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Assessing the Impact of Air Pollutant Dispersion from the manufacture at Van Dien Fused Magnesium Phosphate Fertilizer Joint Stock Company on the Roadmap for Establishing Low Emission Zones in Hanoi

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KEYWORDS

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Air pollution
Phosphate fertilizer
Pollution dispersion
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ABSTRACT

This paper investigated and evaluated the dispersion of air pollutants generated from the ore pyrolysis process at the Van Dien Fused Magnesium Phosphate Fertilizer Joint Stock Company. It also analyzed technical conflicts regarding the roadmap for establishing a Low Emission Zones (LEZs) in Southern Hanoi. Based on multi-temporal modeling data from Quarter 3/2023 to Quarter 2/2024, the study identified the concentration ranges of Total Suspended Particulates (TSP), Nitrogen Oxides (NOx), Hydrogen Fluoride (HF), and Sulfur Dioxide (SO_2) in urban spaces. The results showed that NOx concentrations in the core emission area approached the maximum permissible limits of QCVN 05:2023/BTNMT, creating a significant burden on the background environment. Analysis of dispersion maps presented that in the weather conditions during Quarter 1, pollution plumes containing HF and SO2 tended to migrate deep into the boundaries of the former Ha Dong District and Thanh Oai District. These are key areas designated for implementation of LEZs under Resolution 57/2025/NQ-HDND. The study asserted that the presence of point emission sources operating near permissible limits at the capital's gateway directly contradicted the clean air objectives of the Low Emission Zones (LEZs). Consequently, this paper proposed urgent measures based on Directive 19/CT-UBND (2025), encompassing dynamic manufacturing curtailment mechanisms and strategic relocation roadmaps to alleviate environmental pressure, thereby fostering a sustainable urban ecosystem.

1. Introduction

In the era of infrastructure urbanization and global green transition, air quality management in megacities like Hanoi has become a significant challenge for regulatory authorities. Hanoi is situated in the Red River Delta and is strongly affected by extreme meteorological phenomena, such as temperature inversions and radiation fog. Consequently, the city frequently faces fine particulate matter pollution and acid gas levels that exceed World Health Organization (WHO) recommendations.

Regarding the emission structure, alongside the surge in private vehicles and infrastructure construction, traditional industrial facilities located within residential areas have emerged as major factors pressuring the environment. A typical example is the Van Dien Fused Magnesium Phosphate Fertilizer Plant (Van Dien Plant), a long-standing plant situated in a densely populated area. This plant utilized blast furnace technology for apatite ore pyrolysis – a specific process that generates emission streams containing Total Suspended Particulates (TSP), nitrogen oxides (NO_x) sulfur dioxide (SO_2), and particularly hydrogen fluoride (HF).

Meanwhile, through Resolution 57/2025/NQ-HĐND, Hanoi has introduced guidelines for establishing Low Emission Zones (LEZs). This marks the first time a city in Vietnam has applied spatial management tools to proactively control pollution. According to the roadmap of this Resolution, densely populated areas and sensitive infrastructure – such as Hoang Mai District, Ha Dong District, and Thanh Tri District (under the former administrative boundaries) – will become vital buffer zones. In these areas, air quality standards must not only comply with QCVN 05:2023/BTNMT but also strive toward net-zero emission targets.

This transition requires a comprehensive reassessment of large-scale point sources like the Van Dien Plant. Evaluation must focus not only on stack concentrations but also on the dispersion range and the potential for pollution resonance under real urban meteorological conditions. This study was conducted to scientifically and systematically evaluate the dispersion impact of pollutants (TSP, NO_x, HF, SO_2, CO) from the production processes at the Van Dien Plant using modeling data from 2023 and 2024. Based on the dispersion maps, the research team proposed technical and policy solutions to ensure compatibility between industrial activities and the roadmap for establishing LEZs of Hanoi, aiming for the sustainable development of the capital.

