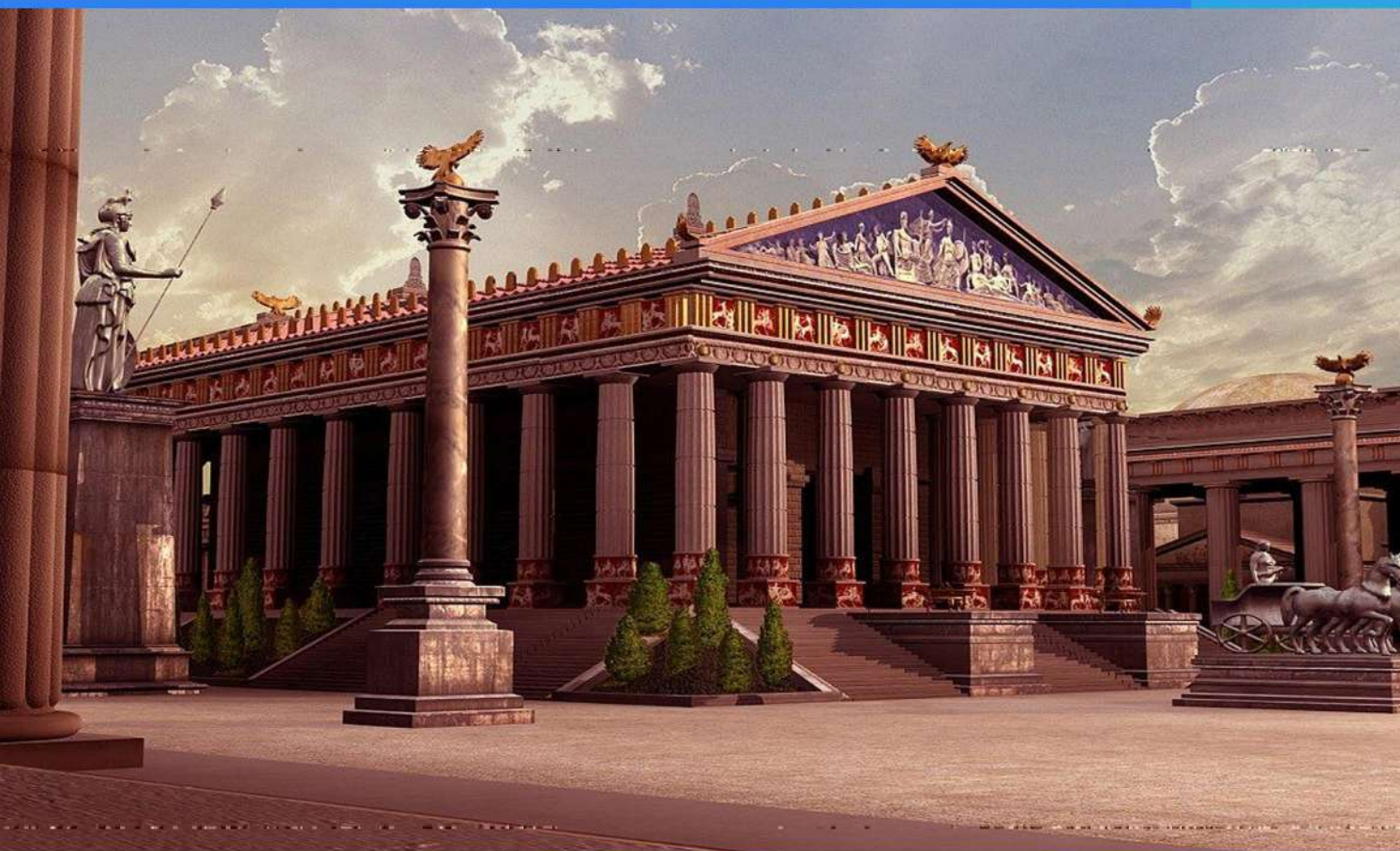


ВЕСТНИК НАУКИ



ВЫПУСК №7 (100)



ТОМ 4

Международный научный журнал

www.вестник-науки.рф

Тольятти 2026

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**APPLICATION OF THE DPSIR FRAMEWORK
FOR ASSESSING THE CURRENT STATUS
OF URBAN AIR QUALITY IN VIETNAM**

***Abstract:** this study applies the DPSIR (Driving Forces - Pressures - State - Impacts - Responses) framework to assess urban air quality in Vietnam using environmental monitoring and socio-economic data from 2020-2024. The results show that urbanization, population growth, transportation, and industrial development are the main drivers of urban air pollution. PM_{2.5} remains the most critical pollutant, with concentrations in several northern cities exceeding national standards. Air pollution poses significant risks to public health and socio-economic development. Current responses include strengthening monitoring systems, controlling emissions, promoting green transportation, and supporting sustainable urban planning. The DPSIR framework provides a useful tool for integrated air quality assessment and sustainable urban environmental management in Vietnam.*

***Keywords:** DPSIR framework, urban air quality, PM_{2.5}, air pollution, Vietnam.*

1. Introduction.

Rapid urbanization and industrialization have significantly contributed to socio-economic development in Vietnam but have also intensified pressures on urban air quality. Major cities such as Hanoi, Ho Chi Minh City, Hai Phong, and Da Nang frequently experience elevated levels of air pollutants, particularly PM_{2.5}, which poses serious risks to human health and the environment.

Urban air pollution arises from complex interactions among population growth, transportation, industrial activities, and energy consumption, requiring integrated assessment approaches. The DPSIR (Driving Forces - Pressures - State – Impacts - Responses) framework provides a systematic tool for analyzing these relationships. However, previous studies in Vietnam have mainly focused on pollutant trends and health impacts, with limited application of integrated DPSIR assessments.

Therefore, this study applies the DPSIR framework to evaluate urban air quality in Vietnam using environmental and socio-economic data. The study aims to identify key drivers and pressures, assess current conditions, and support integrated air quality management and sustainable urban development.

