# Comparative Study of Carbon Monoxide (CO) Concentrations in Different Urban Zones of Klang Valley: Observations from Monitoring Stations by the Department of Environment (DOE), Malaysia

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## ABSTRACT

**Purpose:** The Klang Valley, Malaysia's most densely populated and industrialised region, is experiencing significant air quality deterioration due to rapid urbanisation, industrial activities, and vehicle emissions.

**Methodology:** This study aims to analyse the daily average trend of CO concentration at five monitoring stations operated by the Department of Environment (DOE), namely Klang, Petaling Jaya, Kajang, Shah Alam, and Cheras, from January 1st to December 31st, 2005, by using statistical scatter plot analysis.

**Findings:** The study's findings indicate that Petaling Jaya station has a stable trend in daily CO concentration, with a maximum of 7 ppm and a minimum of 0.5 ppm. The scatter plot shows sporadic fluctuations, but most data points are within the 1-2 ppm range, indicating a typical daily concentration level for CO in Petaling Jaya. Outliers, marked by large spikes, may be due to heavy traffic, industrial activities, or unfavourable weather conditions.

**Research Implication:** The study highlights the need for stricter environmental regulations and urban planning strategies to manage pollution sources and emphasises the importance of continuous air quality monitoring, public health advisories, alternative transportation methods, and industrial emission controls to stabilise CO concentration and improve air quality.

**Keywords:** urban air quality; daily-average CO concentration; DOE monitoring station; statistical analysis; Klang Valley

## INTRODUCTION

The Klang Valley, which includes Kuala Lumpur and its surrounding areas, is the most densely populated and industrialised region in Malaysia. The air quality in this area has significantly worsened in the past few decades, mostly due to the rapid urbanisation, industrialization, and higher levels of vehicle emissions. In 2022, the air quality in the Klang Valley was mainly characterised by moderate API ratings, rather than falling inside the good range of API readings. Among the areas in the Klang Valley, Putrajaya recorded the highest number of days, totalling 98, with 'excellent' Air Pollution Index (API) scores. Conversely, Klang recorded the greatest number of days with 'moderate' API readings, amounting to a total of 360 days. The API reading in Cheras achieved its peak level of 'unhealthy' for a consecutive period of 5 days. Banting and Klang encountered this level for a duration of 2 days, but Batu Muda, Shah Alam, and Kuala Selangor experienced it for a duration of 1 day. Both the stations in Putrajaya and Petaling Jaya did not record any days with air quality levels classified as 'unhealthy'. The increase in PM2.5 pollution, namely in Klang, is caused by the creation of $O_3$ due to vehicle smoke emissions in densely populated areas such as Cheras, Batu Muda, Shah Alam, and Banting. In addition, the open burning activities in agricultural areas like Kuala Selangor also contribute to the rise in the frequency of days with low air quality in the Klang Valley.

Carbon monoxide (CO) is a pollutant that is causing degradation and significant concern because of its origins and the negative impacts on health. The main sources of CO in the Klang Valley include emissions from vehicles, industrial activities, and the burning of biomass. In 2022, there was a slight decrease in the levels of CO compared to 2021, with a value of 0.5283 parts per million (ppm). This number falls comfortably within the limits established by the Malaysian Ambient Air Quality Standard IT-2. From 2018 forward, CO measurements in industrial regions were stopped. Urban areas consistently displayed the greatest annual average levels of carbon monoxide (CO) compared to other types of land use. The predominant source of the elevated levels of carbon monoxide (CO) was mostly attributed to the discharge of gases from automobiles, contributing to 97 percent of the overall CO emissions in 2022.

The region's dense population and subsequent increase in transportation demand have resulted in a significant escalation in CO emissions from motor vehicles. According to the Department of Environment Malaysia (DOE) in 2022, the emissions from vehicles contribute significantly to the levels of CO in metropolitan areas. In 2022, the total cumulative air pollutant emission load was expected to be 2,070,909 metric tonnes of CO. The increase in emission load for CO was 22.7%. Therefore, motor vehicles accounted for the largest proportion of CO emissions, specifically 96.4%. The regular occurrence of traffic congestion in the Klang Valley leading to increased levels of CO in the air, particularly during periods of heavy traffic. Industrial operations significantly contribute to CO emissions.