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2. Research Methodology

This study employed a multi-dimensional approach. It combined atmospheric dispersion modeling, comparison with national technical standards, and spatial overlap assessment to determine the impact of industrial point sources on the roadmap for establishing LEZs

Within the manufacture area of the plant, the authors applied a source consolidation method by merging three individual blast furnace systems of the Van Dien Plant into a single equivalent emission source. This consolidation allowed the study to focus on regional impacts and optimize simulations. At the regional scale (a 5 km radius), emission streams from these three sources rapidly mixed under meteorological conditions to form a single dispersion plume.

Running 12 scenarios (4 quarters per pollutant) for one equivalent source minimizeed data overlap. This approach clearly highlighted dispersion trends driven by seasonal winds (Northeast and Southwest monsoons) affecting sensitive areas such as Thanh Tri and Hoang Mai. The consolidation process was calculated to ensure that the total emission volume remains unchanged. The calculations were performed as follows:

Calculating Consolidated Coordinates for the Equivalent Source: To input a single synthetic source into the CAP software, we used the arithmetic mean of the three original positions. Source coordinates were determined using the VN-2000 coordinate system, with a central meridian of 105 ^{0}, a projection zone of 3 ^{0}, and unit in meter (m).

Table 1. Coordinates of the smokestacks.

The smokestacks	X (m)	Y (m)
KT1 (Smokestack No.1)	2317190	586442
KT2 (Smokestack No.2)	2317121	586420
KT3 (Smokestack No.3)	2317168	586422

To input a single synthetic source into the CAP software, the authors used the arithmetic mean of these three positions. The resulting coordinates for the equivalent source are N_{eq} (2317160, 586428). These coordinates were converted from the VN-2000 system to the WGS 84 / Pseudo-Mercator (EPSG:3857) system to facilitate data integration into the QGIS platform to visualize the impact zones of the pollutants.

- **Determining the Total Emission Load (Q_t):** This is calculated as the sum of the loads from the three blast furnaces: $Q = Q_{L1} + Q_{L2} + Q_{L3}$, which equals 36.000 m^3/h (10 m^3/s). This is the most critical parameter determining pollutant concentrations at sensitive receptors. The research team used periodic environmental monitoring results from the second half of 2023 and the first half of 2024 as input parameters for the simulation. The calculation results for the equivalent source are presented in the following table.
- **Establishing Emission Scenarios (Permissible Threshold Scenario):** Using the maximum concentration limits proposed in the environmental permit. This scenario served to predict the maximum potential impact, helping to identify the high-risk zones if the plant operates at its legal emission thresholds.

To convert the emission load from concentration (mg/Nm^3) to the input for the CAP software (g/s), we applied a formula based on the flow rate of the three blast furnaces identified above.

$$Q(g/s) = \frac{C(mg/Nm^3) \times V(m^3/h)}{3.600.000}$$

Table 2. Input parameters of the model.

No.	Parameters	Emission (g/s)
1	Temperature	200
2	Total particulate matters	4.2
3	F	0.48
4	CO	24
5	SO_2	10.5
6	NO_x	20.4

- Dynamic Parameters: The treated emission gas complied with QCTDHN 01:2014/BTNMT (Hanoi Technical Regulation on Industrial Emissions of Particulate matters and Inorganic Substances). The gas was released into the environment through a smokestack with a height of 45 m above ground level. The specific smokestack parameters selected for the equivalent source calculation included a height of 45 m, a diameter of 2 m (measured via QGIS software), and a temperature of 150 °C.
- This study utilized GIS software and other tools to develop maps containing both spatial and attribute data. The process involved data processing, integrated analysis, modeling, editing, and publishing datasets according to the research objectives. This methodology was widely used to develop maps specializing in socioeconomics, culture, transportation, and the environment, etc. This research combined the Gauss model (via CAP software in the ENVIM) with QGIS for digitalization of data. This approach enabled visual data simulation and facilitated comparisons in Environmental Impact Assessments (EIA) in Vietnam.
- Meteorological Data: Collected data included wind direction, wind speed, ambient temperature, and Pasquill atmospheric stability classes (from A to F). The author used monthly meteorological data specified in QCVN 02:2022/BXD (National Technical Regulation on Natural Condition Data for Construction). Consequently, temperature, seasonal wind frequency, and seasonal wind velocity were synthesized and calculated for four quarters of the year. These quarters represented four distinct meteorological conditions: Quarter 1 (Jan–Mar), Quarter 2 (Apr–Jun), Quarter 3 (Jul–Sep), and Quarter 4 (Oct–Dec), aligning with the annual environmental monitoring frequency.