2. Materials and Methods.

2.1. Data Collection and Analysis.

Secondary data were collected from the National State of the Environment Report 2024, socio-economic statistics, policy documents, and scientific publications. Air quality data from automatic monitoring stations (2020-2024) were analyzed using descriptive statistics to assess spatial and temporal variations in PM_{2.5}, PM₁₀, NO₂, SO₂, CO, and O₃ concentrations. The results were used to develop the DPSIR framework and evaluate the relationships among driving forces, pressures, environmental conditions, impacts, and response measures.

2.2. DPSIR Framework Application.

The DPSIR framework developed by the European Environment Agency (EEA) was applied to assess urban air quality in Vietnam. Driving Forces (D) included urbanization, population growth, industrialization, and transportation development. Pressures (P) referred to emissions from transportation, industry, construction, and energy use. State (S) was evaluated using PM_{2.5}, PM₁₀, NO₂, SO₂, CO, O₃, and VN_AQI data. Impacts (I) focused on public health and socio-economic effects, while Responses (R) included environmental policies, monitoring systems, and emission control measures.

The DPSIR framework provided an integrated approach for identifying key factors affecting urban air quality and evaluating current management responses to support sustainable urban development in Vietnam.

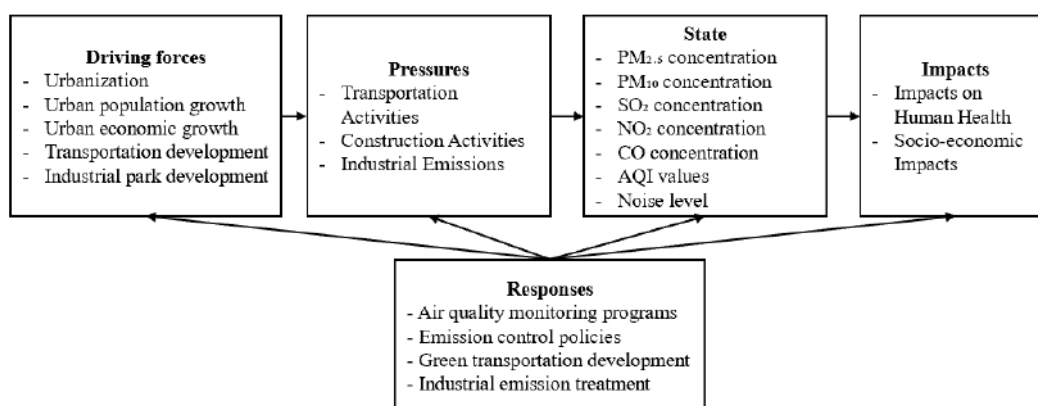


Fig. 1. DPSIR framework for assessing urban air quality in Vietnam.

3. Results and Discussion.

3.1. Driving Forces.

- Urbanization.

Urbanization has been a major driving force affecting urban air quality in Vietnam. By 2024, the country had approximately 900 urban areas, and the urbanization rate reached 44.3%, exceeding the national target and increasing significantly compared to 2016. Urban areas currently account for approximately 70% of national GDP and continue to expand rapidly.

The growth of urban population, infrastructure, transportation networks, and construction activities has substantially increased energy consumption and pollutant emissions. In major cities such as Hanoi and Ho Chi Minh City, the concentration of population and economic activities has intensified traffic congestion, fuel use, and construction operations, contributing to elevated emissions of particulate matter and gaseous pollutants. As a result, urbanization remains one of the key drivers of urban air pollution in Vietnam.

- Urban Population Growth.

Urban population growth is another important driving force affecting air quality in Vietnam. In 2024, the country's population reached approximately 101.3 million people, with about 39 million living in urban areas (38.5% of the total population) [4].

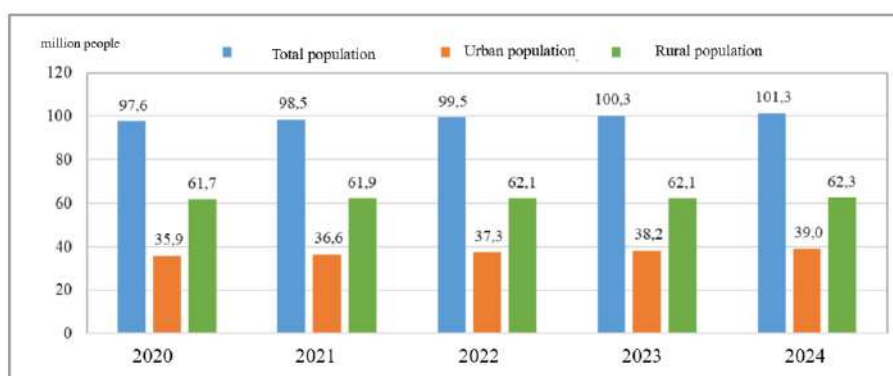


Fig. 2. Trends in Urban and Rural Population in Vietnam, 2020-2024.

The continuous growth of urban populations has increased demand for housing, transportation, energy, and public infrastructure. Consequently, vehicle use, energy consumption, and urban activities have intensified, resulting in higher emissions of particulate matter and gaseous pollutants. Therefore, urban population growth contributes significantly to increasing environmental pressure and deteriorating air quality in major urban areas.

- Economic Growth and Industrial Development.

Economic growth and industrial development have been major driving forces affecting urban air quality in Vietnam. Rapid economic expansion has accelerated urban development, industrialization, and the growth of commercial and service activities, increasing demand for energy, transportation, construction, and natural resources. In 2024, total retail sales of goods and consumer service revenues reached approximately VND 6,447.4 trillion, reflecting the continued growth of urban economies.

Industrialization has also expanded significantly, with 447 industrial parks covering approximately 134,900 hectares nationwide. While these developments contribute to economic growth, employment, and investment, they also increase emissions from industrial production, transportation, construction, and energy consumption. As a result, higher levels of particulate matter, SO₂, NO_x, CO, and VOC emissions have intensified environmental pressures and contributed to urban air pollution, particularly in major economic and industrial regions.