The abundance of manufacturing plants, refineries, and other industrial facilities in and around Klang Valley results in the emission of CO and other harmful pollutants. CO is an undetectable, scentless gas that can cause significant health effects even at low concentrations. CO chemically combines with haemoglobin in the bloodstream to produce carboxyhemoglobin, resulting in a decrease in the blood's ability to transport oxygen. This can result in a range of health problems, including cardiovascular and neurological impacts, and is especially detrimental to susceptible groups such as children, the elderly, and persons with pre-existing medical illnesses (WHO, 2024). Recent research indicates that brief exposure to elevated amounts of CO can lead to symptoms such as headaches and dizziness. In more extreme instances, it can cause decreased cognitive function and loss of consciousness.

The significance of mitigating CO pollution in Klang Valley is emphasised by these health hazards, in order to safeguard public health. In recent years, there has been a significant increase in efforts to continuously monitor the air quality in the Klang Valley. The Malaysian government has implemented a comprehensive system of air quality monitoring stations that assess a range of pollutants, including CO. According to the DOE (2022), data from these stations show that CO levels frequently surpass the national air quality guidelines during periods of heavy traffic and occurrences of haze. The findings are supported by the Ambient Air Quality Database of the World Health Organisation, which indicates that urban areas in Klang Valley often have CO concentrations that exceed the acceptable standards (WHO, 2024a).

Therefore, this study was conducted with the aim of analyzing the daily trend of CO concentrations at five air quality monitoring stations of the Department of Environment Malaysia, namely Klang, Petaling Jaya, Kajang, Shah Alam, and Cheras in the year 2005. This is because the rapid urban growth and vehicle emissions in the Klang Valley area have been identified as the main contributors to high CO concentrations, besides transboundary haze events.

## MATERIALS AND METHODS

### Study area – The Klang Valley

The Klang Valley, located in the central region of Peninsular Malaysia, is a prominent metropolitan area encompassing the capital of Kuala Lumpur and its adjacent suburbs in the state of Selangor. The region is delimited by the Titiwangsa Mountains in the north and east, and the Straits of Malacca in the west. This region is the most densely populated and economically important area in Malaysia, serving as the main centre for

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financial, commercial, and industrial activities (Allabakash *et al.,* 2022). The Klang Valley is characterised by its dense population and rapid urban development. According to recent estimates, the population of Klang Valley exceeds 7 million, making it the most densely populated urban area in Malaysia. The swift expansion of urban regions has been accompanied by substantial infrastructure development, encompassing transit networks, commercial hubs, and residential zones (WHO, 2024b).

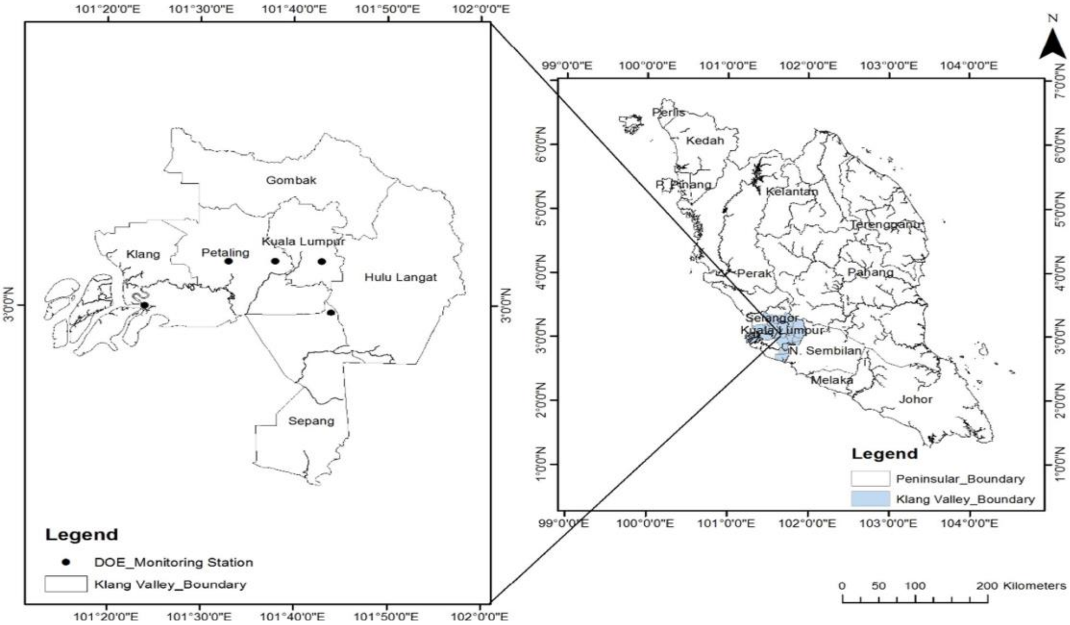


Figure 1: Map of DOE monitoring station sites in the Klang Valley (left) and peninsular Malaysia (right)