Table 3. Quarterly temperature conditions in Hanoi.

Quarterly ambient air temperature T(^{0}C)			
Quarter 1	Quarter 2	Quarter 3	Quarter 4
18.2	27.0	28.4	21.8

Table 4. Quarterly wind speed and frequency P (%).

No.	Wind direction	Wind frequency				Wind speed			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Calm wind	16.9	14.0	21.3	24.5	0.0	0.0	0.0	0.0
2	North	8.6	4.3	7.3	14.8	2.4	2.3	2.3	2.4
3	Northeast	24.8	9.2	9.0	19.9	2.8	2.5	2.2	2.7
4	East	9.8	14.2	10.7	6.7	2.1	2.2	2.1	2.0
5	Southeast	29.1	41.0	25.1	15.9	2.7	2.7	2.2	2.3
6	South	4.5	7.9	7.1	3.4	2.3	2.4	2.0	1.9
7	Southwest	1.0	2.8	3.2	1.3	1.6	1.9	1.7	1.5
8	West	1.3	2.4	5.7	3.4	1.4	1.7	2.1	1.6
9	Northwest	4.0	4.2	10.6	10.0	1.7	2.2	2.3	2.0

The CAP software calculated pollutant concentrations at grid nodes based on meteorological scenarios, including wind direction, wind speed, and atmospheric stability. The simulation produced a dataset containing pollutant concentrations at each grid node (x, y, C) and an emission grid map. This data served as the primary input for QGIS.

The mapping process in QGIS consisted of spatial data normalization, classification, and map layering:

- **Spatial data normalization:** Grid nodes from the CAP software were imported into QGIS as point layers. The VN-2000 coordinate system (Hanoi central meridian 105,000, projection zone 3 ^{0}) was used to ensure spatial accuracy when overlaying the data onto the administrative map of Thanh Tri District.
- **Classification and Layering:** This stage involved concentration zoning and basemap overlay.
  - Concentration zoning: The Graduated Symbology method was used to classify concentrations according to the thresholds defined in QCVN 05:2023/BTNMT. Areas with higher emission levels were displayed in warm tones (red, orange, yellow), while areas with lower levels were shown in green.
  - Basemap Overlay: OpenStreetMap data were used to identify the correlation between polluted zones and sensitive receptors. Furthermore, this zoning allowed a clear identification of pollutant dispersion boundaries following the prevailing wind directions.

3. Results and Discussion

3.1. Map of pollutant dispersion in the third quarter of 2023

The calculation results for pollution dispersion in Quarter 3/2023 at the Van Dien Plant revealed a complex interaction between industrial emissions and characteristics of seasonal transition of Hanoi. The dominant Southeast winds and seasonal wind shift shaped a pollution dispersion grid extending toward the West and Northwest. The maps indicated that the pollution range did not only spread over agricultural lands but directly encroached upon densely populated areas.

The core concentration bands of Particulate Matter (PM) and Hydrogen Fluoride (HF) covered a large portion of Vinh Quynh, Ta Thanh Oai, and Huu Hoa wards. Due to the high humidity and heavy rainfall of Quarter 3, suspended particles were partially washed away. However, HF easily hydrated to form acid aerosols. This posed a risk of surface corrosion for infrastructure materials in the rapidly developing new urban areas within these wards.