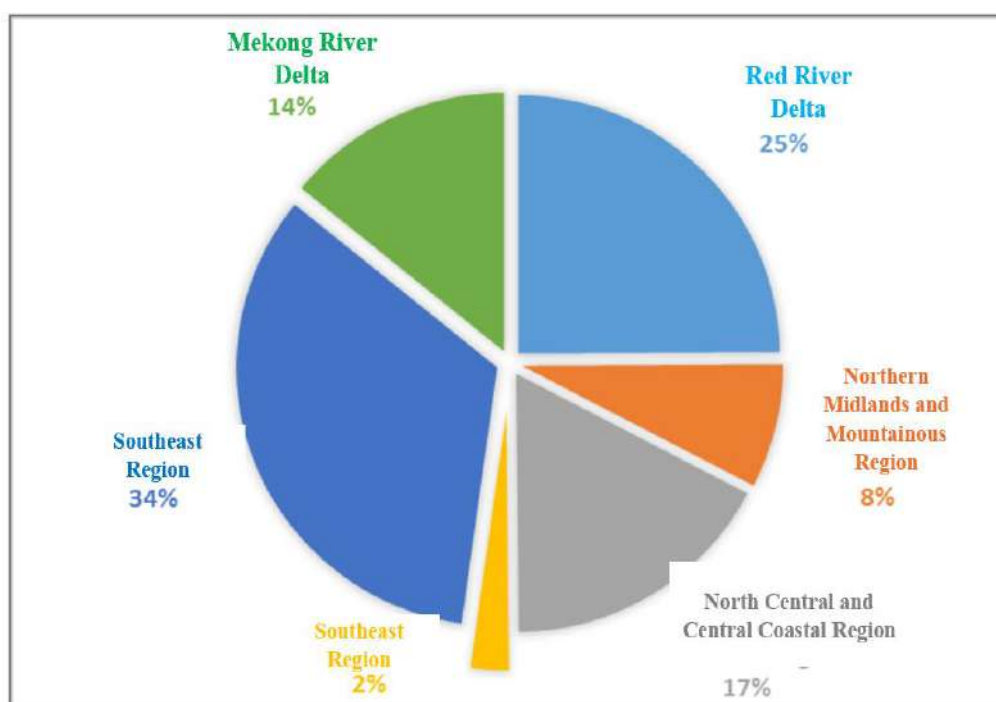


Fig. 3. Distribution of Industrial Parks by Region in Vietnam (%) [2].

- Transportation Development.

Transportation development is another major driving force shaping urban air quality in Vietnam. Significant investments in road infrastructure have improved connectivity and supported economic growth. However, rapid urbanization has also increased vehicle ownership and travel demand, particularly in major cities such as Hanoi and Ho Chi Minh City. Due to the relatively low share of public transportation, road traffic remains the dominant transport mode. As a result, transportation has become a major source of PM_{2.5}, PM₁₀, NO_x, CO, and VOC emissions, contributing significantly to urban air pollution and air quality deterioration.

3.2. Pressures.

- Transportation Activities.

Transportation is one of the most significant pressures on urban air quality in Vietnam. In 2024, approximately 77 million motorcycles and nearly 6 million automobiles were in operation nationwide. The rapid growth of vehicle ownership, combined with aging vehicles and increasing traffic demand, has led to substantial emissions of PM_{2.5}, PM₁₀, NO_x, CO, and VOCs.

The impact of transportation emissions is particularly evident in major metropolitan areas. In Ho Chi Minh City, road transport has been identified as the dominant source of PM_{2.5} emissions, accounting for approximately 44.8% of total PM_{2.5} emissions. Similarly, in Hai Phong, transportation contributes 81.8% of PM_{2.5} emissions, 74.1% of PM₁₀ emissions, and 94.5% of non-methane volatile organic compound (NMVOC) emissions. These findings highlight the critical role of transportation as a major pressure on urban air quality.

Table 1. Annual Emissions from Transportation Sources
in Hai Phong City (tons/year)[5].

Source	PM ₁₀	PM _{2.5}	SO ₂	NO _x	CO	VOC	CH ₄
Road Transportation	4,545	4,265	304	9,194	118,103	22,469	1,613
Other Transportation Sources	36	38	28	295	454	74	32

- Construction Activities.

Construction activities constitute another important source of air pollution pressure in urban areas. Rapid urbanization and infrastructure development have increased construction activities in many urban areas. Construction processes generate dust from excavation, demolition, material handling, and transportation, while construction equipment emits particulate matter and gaseous pollutants. Although dust control measures are required, implementation remains inconsistent, making construction an important source of urban air pollution.

- Industrial Emissions.

Industrial production remains a major source of atmospheric pollution in Vietnam. By 2024, the country had established 447 industrial parks, including 304 operational parks. Industrial activities, energy consumption, commercial services, and residential fuel use contribute to emissions of PM, SO₂, NO_x, CO, and VOCs. Despite improvements in environmental management, emissions from industrial facilities, small-scale enterprises, and other urban activities continue to exert significant pressure on air quality, particularly in rapidly industrializing regions.

3.3. State.

- Particulate Matter (PM_{2.5} and PM₁₀).

Particulate matter, particularly PM_{2.5}, remains the most critical air quality issue in urban areas of Vietnam. Monitoring data from 2020-2024 indicate significant spatial and temporal variations in particulate pollution, with the most severe conditions observed in northern cities. Annual average PM_{2.5} concentrations in Hanoi ranged from 26.0 to 52.0 µg/m³, exceeding the national standard by 1.1-2.1 times. Similarly, concentrations in Thai Nguyen ranged from 37.5 to 49.1 µg/m³, corresponding to exceedances of 1.5-2.0 times the standard [3, 5].

In contrast, lower PM_{2.5} levels were generally recorded in coastal and southern urban areas, including Hai Phong, Quang Ninh, Nha Trang, and cities in the Central Highlands and Southeast regions, where annual concentrations ranged from 12.0 to 23.0 µg/m³. However, short-term pollution episodes exceeding daily standards were still observed. These results indicate that particulate pollution remains a persistent challenge, particularly in rapidly urbanizing and industrializing urban areas.