Source: Mohd Shafie et al., (2022)

The DOE Malaysia maintains a comprehensive network of air quality monitoring stations throughout the Klang Valley region. The placement of these stations is essential in order to monitor air pollution levels originating from several sources, including transportation emissions, industrial activity, and transboundary haze. Within Malaysia, the Klang Valley is equipped with six air quality monitoring stations situated at Gombak, Klang, Kuala Lumpur, Petaling Jaya, Shah Alam, and Kajang (Table 1). These stations are part of the overall air quality monitoring network established by the Department of Environment (DOE). In this study, the researcher has identified and chosen five specific areas: Klang, Shah Alam, Petaling Jaya, Kajang, and Cheras stations. These stations are situated within the districts of Klang, Petaling, Hulu Langat, and the Federal Territory of Kuala Lumpur.

Table 1. DOE Monitoring Station in Klang Valley

| Monitoring site ID | Monitoring site | Longitude | Latitude |
|---|---|---|---|
| CAC 011 | SM (P) Raja Zarina, Klang | 101 24.484’E | 3 0.620’N |
| CAC 016 | SK Sri Petaling, Petaling Jaya | 101 42.274’E | 3 6.612’N |
| CAC 023 | Country Heights, Kajang | 101 44.417’E | 2 59.645’N |
| CAC 025 | Sekolah TTDI Jaya, Shah Alam | 101 33.368’E | 3 6.278’N |
| CAC 054 | SMK Seri Permaisuri, Cheras | 101 43.072’E | 3 6.376’N |

Source: DOE 2010

The selection of the five study areas is determined by various factors, including the severe deterioration of air quality and the high and maximum levels of pollutants. Other factors include the level of activity in the area, the large and congested municipal land use, and the increasing population, which contributes to the concentration of pollutants.

The Klang Valley is a conglomeration of districts in the state of Selangor and the Federal Territory of Kuala Lumpur, specifically Petaling, Klang, Hulu Langat, and Gombak. The Klang Valley encompasses all of these regions, which are extensive and densely populated. It is characterised by its compactness, high level of development, and diverse land use patterns, as well as its diverse demographic groups. Therefore, this circumstance exposes the Klang Valley to numerous environmental challenges at both a broad and small scale.

The Klang Valley area exhibits diverse local land use patterns due to the dynamic and bustling human activities in the region, encompassing many distinct locales. The five major cities in the Klang Valley have been categorised into seven distinct types and classifications of land use, as defined by the Intergovernmental Panel for Climate Change (IPCC). The land use classes include residential and municipal areas, agricultural, woods, grasslands, mangrove swamps, and other land uses. The many categories of land use, as defined and established by the IPCC, vary depending on the specific region and its size.

The township and housing class is the predominant and largest land use type in the Klang Valley area, with a total area of 1203.28 hectares. The domain of housing and townships encompasses the five primary urban regions of Klang, Shah Alam, Petaling Jaya, Kajang, and Cheras. The agricultural sector is recognised as a significant land use area and is the primary focus in the Klang Valley region, covering a total area of 957.05 hectares. The agricultural expansion in the Klang Valley area is occurring at a rather fast pace and encompasses the suburban areas of the five study locations. The forest area encompassed a total of 741.62 hectares, specifically inside the Hulu Selangor district, particularly in Gombak. The mangrove swamp region spans 229.35 hectares, encompassing the water area at Port Klang within the Klang district, as well as a tiny portion of the Kelanang Beach area inside the Banting district. Furthermore, the land utilisation of grassy areas, other places, and wet areas in the Klang Valley region amounted to 124.13 hectares, 84.36 hectares, and 54.53 hectares, correspondingly.

**Air pollutant data**

In this study, the main data used is the average daily CO concentration obtained from the Air Division DOE, which was taken from January 1$^{st}$ , 2005 to December 31$^{st}$, 2005 at five air quality monitoring stations in the Klang Valley. The selection of 2005 in this study was influenced by the occurrence of serious cross-border haze incidents in Kalimantan and West Sumatra which affected the air quality in the western part of Peninsular Malaysia, especially the Klang Valley. In the process of analyzing CO concentration data in the Klang Valley using statistical analysis found in Microsoft Excel to compare each study station; Klang, Petaling Jaya, Kajang, Shah Alam and Cheras.