Notably, the wide-range dispersion (0.0001 mg/m^3) directly impacted the spaces of Kien Hung and Phuc La wards (within the former Ha Dong District) and extended to Kim Giang and Khuong Dinh wards (within the former Thanh Xuan District).

The pollution dispersion modeling results for Quarter 4/2023 at the Van Dien Plant demonstrated a distinct shift in pollution patterns, following the winter trend of Hanoi. Under the dominant influence of the Northeast monsoon, the emission plume no longer spread widely toward the West as it did in summer. Instead, the impact zone extended toward the South and Southwest, covering the administrative boundaries of Tu Hiep, Ngu Hiep, and Ngoc Hoi wards. These areas become directly affected by concentration bands of particulate matter and acid gases.

Specifically, the dry climate combined with low-level temperature inversions – which frequently occurred during the night and early morning in Quarter 4 – prevented upward dispersion. This phenomenon trapped and forced pollutants to accumulate near ground level at higher concentrations. The dispersion range also encroached upon Kien Hung and Hoang Liet wards, specifically near the Phap Van - Cau Gie intersection. Core NO_x concentrations remained near the threshold of 100 µu g/m^3 of QCVN 05:2023/BTNMT, which was the environmental carrying capacity of these newly urban wards.

The dispersion modeling results for Quarter 1/2024 at the Van Dien Plant revealed a unique pollution scenario. This period was heavily influenced by seasonal transition of Hanoi and the stringent requirements of the new legal framework.

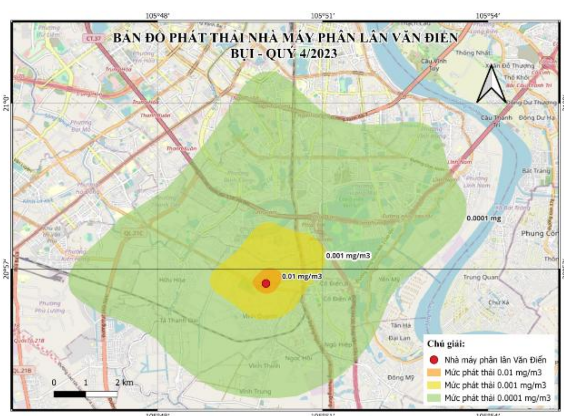
During this phase, the Northeast monsoon combined with low-level temperature inversions and dense fog facilitated pollutants to concentrate near the ground instead of allowing upward dispersion. The dispersion maps showed that “polluted plumes" - specifically NO_x and particulate matters – did not spread evenly. Instead, they formed narrow bands extending over 5 km toward the Southwest and West, directly covering Vinh Quynh and Huu Hoa communes and encroaching deep into Kien Hung Ward and the Thanh Ha Urban Area.

Core NO_x concentrations were recorded at 0.1 mg/m^3 (100 μg/m^3), reaching the maximum allowable 24-hour limit of QCVN 05:2023/BTNMT. This created a direct technical barrier to the roadmap for establishing Low Emission Zones (LEZs) under Resolution No. 57/2025/NQ-HDND. In areas designated for LEZ implementation, such as Ha Dong District, the industrial pollution stream from the plant acted as a "background concentration" that exhausted the entire environmental carrying capacity. Consequently, local efforts to reduce traffic emissions become less effective; even if private vehicles were restricted, air quality was still threatened by large-scale external point sources flowing into the zone.