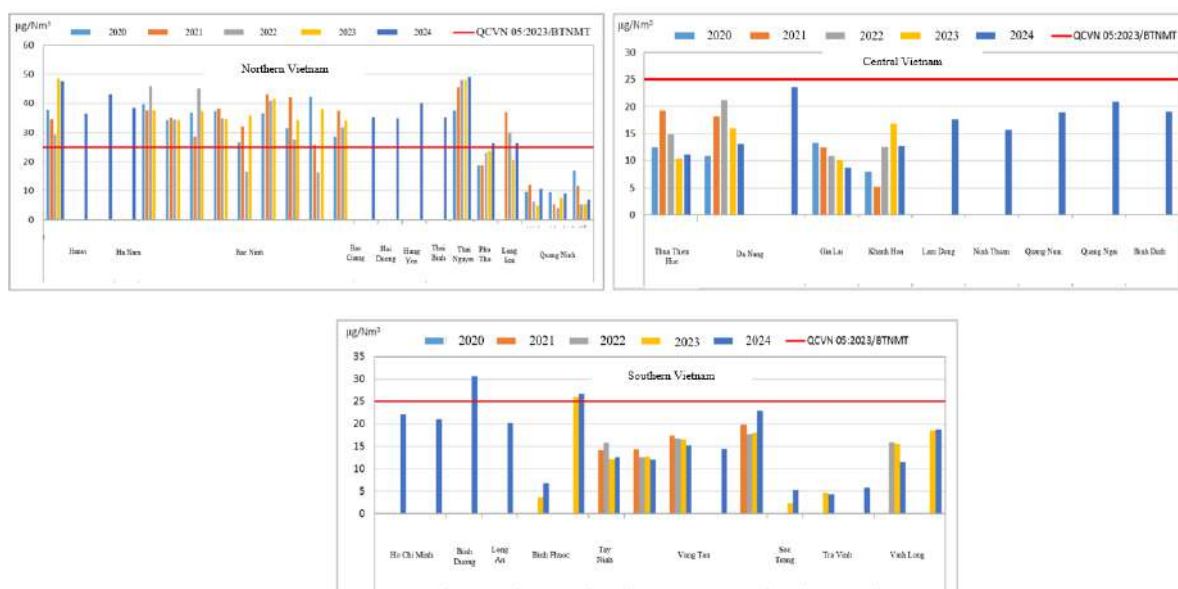


Fig. 4. Annual Average PM_{2.5} Concentration Trends at Selected Automatic Continuous Monitoring Stations.

Analysis of monitoring data showed considerable regional differences in PM_{2.5} exceedance frequencies. In 2024, the proportion of days exceeding the 24-hour PM_{2.5} limit value of 50 µg/m³ specified in QCVN 05:2023/BTNMT was substantially higher in Northern Vietnam than in Central and Southern regions. The exceedance frequency reached 33.04% in Hanoi, 36.05% in Thai Nguyen, and 23.56% in Ha Nam. These results indicate that particulate pollution remains a persistent challenge in northern urban areas.

The higher exceedance rates are associated with intensive traffic and industrial activities, construction emissions, and unfavorable meteorological conditions during winter, which limit pollutant dispersion and promote the accumulation of particulate matter in the atmosphere.

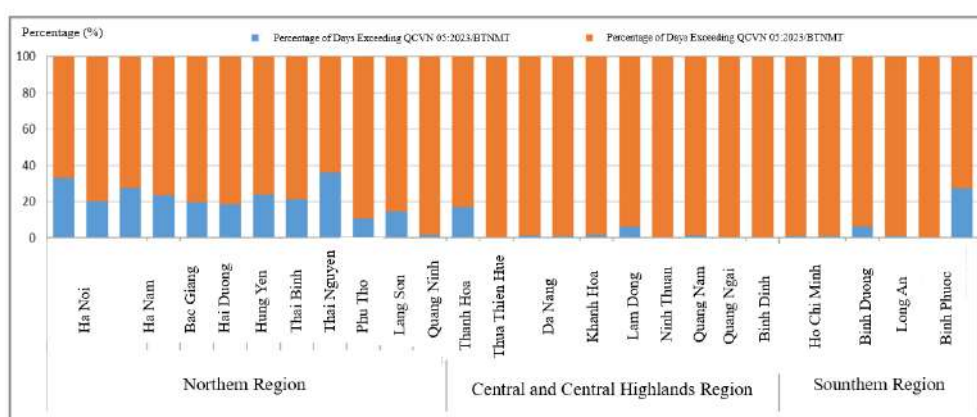


Fig. 5. Percentage of Days Exceeding the 24-Hour Average PM_{2.5} Limit Value at Selected Automatic Continuous Monitoring Stations in Urban Areas, 2024.

TSP concentrations were highest near major traffic corridors, industrial areas, and construction sites and frequently exceeded the 24-hour limits of QCVN 05:2023/BTNMT at several urban monitoring locations, indicating that traffic- and construction-related emissions remain dominant sources of particulate pollution [3, 5].

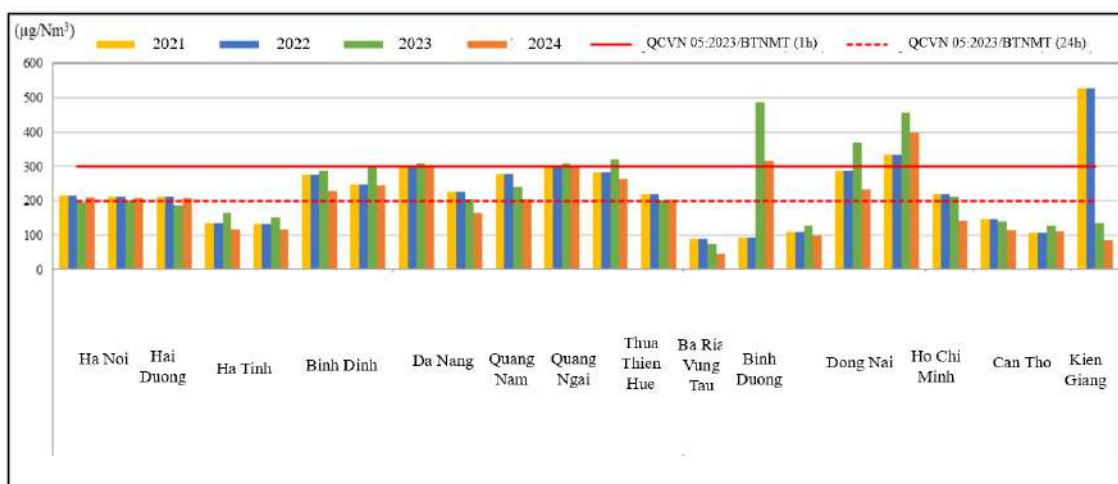


Fig. 6. Temporal Variation of TSP Concentrations at Selected Urban Traffic Corridors during the Period.