To examine the daily concentrations of CO at DOE monitoring stations in the Klang Valley using a scatter plot in Excel, use a systematic approach that involves generating the plot, including statistical components, and evaluating the findings. The equation of the trendline, $y = mx + b$, where m represents the slope and b represents the y-intercept, shows the overall trend of CO concentrations throughout time. A positive slope implies a rise in CO levels, while a negative slope denotes a decrease. The r-squared number, which ranges from 0 to 1, quantifies the degree of accuracy of the trendline in representing the data. A higher r-squared number indicates a stronger correlation between the variables, indicating a more accurate fit of the model. Conversely, a low R-squared value shows that the model only accounts for a tiny amount of the variability seen in CO concentrations. Analysing scatter plots and their statistical elements enables the detection of patterns and fluctuations in CO concentrations, offering valuable information for environmental monitoring and policy development. Furthermore, it emphasises the need for more extensive models to get a deeper understanding of the elements that impact air quality in the Klang Valley.

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## RESULTS AND DISCUSSIONS

Klang station demonstrates the daily concentrations of CO across a specific time frame with a straight-line pattern, characterised by the equation y = -0.0014x + 1.3168, and possesses an r-squared value of 0.0643. The dispersion of daily CO concentration data points, with the maximum daily concentration reaching approximately 6 ppm and the minimum daily value around 0.5 ppm. The trend line exhibits a progressive decrease in the concentration of carbon monoxide over time, typified by a negative slope of -0.0014. However, the $r^2$ value of 0.0643 suggests that only 6.43% of the variability in the CO contents can be explained by this linear model. This suggests that there are other significant causes that have a considerable impact on CO levels, extending beyond the linear trend observed throughout time (Figure 2).

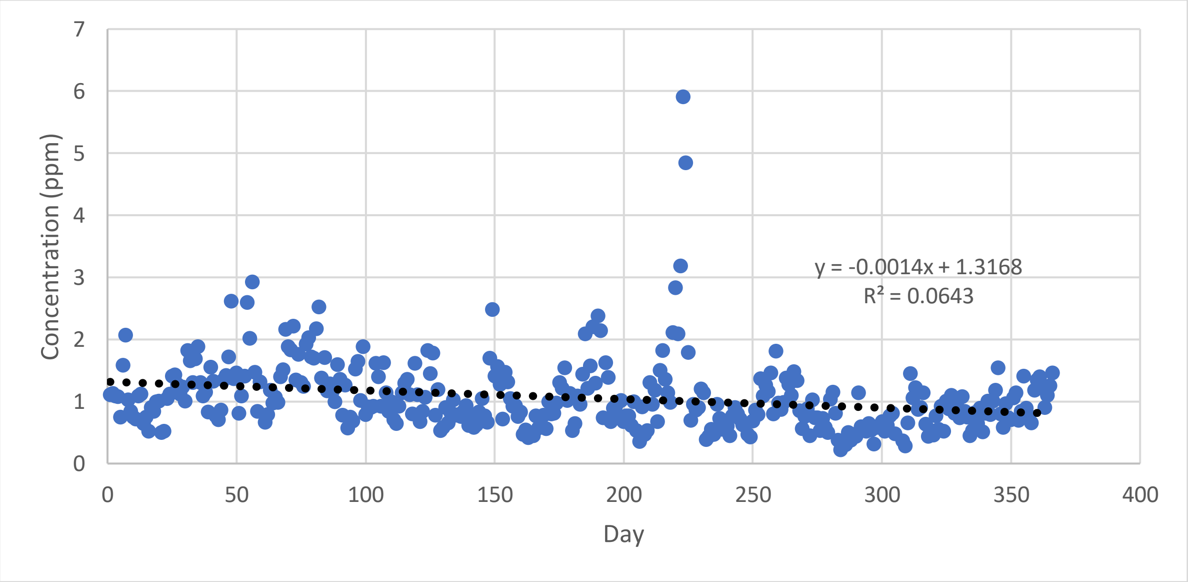


Figure 2: Daily-averaged CO concentration in Klang station in 2005

The majority of data points are clustered within the range of 1-2 ppm, indicating that these levels typically represent the everyday concentrations of CO in Klang. The presence of outliers, which are marked by significant increases in CO concentrations, can be attributed to particular events or circumstances such as heavy traffic, emissions from industrial activities, or unfavourable weather conditions like temperature inversions that trap pollutants close to the ground. The intermittent increases highlight the variability and complexity of air pollution patterns in urban areas such as Klang.

The daily concentrations of carbon monoxide (CO) in Petaling Jaya station indicates the dispersion of daily CO concentration with the maximum daily concentration reaching approximately 7 ppm and the minimum daily value around 0.5 ppm (Fig. 3).