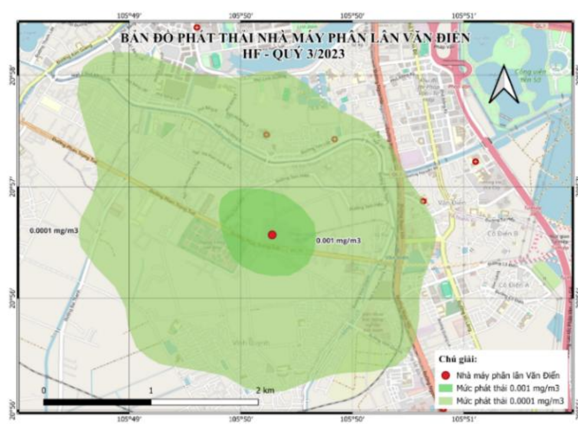
The pollution dispersion modeling results for Quarter 2/2024 at the Van Dien Plant indicated a significant shift in dispersion patterns. Entering the second quarter, Hanoi’s climate underwent a major transition from spring to summer, characterized by the increasing activity of the Southeast monsoon and seasonal wind currents.

Unlike the winter trend of extending toward the Southwest, the dispersion maps for this period showed the pollution bands shifting strongly toward the North and Northwest. The emission plumes, carrying suspended particulates and nitrogen compounds, no longer dispersed far into suburban areas. Instead, they tend to directly encroach upon urban core areas with extremely high population densities.

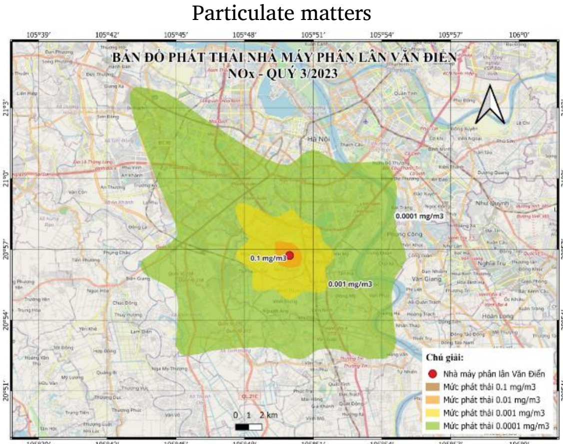
Wide-range pollution traces (0.0001 mg/m^3) covered Hoang Liet Ward (Linh Dam Peninsula was the center), Thinh Liet Ward, Phuc La Ward, and Kien Hung Ward. The infrastructure of these areas was characterized by numerous high-rise buildings, which created wind eddy effects (turbulence). This phenomenon caused pollutants to become trapped and hindered dispersion, especially during the calm wind conditions preceding summer rainstorms.



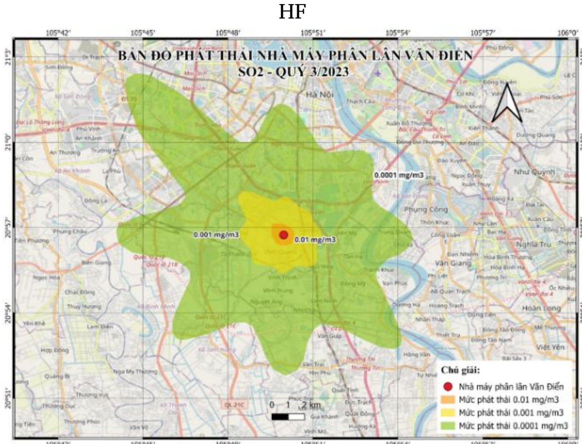
Particulate matters



HF

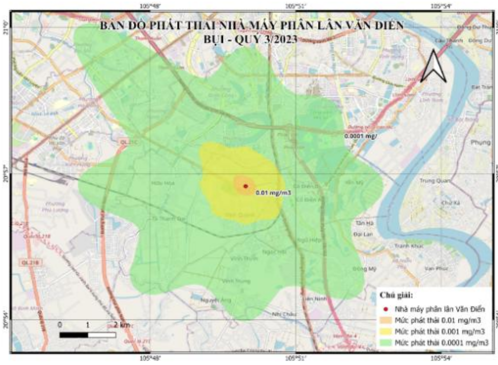


NO_x



SO_2

Figure 1. Map of pollutant dispersion in the third quarter of 2023.