Road traffic is a major source of urban particulate pollution in Vietnam. High traffic density increases emissions from vehicle exhaust, tire and brake wear, and the resuspension of road dust. Monitoring results show that TSP concentrations at major traffic intersections in Hanoi, Ho Chi Minh City, Da Nang, Hue, Quy Nhon, and Bien Hoa frequently exceeded the 24-hour limits specified in QCVN 05:2023/BTNMT. In several locations in Bien Hoa, TSP concentrations also exceeded the 1-hour standard, highlighting the significant contribution of transportation activities to urban particulate pollution [3, 5].

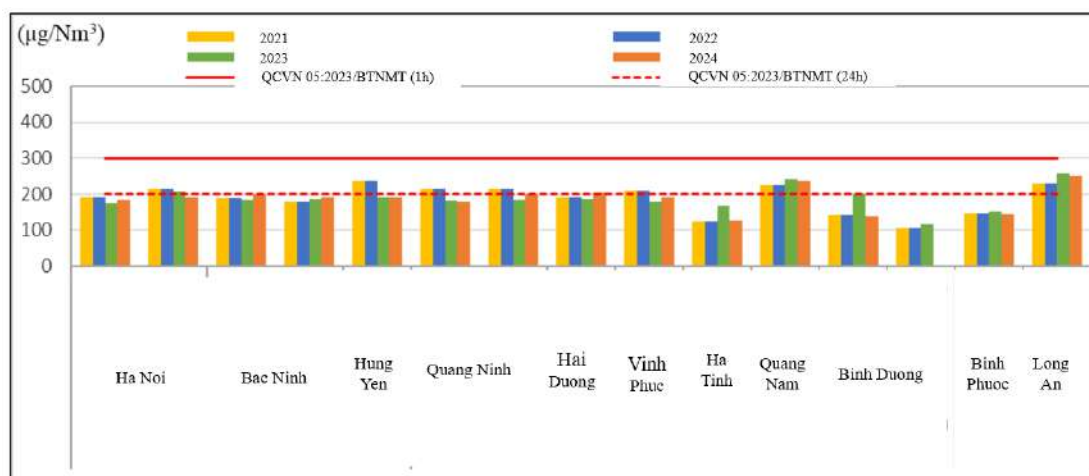


Fig. 7. Temporal Variation of TSP Concentrations at Selected Urban Residential Areas.

Particulate pollution levels in residential areas were generally lower than those observed along major traffic corridors. However, several rapidly developing urban areas, including Hanoi, Ho Chi Minh City, Quang Nam, Long An, and Binh Duong, recorded TSP concentrations approaching or occasionally exceeding the 24-hour limit specified in QCVN 05:2023/BTNMT. These results indicate that particulate pollution can extend beyond transportation corridors and affect residential environments, increasing population exposure to airborne pollutants.

The VN_AQI results in 2024 showed considerable temporal variation in urban air quality. Most days were classified as «Moderate» or «Unhealthy for Sensitive Groups,» while several pollution episodes reached the «Unhealthy,» «Very Unhealthy,» and «Hazardous» categories. Poor air quality was most frequently observed during the winter and early spring months (November-March), whereas air quality generally improved during the summer and rainy season [3, 5].

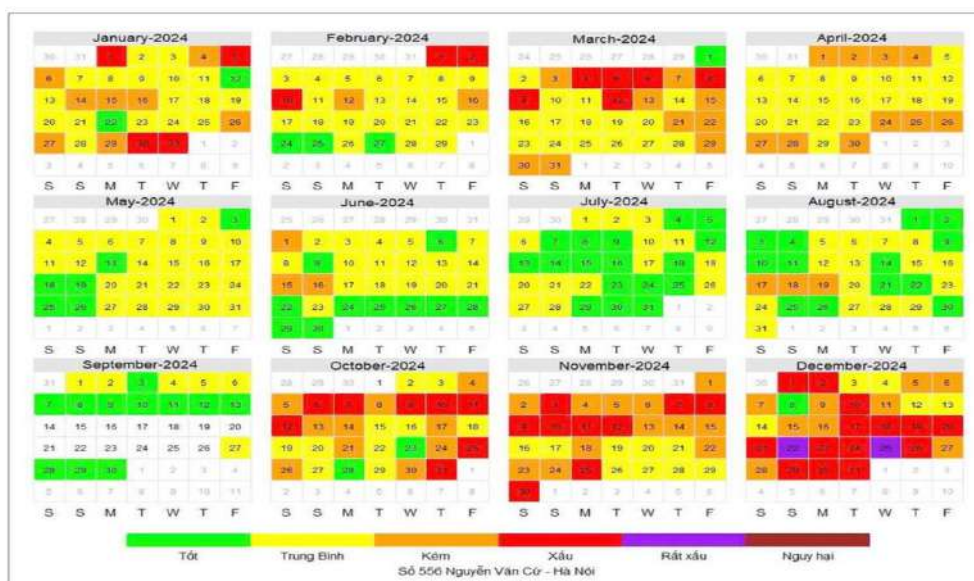


Fig. 8. Variation of the VN_AQI in 2024 at the Automatic Continuous Monitoring Station Located at 556 Nguyen Van Cu Street, Hanoi.

