

Research on the air pollution spreading from activities of motor vehicles to residential areas at the Lang - Lang Ha interchange

Nghiên cứu lan truyền ô nhiễm không khí từ các phương tiện giao thông cơ giới tới các khu vực dân cư xung quanh nút giao Láng- Láng Hạ

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ABSTRACT:

According to Hanoi city's master plan for transportation by 2030 with a vision to 2050 approved by the Prime Minister, Hanoi will renovate and build 185 new interchanges. The construction of interchanges will reduce traffic conflicts, and partly limit traffic congestion and accidents. However, the formation of traffic flows at different elevations will aggravate environmental pollution problems from the operation of motor vehicles. This research was conducted to assess the current situation of traffic operation at the Lang Ha - Lang interchange. The results show that this is an area with a large number of vehicles, the direction of the vehicles is quite complicated with pollution sources at different elevations, which causes the pollution to spread further. The residential area near this interchange has the amount of dust, SO_2 , and VOC exceeding the standards. Calculation results show that the dust pollution level during rush hours in the morning and afternoon both exceeds QCVN 05:2023/BTNMT ($0.3 \text{ mg}/\text{Nm}^3$) with the highest level exceeding 100 times. With the regulation on SO_2 content in the air being $0.35 \text{ mg}/\text{Nm}^3$, in the locations 90m far from the source, SO_2 content still exceeds the regulation (the lowest value is $1.06 \text{ mg}/\text{Nm}^3$ in the morning and $0.54 \text{ mg}/\text{Nm}^3$ in the afternoon). Similarly, the VOC concentration measured at a distance of 80m far from the source reached the value from $852.44 \text{ mg}/\text{Nm}^3$ and a maximum value of $3072.34 \text{ mg}/\text{Nm}^3$. This is a concentration that is harmful to human health if being exposed for a long time.

Keywords: air pollution, SO_2 , dust, VOC, traffic, interchange.

TÓM TẮT:

Theo quy hoạch giao thông vận tải thủ đô Hà Nội đến năm 2030, tầm nhìn đến năm 2050 đã được Thủ tướng Chính phủ phê duyệt, Hà Nội sẽ cải tạo, xây dựng mới 185 nút giao thông. Việc xây dựng các nút giao thông sẽ giúp giảm xung đột giao thông, hạn chế phần nào tình trạng ùn tắc và tai nạn giao thông. Tuy nhiên, việc hình thành các luồng giao thông ở các độ cao khác nhau sẽ làm trầm trọng thêm vấn đề ô nhiễm môi trường từ hoạt động của các phương tiện cơ giới. Nghiên cứu này được tiến hành nhằm đánh giá hiện trạng hoạt động giao thông tại nút giao Láng Hạ - Láng. Kết quả cho thấy đây là khu vực có lưu lượng phương tiện lớn, hướng di chuyển của các phương tiện khá phức tạp với các nguồn ô nhiễm ở các độ cao khác nhau khiến tình trạng ô nhiễm lan rộng hơn. Khu vực dân cư gần nút giao này có lượng bụi, SO_2 , VOC vượt tiêu chuẩn cho phép. Kết quả tính toán cho thấy, mức độ ô nhiễm bụi vào giờ cao điểm sáng và chiều đều vượt QCVN 05:2023/BTNMT ($0,3 \text{ mg}/\text{Nm}^3$) với mức cao nhất vượt 100 lần. Với quy định về hàm lượng SO_2 trong không khí là $0,35 \text{ mg}/\text{Nm}^3$, tại các vị trí cách nguồn 90m, hàm lượng SO_2 vẫn vượt quy định (giá trị thấp nhất là $1,06 \text{ mg}/\text{Nm}^3$ vào buổi sáng và $0,54 \text{ mg}/\text{Nm}^3$ vào buổi chiều). Tương tự, nồng độ VOC đo được ở khoảng cách xa nguồn 80m đạt giá trị từ $852,44 \text{ mg}/\text{Nm}^3$ và giá trị tối đa là $3072,34 \text{ mg}/\text{Nm}^3$. Đây là nồng độ có hại cho sức khỏe con người nếu tiếp xúc trong thời gian dài.

Từ khóa: Ô nhiễm không khí; SO_2 ; bụi; VOC; giao thông; nút giao khác mức.