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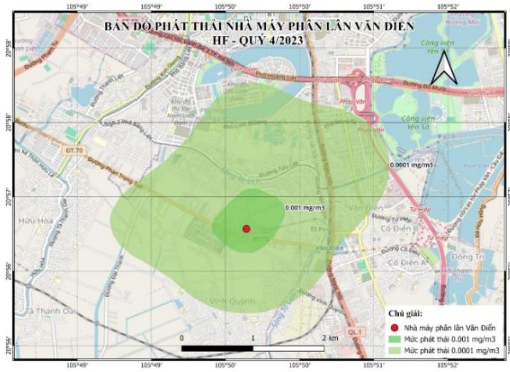
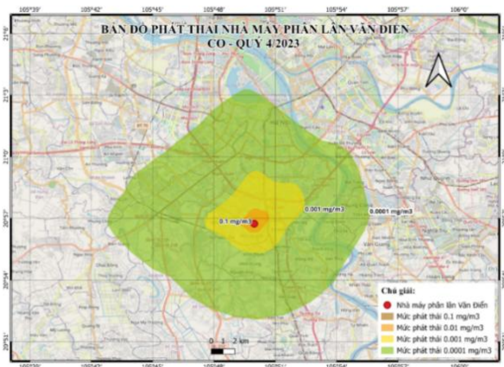
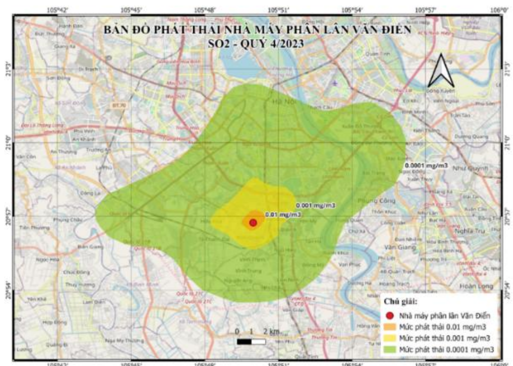


HF

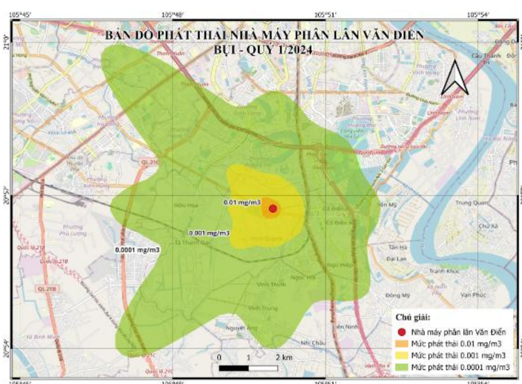


NO_x

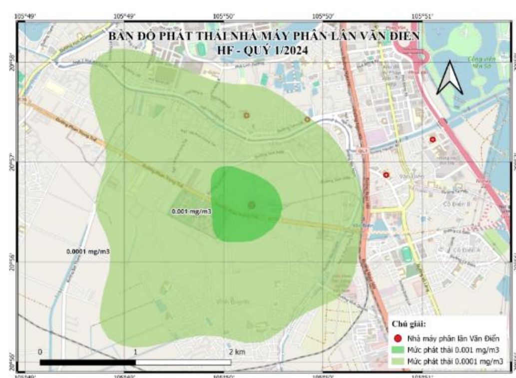


SO_2

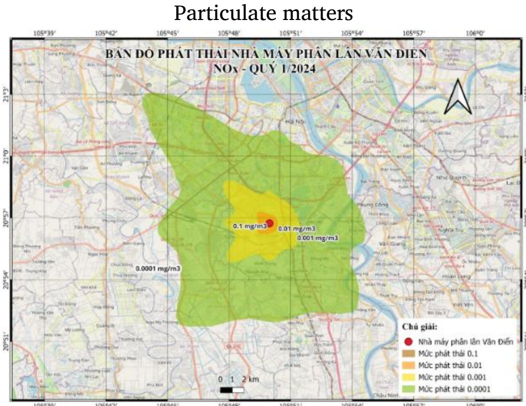
Figure 2. Map of pollutant dispersion in the fourth quarter of 2023.