The observed seasonal variation in air quality is strongly influenced by meteorological conditions. In Northern Vietnam, winter conditions characterized by temperature inversions, weak winds, and limited rainfall reduce pollutant dispersion and promote the accumulation of PM_{2.5}, resulting in frequent pollution episodes and elevated VN_AQI values. In contrast, increased rainfall and stronger atmospheric mixing during summer enhance pollutant removal and improve air quality. Similar seasonal patterns have been observed in other northern cities, highlighting the important role of meteorological factors in shaping urban air quality.

Particulate concentrations showed distinct diurnal patterns, especially near major roads. Peak concentrations were typically observed during morning and evening rush hours (07:00–08:00 and 18:00–20:00), while lower levels occurred during midday, nighttime, and weekends [3, 5].

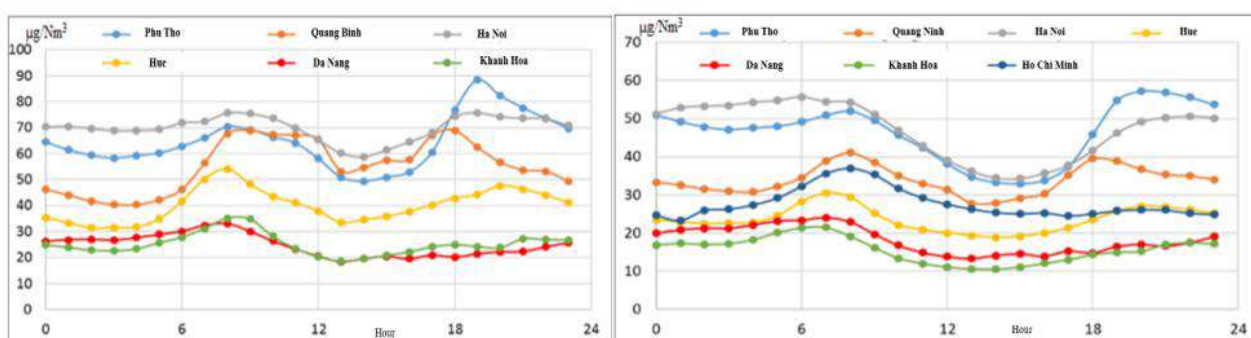


Fig. 9. Diurnal Pattern of 1-Hour Average PM₁₀, PM_{2.5} Concentrations (Averaged Across Years) at Selected Automatic Continuous Monitoring Stations.

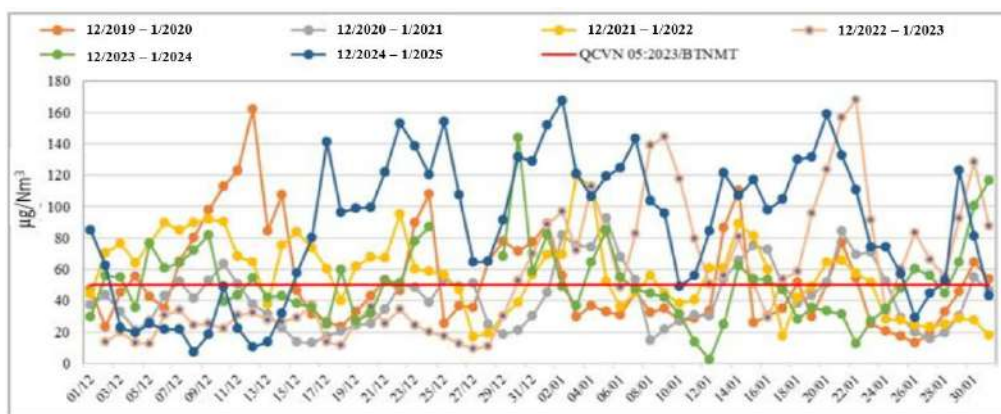


Fig. 10. Temporal Variation of 24-Hour Average PM_{2.5} Concentrations from December of the Previous Year to January of the Following Year at the Automatic Continuous Monitoring Station at 556 Nguyen Van Cu, Hanoi, during the Period 2019–2025.

Previous national environmental assessments have consistently identified PM_{2.5} pollution as one of the most serious environmental challenges in Vietnamese cities. Monitoring results indicate that PM_{2.5} concentrations continue to exhibit strong seasonal variations, with the highest levels occurring during the winter and early spring months in Northern Vietnam due to unfavorable meteorological conditions that limit pollutant dispersion. Despite recent air quality management efforts, PM_{2.5} concentrations in several urban areas remain above national standards and show limited improvement compared with previous assessment periods. These findings highlight the need for more effective emission control measures targeting transportation, industrial activities, construction, and residential fuel use to improve urban air quality and protect public health.

- Other Air Pollutants (NO₂, CO, SO₂, and O₃).

Monitoring data for 2020-2024 were also analyzed for NO₂, CO, SO₂, and O₃. While NO₂, CO, and SO₂ are mainly emitted from transportation and industrial activities, O₃ is formed through photochemical reactions involving NO_x and VOCs. These pollutants are important indicators of urban air quality conditions [3, 5].

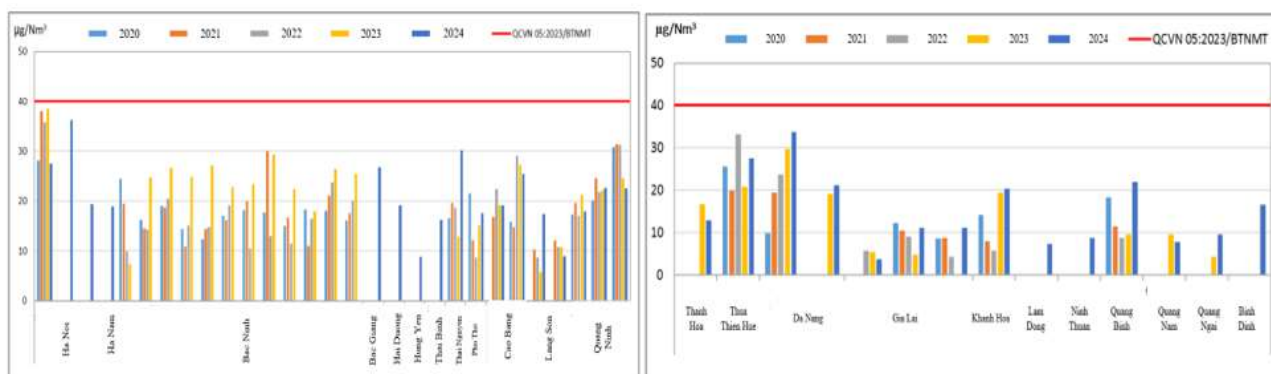


Fig. 11. Temporal Variation of Annual Mean NO₂ Concentrations at Selected Automatic Continuous Monitoring Stations in Northern and Central Vietnam.