The equation of the trend line, y = -2E-05x + 1.6842, suggests only a slight decrease in CO concentration over time, as seen by the exceedingly low slope value (-2E-05). This indicates that the overall trend in CO concentration is quite stable, with only a slight downward inclination. The r-squared value ($r^2$ = 1E-05) is remarkably low, indicating that the linear model does not sufficiently explain the variability in the CO concentration data. Statistically speaking, a $r^2$ value of 1E-05 suggests that only around 0.001% of the variability in daily CO concentrations can be explained by the time variable in this linear model. This implies that there are probably other factors that have a greater impact on CO levels than time.

The scatter plot demonstrates that while there are sporadic fluctuations in CO concentrations, the majority of the data points are clustered within the 1-2 ppm range. This indicates that the typical daily concentration level for CO in Petaling Jaya is within this range. The specified concentration level correlates to the findings of other studies that emphasise automotive emissions as the primary source of CO in densely populated metropolitan areas like Petaling Jaya, where there is a significant presence of traffic and industrial operations (Usmani *et al.*, 2020; DOE, 2019).

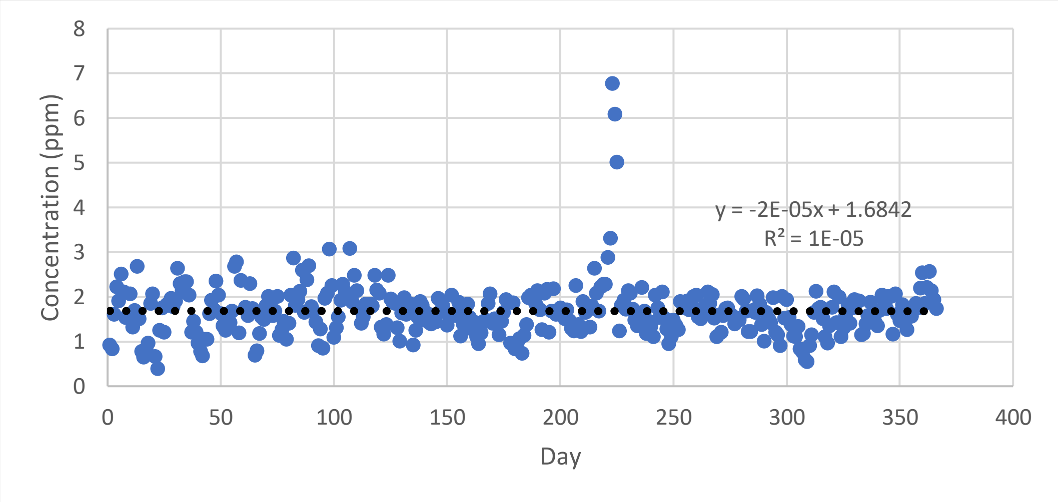


Figure 3: Daily-averaged CO concentration in Petaling Jaya station in 2005

The presence of outliers in the plot, which are marked by large spikes in CO concentrations can be attributed to specific events or circumstances such as heavy traffic during peak hours, industrial activities, or unfavourable weather conditions like temperature inversions that trap pollutants close to the ground. These sporadic increases emphasise the variability and complexity of air pollution patterns in urban areas.

At some point the graph illustrates significant fluctuations in the levels of CO concentration in Kajang station ranging from a high of over 3.0 ppm to a low of roughly 0.3 ppm. The scatter plot for Kajang provides a dataset where the x-axis represents an independent variable and the y-axis represents a dependent variable, with a linear regression line defined by the equation $y=-0.0006x+0.791y$. The slope of -0.0006 suggests a little negative trend, meaning that as the independent variable grows, the dependent variable slightly drops. Nevertheless, the $r^2$ value of 0.0488 indicates that only 4.88% of the fluctuations in the dependent variable can be accounted for by the independent variable, indicating a weak linear correlation. The dispersion of data points around the regression line, together with prominent outliers, indicates a significant amount of unexplained variability in this model. The slight decrease in the trend and the limited ability of the $r^2$ value to explain the variation indicate that there may be other relevant variables that affect the dependent variable. Hence, it is recommended that future study should investigate non-linear models or integrate additional variables to improve the model's explanatory power and get a deeper understanding of the underlying processes that contribute to the observed variability in Kajang's data (Figure 4).