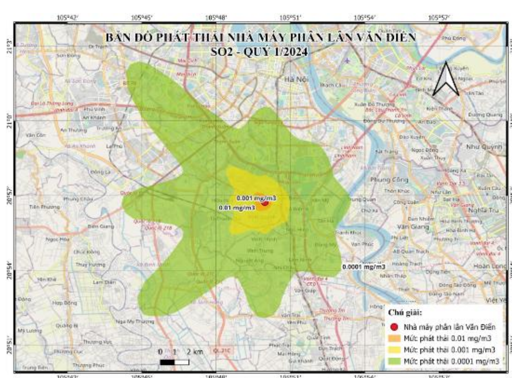
Particulate matters



HF



NO_x



SO_2

Figure 3. Map of pollutant dispersion in the first quarter of 2024.

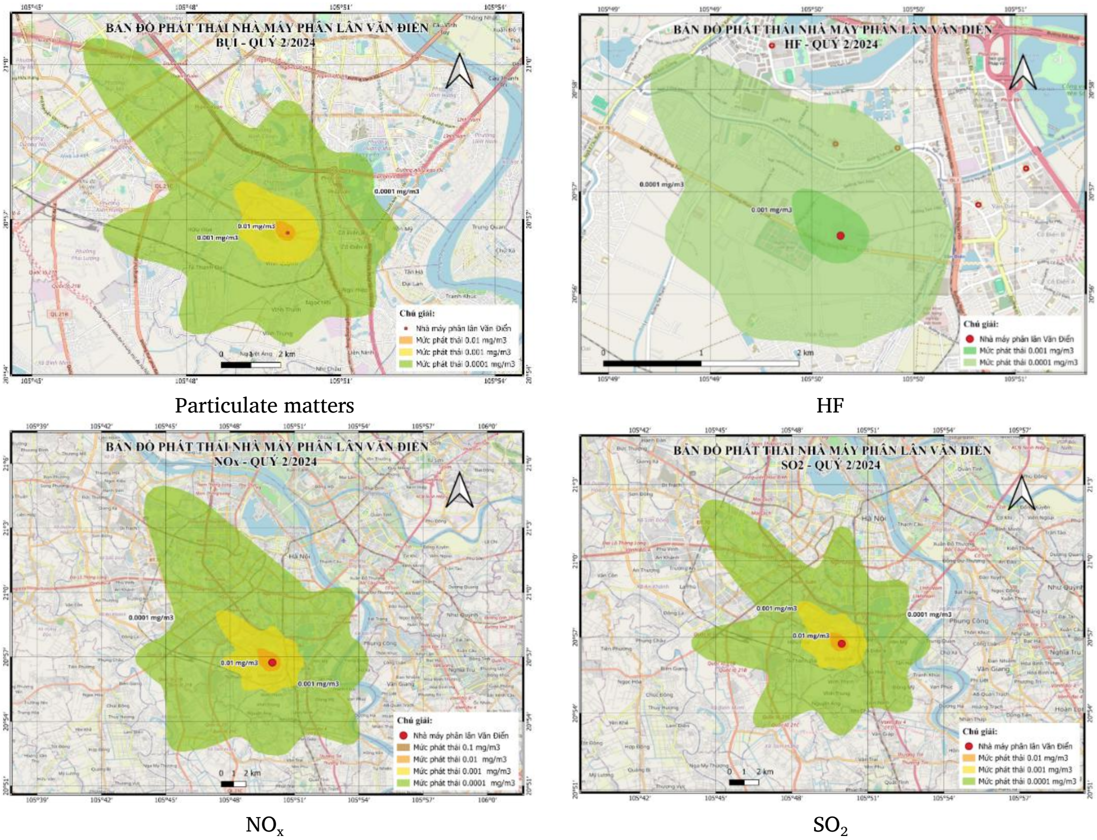


Figure 4. Map of pollutant dispersion in the second quarter of 2024.