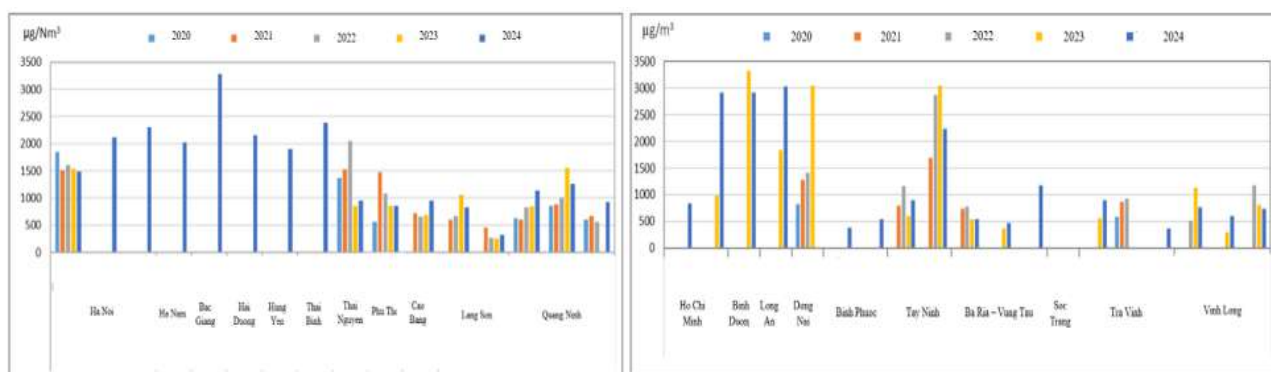


Fig. 12. Temporal Variation of 1-Hour Average CO Concentrations at Selected Automatic Continuous Monitoring Stations in Northern and Southern Vietnam.



Fig. 13. Temporal Variation of Annual Mean SO₂ Concentrations at Selected Automatic Continuous Monitoring Stations in Northern and Southern Vietnam.

CO concentrations were highest during morning and evening traffic peaks, reflecting the influence of vehicle emissions. A gradual decline in CO levels was observed in recent years, likely due to cleaner fuels and stricter vehicle emission standards.

O₃ concentrations increased during daytime, peaked in the early afternoon (13:00-15:00), and decreased in the evening. At some monitoring stations, 1-hour average O₃ concentrations exceeded the limit value of QCVN 05:2023/BTNMT around midday, reflecting the influence of photochemical processes under strong solar radiation.

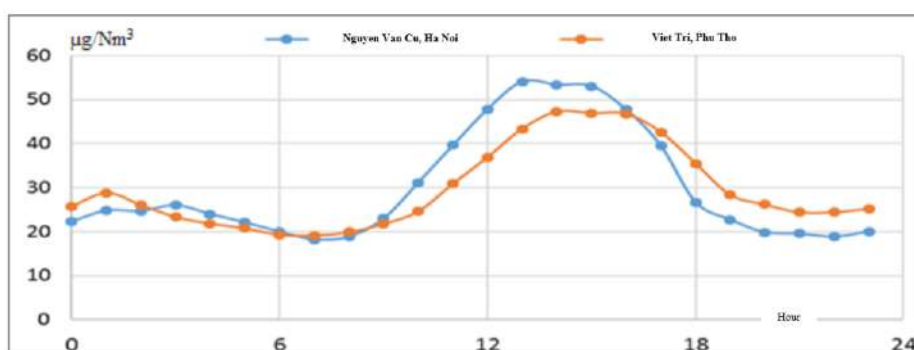


Fig. 14. Diurnal Variation of 1-Hour Average O₃ Concentrations at Selected Automatic Continuous Monitoring Stations.

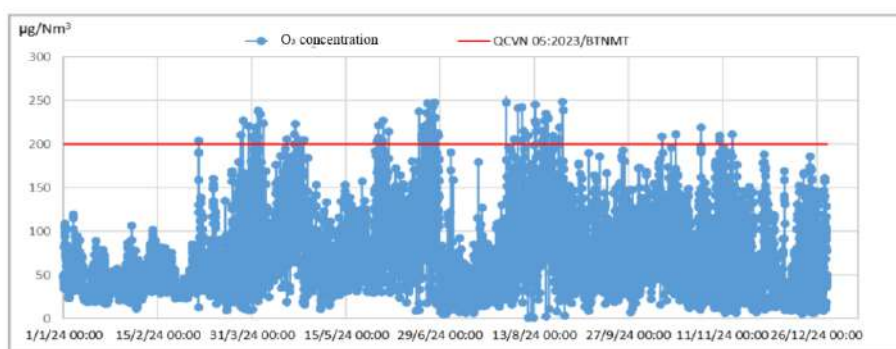


Fig. 15. Temporal Variation of 1-Hour Average O₃ Concentrations at the Automatic Continuous Monitoring Station of Hanoi University of Science and Technology.

- Current Status of Urban Noise Pollution.

Urban noise pollution in Vietnam is mainly generated by transportation activities. Increasing traffic volume and vehicle density have resulted in elevated noise levels, particularly along major roads, highways, and traffic intersections, affecting the quality of the urban environment.