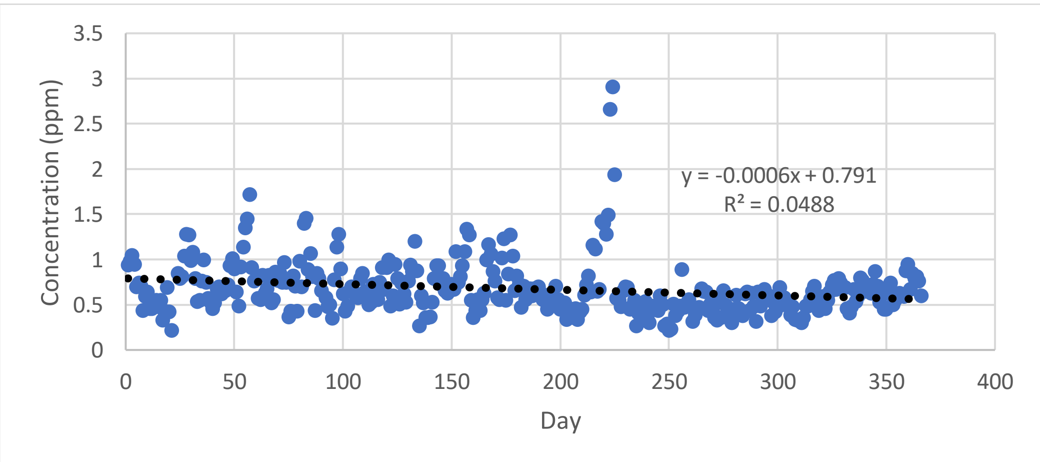


Figure 4: Daily-averaged CO concentration in Kajang station in 2005

The vast variation in CO concentration levels in Shah Alam station, with a high value of roughly 6.5 ppm and a low value of around 0.5 ppm. The scatter plot for Shah Alam displays a dataset where the x-axis represents an independent variable and the y-axis represents a dependent variable. It also includes a linear regression line given by the equation y = -0.0018x + 1.4531. The slope of -0.0018 suggests a small but consistent decline in the dependent variable as the independent variable rises. The $r^2$ value of 0.0928 indicates that 9.28% of the variation in the dependent variable can be accounted for by the independent variable, suggesting a rather weak linear association. The data points exhibit dispersion around the regression line, with a few prominent outliers, notably located above the y = 5 threshold. The wide range and the $r^2$ indicate substantial unexplained variation that is not accounted for by the linear model, indicating the presence of additional variables that may be affecting the dependent variable. The slight decline and limited capacity of the model to explain the data highlight the need for further examination, which may include the use of non-linear models or other variables, in order to get a more comprehensive understanding and explanation of the observed variability in the Shah Alam data (Figure 5).

The significant variation in CO levels in Cheras station ranging from a maximum of around 3.7 ppm to a minimum of 0.5 ppm. The scatter plot for Cheras exhibits a collection of data points, where the x-axis represents an independent variable and the y-axis represents a dependent variable (Figure 6). Additionally, it includes a linear regression line defined by the equation y=−0.0009x+1.2556y. The slope of -0.0009 indicates slightly negative trend, meaning that as the independent variable grows, the dependent variable falls somewhat. Nevertheless, the $r^2$ value of 0.0433 indicates that just 4.33% of the variability in the dependent variable can be accounted for by the independent variable, indicating a weak linear association. The scattering of data points around the regression line and the existence of outliers indicated substantial variability that is not accounted for by this model. Therefore, while there is a little decrease, its impact is insignificant, and the low $r^2$ value indicates that there are probably other variables that affect the dependent variable.