3.2. Evaluating Pollution Dispersion in accordance with the objective of LEZs

An overall analysis of the 2023–2024 cycle regarding pollution dispersion from the Van Dien Plant revealed a distinct conflict between traditional industrial infrastructure and urban modernization under the Law on the Capital of Vietnam 2024. Influenced by tropical monsoon climate of Hanoi, the plant's emission plumes formed seasonal pollution bands that directly encroach upon densely populated areas.

During Quarters 2 and 3, the Southeast monsoon, combined with strong thermal radiation and high humidity, drove acid gas plumes – specifically hydrogen fluoride (HF) and sulfur dioxide (SO_2) – toward the North and Northwest. These plumes covered Hoang Liet Ward (centered on the Linh Dam Peninsula) and extended to Kim Giang and Khuong Dinh wards. In these areas, gaseous precursors easily underwent photochemical reactions and hydration to form secondary fine particulate matters and acid aerosols, posing risks to urban infrastructure and resident health.

Conversely, in Quarters 4 and 1, when the Northeast monsoon prevailed alongside characteristic low-level temperature inversions, the pollution band extended toward the Southwest and Southeast. This directly impacted Vinh Quynh, Tam Hiep, and Tu Hiep wards, and penetrated deep into Kien Hung and Phuc La wards. Notably, core NOx levels frequently reached 100 µg/m^3, touching the maximum allowable limit of QCVN 05:2023/BTNMT and exhausting much of the local environmental carrying capacity. This situation created a direct conflict with the roadmap to Low Emission Zones (LEZs) under Resolution No. 57/2025/NQ-HDND. Efforts to reduce traffic emissions in urban wards were effectively neutralized because the "clean air quota" was already occupied by external industrial NO_x and particulate matters.

This interaction necessitated environmental governance that strictly adhered to Directive No. 19/CT-UBND (2025), requiring the plant to shift from static compliance to a rapid-response mechanism, including the scenario of blast furnace capacity reduction during calm-wind or temperature-inversion days to ensure resident safety. In the long term, the plant is required to possess source-treatment technological solutions to eliminate critical pollutants, aiming to cut current emission loads by at least 50 % and reduce core NO_x concentrations below 50 µu g/m^3. This reduction is the key threshold to free up the capacity of background environment, allowing air quality policies of LEZs to take effect.

Additionally, scrubbers should be upgraded with next-generation adsorbent materials to strictly control HF and acid aerosols. To eliminate toxic gases from fossil fuels, the plant should research replacing coke with cleaner energy sources or transitioning to advanced electric arc furnace technology. The long-term vision after 2028 targets a strategic relocation of the entire production facility away from densely populated areas, aligning with the 2030 master plan on Ha Noi capital.

4. Conclusion

The study evaluated the dispersion impacts from the Van Dien Plant and confirmed that this point-source emission activity served as a direct technical barrier to the roadmap for establishing Low Emission Zones (LEZs) of the capital. With NO_x concentrations in the core zone frequently reaching the limits of QCVN 05:2023/BTNMT, emissions from the plant effectively neutralized efforts to reduce traffic-related gases in the affected areas. Seasonal climate characteristics drove the alternating encroachment of pollution into densely populated areas – from Hoang Liet Ward in the summer to Kien Hung Ward in the winter, which necessitated a decisive dynamic governance mechanism in accordance with Directive No. 19/CT-UBND.

To align with LEZ standards, the plant must implement a technological upgrade roadmap for emission treatment to reduce at least 50 % of its emission load by 2028. Simultaneously, it must strictly apply flexible manufacture reduction scenarios based on real-time meteorological developments. In the long term, the strategic relocation of the manufacture facility away from densely populated areas and the redevelopment of the land into green space are essential solutions to fully relieve environmental pressure and ensure the sustainability of the Capital’s ecosystem in 2026.

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