres during lockdown periods, with PM10 levels dropping by as much as 58%. Similarly, Mohd Nadzir et al. (2020) found that reduced industrial activity and heavy rainfall helped disperse atmospheric pollutants. Thus, 2021 reflected an exceptional, short-term improvement in urban air quality due to restricted human mobility rather than structural environmental reform. Even in a densely populated and rapidly urbanising area like Cheras, these temporary measures demonstrated that human activities especially transport and industrial output play a decisive role in determining air pollution intensity. Studies such as Ghahremanloo et al. (2021) also observed that reduced mobility during lockdowns substantially improved air quality across Malaysia's cities.

Air Pollution Index (API) Map - 2023

By 2023, Cheras experienced a marked deterioration in air quality. Data from the same five monitoring stations revealed API readings ranging from 79 to 95, with all stations falling within the "Unhealthy" category as defined by Malaysia's Department of Environment. The highest value, 95, was recorded at the Cheras station, followed by Salak Selatan (84), Sungai Besi (82), Cheras Baru (80), and Bandar Tun Razak (79).

Figure 7: Map of Air Pollution Index (API) Levels in Cheras, Kuala Lumpur for the Year 2023



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This deterioration is directly linked to the post-pandemic economic and social recovery. As all sectors reopened, traffic congestion and industrial emissions surged. The Department of Statistics Malaysia (2023) and Malaysian Highway Authority (2023) reported significant increases in vehicle density and construction activity, contributing to elevated levels of CO, NO_2, and PM2.5. Additionally, industrial plants and power stations resumed full-scale operations, producing higher volumes of greenhouse gases that intensified the urban heat island effect (Oke, 1982).

These combined factors of vehicle exhaust, industrial emissions, and reduced natural ventilation due to dense building structures led to pollutant accumulation, particularly on hot, dry days. The lack of sufficient green infrastructure further worsened air stagnation. According to Seinfeld and Pandis (2016), global warming and limited atmospheric convection can trap pollutants in lower atmospheric layers, a condition amplified in high-density areas like Cheras. Urban development that replaces vegetation with concrete diminishes the city's natural filtering capacity, as noted by Gill et al. (2007).

CONCLUSION

Key Findings

The analysis revealed a significant environmental regression between 2021 and 2023, as air quality in Cheras shifted from moderate to unhealthy levels, with direct implications for public health. Urban air quality was found to be highly dependent on human activity patterns notably traffic congestion, industrial output, and land development intensity. The temporary improvement observed in 2021, during Malaysia's COVID-19 lockdown, demonstrated how quickly pollution levels can decline when emissions are curtailed. However, the return to unrestricted mobility and economic growth in 2023 reversed these gains, exposing vulnerable groups such as children, the elderly, and individuals with chronic respiratory diseases (asthma, COPD) to greater health risks. Spatial and temporal data further confirmed a strong correlation between pollution density and respiratory vulnerability across Cheras. Sustained exposure to high PM2.5 concentrations can exacerbate respiratory illnesses and contribute to long-term cardiovascular issues. These findings underscore the urgency of adopting sustainable urban management practices that balance development with environmental protection.

POLICY RECOMMENDATIONS

To advance sustainable air quality management in Malaysia's urban areas, a multi-dimensional strategy is required one that transcends short-term or reactive measures. This includes enforcing stricter emission standards through comprehensive regulations for industrial and vehicular emissions to limit pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), and PM2.5, supported by continuous monitoring, transparent reporting, and inter-agency coordination to ensure compliance and encourage investment in cleaner technologies. Strengthening green urban planning is equally crucial by integrating nature-based solutions such as urban forests, green corridors, and vertical gardens into city design to improve air filtration, mitigate heat islands, and enhance residents' quality of life. Municipal policies should prioritise green zoning and incentivise developers to include environmental buffers and sustainable landscapes in new projects. Promoting sustainable mobility through low-emission transport options such as electric vehicles, cycling infrastructure, and efficient public transit systems can significantly reduce congestion, emissions, and associated health risks. Finally, implementing integrated monitoring systems that combine GIS-based pollution data with hospital health records would enable continuous air-health surveillance, allowing early identification of respiratory risk zones and more targeted public interventions. Collectively, these actions reinforce Malaysia's broader commitment to carbon neutrality and urban climate resilience.

Future Research Needs

Future research should prioritise the development of longitudinal and harmonised datasets that integrate weekly or monthly health statistics with spatial pollution indicators. Such data consistency will enable more accurate analyses of causal relationships between air quality fluctuations and respiratory health outcomes. Moreover, exploring machine learning and GIS-based predictive models could enhance early warning systems for respiratory risks. Interdisciplinary collaboration among environmental scientists, urban planners, and public health experts will be key to designing data-driven, evidence-based interventions for sustainable city development.

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