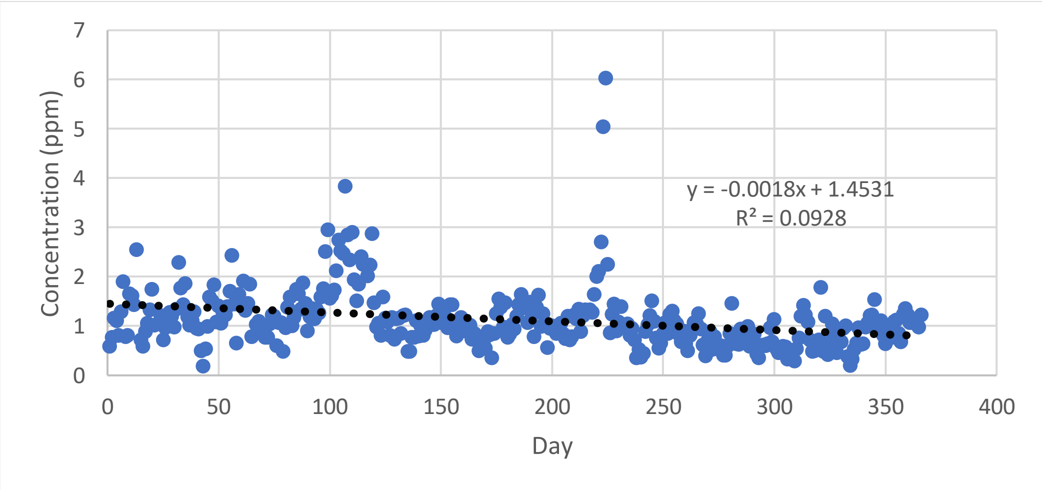


Figure 5: Daily-averaged CO concentration in Shah Alam station in 2005

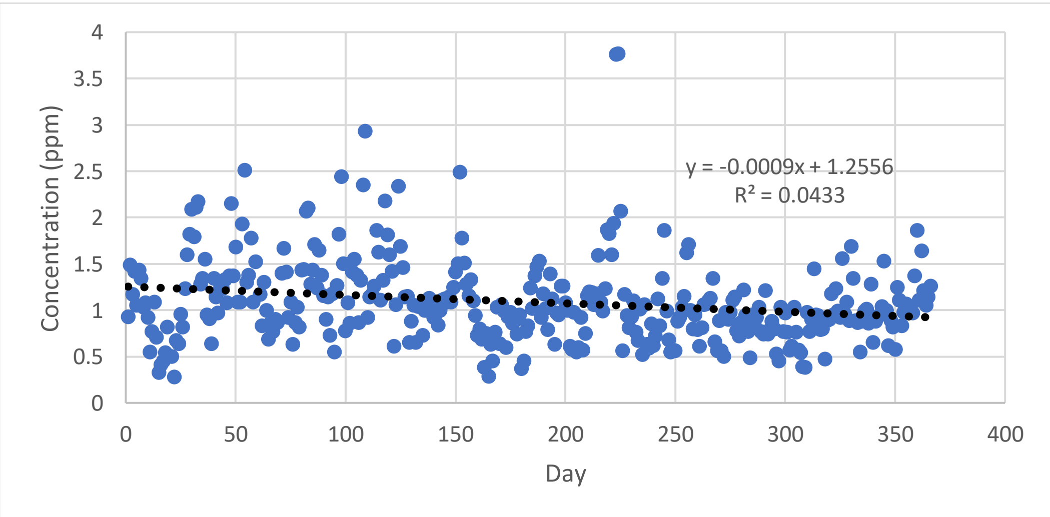


Figure 6: Daily-averaged CO concentration in Cheras station in 2005

The high concentrations of CO in the Klang Valley may be attributed to many significant sources. The main determinant is the concentrated urban development and elevated population density in the Klang Valley, including prominent metropolitan centres like Cheras, Petaling Jaya, and Shah Alam. These regions encounter high levels of automobile congestion, leading to considerable emissions of CO as a consequence of the burning of fossil fuels in vehicle engines. The quantity of automobiles on Malaysian roadways has seen a consistent growth, resulting in elevated levels of CO emissions, given that motor vehicles are a significant contributor of this pollutant (Angatha *et al.*, 2020). Moreover, the industrial activities taking place in these metropolitan locations are responsible for the increased levels of CO. Factories and industrial facilities often use fossil fuels, resulting in the emission of CO as a consequence of incomplete combustion processes. The industrial pollutants, together with those from automobile traffic, worsen the air quality issues in the Klang Valley (Mohd Shafie, 2024).

Furthermore, meteorological conditions also identified a crucial factor. The tropical climate of Malaysia, characterized by high temperatures and humidity, can exacerbate the formation and persistence of air pollutants. During specific periods, particularly the monsoon seasons, weather conditions can lead to temperature inversions, trapping pollutants near the ground and preventing their dispersion. This phenomenon is more pronounced in the Klang Valley due to its topographical features, including valleys and low-lying areas surrounded by hills, which further hinder the dispersal of pollutants. The tropical climate of Malaysia, particularly in the Klang Valley, significantly affects the formation and persistence of air pollutants such as CO. High temperatures and humidity prevalent in the region can enhance the chemical reactions that generate air pollutants, leading to higher concentrations. During the monsoon seasons, weather conditions can lead to temperature inversions, where a layer of warm air traps pollutants near the ground, preventing their dispersion. This effect is exacerbated by the topographical features of the Klang Valley, which includes valleys and low-lying areas surrounded by hills. These geographical features can hinder the natural dispersion of pollutants, leading to higher local concentrations of CO and other air pollutants (Breath Safe Air, 2024). Additionally, the seasonal monsoon cycles in Malaysia comprising the Southwest Monsoon from May to September and the Northeast Monsoon from November to March play a crucial role in air pollution dynamics. During the dry periods of the Southwest Monsoon, reduced rainfall means less washout of pollutants, leading to their accumulation in the atmosphere. Conversely, the Northeast Monsoon brings heavy rainfall, which can help cleanse the air by removing pollutants from the atmosphere, although this can sometimes lead to other pollution-related problems like waterlogging and increased particulate matter from disturbed sediments.