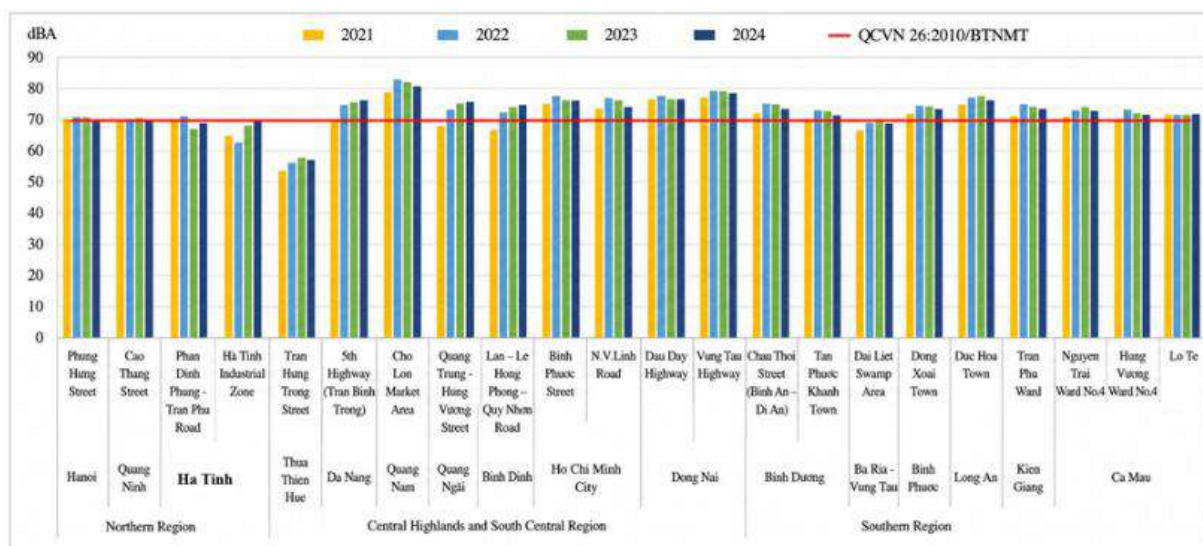


Fig. 16. Temporal Variation of Noise Levels at Selected Urban Traffic Corridors.

Monitoring results indicate that noise levels along major urban roads frequently approach or exceed the daytime limit of 70 dBA specified in QCVN 26:2010/BTNMT. Increasing traffic volume associated with rapid urbanization has intensified noise pollution, which remains a significant environmental challenge in Vietnamese cities.

3.4. Impact.

- Impacts on Human Health.

Urban air pollution poses significant risks to public health in Vietnam. Exposure to elevated concentrations of PM_{2.5}, PM₁₀, NO₂, CO, and other pollutants has been associated with respiratory and cardiovascular diseases, including asthma, chronic obstructive pulmonary disease (COPD), lung cancer, heart disease, and premature mortality. Among these pollutants, PM_{2.5} is considered particularly harmful due to its ability to penetrate deep into the respiratory system and bloodstream.

Children, older adults, pregnant women, and individuals with pre-existing health conditions are especially vulnerable. In addition, traffic-related noise pollution may contribute to sleep disturbances, stress, and reduced quality of life.

- Socio-economic Impacts.

Air pollution also generates substantial socio-economic costs through increased healthcare expenditures, reduced labor productivity, and environmental degradation. Persistent pollution negatively affects urban livability, investment attractiveness, and tourism development. As urbanization and industrialization continue to expand, improving air quality has become essential for protecting public health, enhancing quality of life, and supporting sustainable urban development in Vietnam.

3.5. Responses.

To improve urban air quality, Vietnam has implemented various policy, technical, and management measures. Key responses include strengthening the regulatory framework through national air quality management programs, expanding automatic air quality monitoring networks, and improving environmental data management systems.

Emission reduction has been prioritized in major sectors, particularly transportation and industry, through stricter emission standards, promotion of public transportation, adoption of cleaner production technologies, and development of low-emission and electric vehicles. In addition, urban planning strategies increasingly emphasize green infrastructure, urban green spaces, and sustainable development principles to reduce environmental pressures.

Public awareness campaigns and community participation programs have also been promoted to encourage environmentally responsible behaviors. Together, these measures provide an integrated approach to mitigating urban air pollution and supporting sustainable urban development in Vietnam.

4. Solutions for Mitigating Air Pollution.

Based on the DPSIR analysis, improving urban air quality in Vietnam requires integrated measures targeting major emission sources and strengthening environmental governance.

- Air Quality Monitoring and Management. Improving urban air quality requires the expansion of automatic monitoring networks and the application of advanced technologies such as AI, IoT, and big data analytics to support real-time monitoring, forecasting, and environmental decision-making.

- Emission Reduction from Transportation and Industry. As transportation and industrial activities are the major sources of urban air pollution, stricter emission standards, cleaner production technologies, public transportation systems, and electric vehicles should be promoted to reduce PM_{2.5}, NO₂, and other pollutant emissions.

- Green and Sustainable Urban Development. Urban planning should incorporate green infrastructure, urban green spaces, and renewable energy development. The adoption of smart-city and sustainable development approaches can help reduce environmental pressures and improve urban resilience.

- Environmental Governance and Public Participation. Effective air quality management requires stronger enforcement of environmental regulations, improved institutional coordination, greater transparency of environmental information, and enhanced public awareness to encourage environmentally responsible behaviors.

Overall, improving urban air quality in Vietnam requires coordinated actions among government agencies, industries, local authorities, and communities to support sustainable urban development and protect public health.

5. Conclusions.

This study applied the DPSIR framework to assess urban air quality in Vietnam using environmental monitoring and socio-economic data. The results show that urbanization, population growth, transportation development, and industrialization are the main driving forces contributing to air pollution. Among the monitored pollutants, PM_{2.5} remains the most critical concern, particularly in northern cities where concentrations frequently exceed the limits of QCVN 05:2023/BTNMT.

Air pollution poses significant risks to public health and urban sustainability. Current response measures focus on strengthening monitoring systems, controlling emissions, promoting cleaner technologies, and supporting sustainable urban development. The DPSIR framework provides a useful tool for understanding the interactions between socio-economic development and environmental quality, supporting integrated air quality management in Vietnam.

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