The geographic and spatial distribution of land use in the Klang Valley influences air quality. Urban areas with high traffic density and industrial zones show higher concentrations of CO compared to rural or less developed areas. Spatial analysis indicates that urban districts like Klang, Shah Alam, and Petaling Jaya have higher pollution levels due to their larger settlement areas and industrial activities (Mohd Shafie *et al.,* 2022). These factors combined make the Klang Valley particularly susceptible to high CO concentrations, necessitating targeted air quality management strategies and policies to mitigate pollution levels and protect public health.

The geographic and spatial distribution of land use in the Klang Valley significantly impacts air quality, particularly with respect to CO levels. Urban areas within the Klang Valley, such as Klang, Shah Alam, and Petaling Jaya exhibit higher concentrations of CO due to dense traffic and extensive industrial activities. These regions are characterized by larger settlement areas and a high density of industrial zones, which contribute to elevated pollution levels. Studies have shown that urban districts with significant traffic and industrial operations are more likely to experience higher levels of air pollutants. This correlation is evident in the Klang Valley, where the concentration of CO is notably higher in areas with intense vehicular emissions and industrial outputs. Spatial analysis indicates that these urban districts are hotspots for air pollution, necessitating robust air quality management strategies (Choi & Chong, 2022).

The topographical features of the Klang Valley, including valleys and low-lying areas surrounded by hills, exacerbate the issue by trapping pollutants and preventing their dispersion. This phenomenon is particularly severe during specific meteorological conditions, such as temperature inversions, which occur more frequently in this region due to its unique geographic characteristics (Junninen *et al.,* 2004). Furthermore, the combination of these geographic and industrial factors makes the Klang Valley especially vulnerable to high CO concentrations. Effective mitigation strategies, including stricter emission controls, enhanced public transportation systems, and the promotion of cleaner industrial practices, are essential to address this issue and protect public health.

# CONCLUSION

The Klang Valley, including Kuala Lumpur, is Malaysia's most densely populated and industrialized region, leading to significant air quality deterioration over recent decades. Rapid urbanization, industrial activities, and vehicle emissions are primary contributors to this decline. This study examined the daily concentrations of CO at five monitoring stations, revealing different pollution patterns and fluctuations across Klang, Petaling Jaya, Kajang, Shah Alam, and Cheras.

The Klang station showed a declining trend in CO levels with a weak linear correlation, likely influenced by other environmental and anthropogenic variables. Petaling Jaya displayed a more stable trend, with most values within a typical urban CO range. Kajang and Cheras stations exhibited significant fluctuations and low $r^2$ values, suggesting external factors beyond time that drive pollution levels. In Shah Alam, the data revealed a mild declining trend but also considerable variability, marked by outliers potentially caused by episodic traffic congestion or industrial emissions. These findings confirm spatial heterogeneity in CO patterns, reflecting variations in land use, population density, traffic volumes, and industrial activities across the Klang Valley.

To reduce CO concentrations and improve regional air quality, a comprehensive and integrated strategy must be adopted. For motor vehicle emissions, stricter emission standards, promotion of electric vehicles, and enhancement of public transportation networks are critical. Government efforts should also support cleaner fuels and regular vehicle maintenance. In the industrial sector, the implementation of pollution control technologies, stricter emission limits, and a shift towards renewable energy sources are essential to reducing CO output. Open burning should be addressed through enforcement of anti-burning laws and the promotion of sustainable agricultural practices. Importantly, public awareness campaigns on air pollution risks and community-based monitoring programs can strengthen mitigation efforts.

Moreover, these policy measures should be informed by interdisciplinary collaboration. Urban planners can utilize spatial analysis from this study to guide zoning regulations and optimize green infrastructure. Transportation agencies can use hotspot data to design low-emission zones and re-route high-traffic corridors. Public health experts can link air quality exposure data with respiratory disease trends to guide preventive healthcare planning. The integration of scientific evidence from air monitoring with actionable input from relevant stakeholders ensures that mitigation strategies are practical, localized, and effective. Through these combined measures, the Klang Valley can achieve sustained reductions in CO pollution and enhanced public health outcomes.

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### Authors' contributions

Data curation, methodology, analysis, writing—original draft, review and editing: SHMS. The author has read and agreed to the published version of the manuscript.

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