1. OVERVIEW

At intersections, accidents and traffic jams often occur because there are many traffic flows with large numbers of vehicles, high speed, complex vehicle composition, limited visibility. According to

calculations by the American Society of Highway Engineers, 50% of urban traffic accidents occur at intersections. These are also places that cause environmental pollution, negatively affecting the health of people living around and the socio-economy in the area due to the

delay of goods and passengers passing through the intersections. Bridge and road specialists and designers around the world have proposed technical measures and design solutions to solve the situations and huge consequences caused at intersections. One of the most effective solutions for overcoming the problems above is designing interchanges. Interchanges are a large item, directly affecting the quality and aesthetics of the entire project and especially contributing to increasing traffic safety on the roads. In urban areas, they are architectural highlights, a tourist attractions. However, the land area occupied by interchanges is very large, the construction cost is high and the construction measures are quite complicated. In the

period of 2012-2015, Hanoi has constructed a series of overpasses at a number of intersections to form interchanges to reduce traffic conflicts and limit traffic congestion at intersections. The occurrence of these items has helped limit congestion at intersections such as Thai Ha-Lang Ha, Lang-Lang Ha, etc.

Lang – Lang Ha interchange uses traffic lights, islands and painted lines to organize traffic. There are routes leading to the interchange including Lang Ha, Lang (Ring Road 2), Le Van Luong, Nguyen Ngoc Vu. In which, an overpass which connects Lang Ha Street to Le Van Luong Street allows buses (including bus rapid transit (BRT)) to operate.



Figure 1. Lang- Lang Ha interchange

In the announcement of the results of the implementation of the Environmental Protection Assessment Index of 63 provinces/cities in 2021 by the Ministry of Natural Resources and Environment, Hanoi is one of the 5 localities with the lowest index of people's satisfaction with the quality of the living environment. One of the environmental issues in Hanoi that makes people upset is air pollution and noise from traffic activities. During operation, motor vehicles create noise, exhaust gas and dust, etc. These pollutants will be spread and diffused in the air. Depending on the number of vehicles and the height of the pollution source, it will create different impacts on residential areas on both sides of the road. This research was conducted to consider and calculate the spread of pollution from traffic activities in two cases of at-grade and grade-separated traffic at the Lang - Lang Ha intersection area to clarify the negative environmental impacts when constructing interchanges. This will support a more detailed investment effectiveness assessment of the environmental aspect of interchanges. In fact, more than 90% of vehicles in Hanoi use fossil fuels such as gasoline or diesel, which during combustion, they produce typical pollutants such as dust, SO₂, NO_x, CO₂, and VOC. Dust is an annual pollution problem that causes frustration for people living in Hanoi. Although Hanoi has made many efforts to reduce pollution such as watering streets and planting trees, dust pollution remains high. In particular, on the morning of March 5, 2024, Hanoi was the most polluted city in the world with very poor air quality (AIQ index of 241). Traffic emissions also contain several acidic

gases and can cause secondary pollution such as SO₂, NO_x, CO₂ or carcinogenic substances such as VOC. In this research, we focus on parameters of dust, SO₂ and VOC caused by traffic activities because these are three typical pollution groups from using fossil fuels.

2. RESEARCH SUBJECTS AND METHODS

2.1 Research subjects

The main subject of this research is limited to three air quality parameters: dust, SO₂ and VOC generated from vehicle operation. The research is limited to the Lang Ha - Le Van Luong section at the Lang - Lang Ha interchange because in this area, the noise sources have different heights. The route for the pollution spreading assessment is Lang Ha section from the beginning of the Lang Ha - Le Van Luong intersection to the Lang Ha - Vu Ngoc Phan intersection.



Figure 2. Overpass at Lang Ha- Le Van Luong intersection

Measured and calculated values of dust, SO₂ and VOC are compared with QCVN 05:2023/BTNMT to assess the level of air pollution.

Table 1: Maximum limit values of basic parameters in ambient air according to QCVN 05:2023/BTNMT

Unit: µg/Nm³

Or.	Parameter	Average in 1 hour	Average in 8 hours	Average in 24 hours	Average in a year
1	SO ₂	350	-	125	50
2	CO	30,000	10,000	-	-
3	NO ₂	200	-	100	40
4	O ₃	200	120	-	-
5	Total Suspended Particles (TSP)	300	-	200	100
6	PM10	-	-	100	50
7	PM2.5	-	-	50	45

Note (-) No regulation
 (*): Concentration values to be applied from January 1, 2026

2.2 Research methods

The vehicle counting method was used to determine the number of vehicles, emission factor calculation method was applied to determine the pollution level from the operation of vehicles at the center of the road, then based on the Sutton's modified model, the pollution spread was calculated. The vehicle counting activity was deployed at the intersection corners, both ends of the overpass. The camera locations are described in Figure 3.

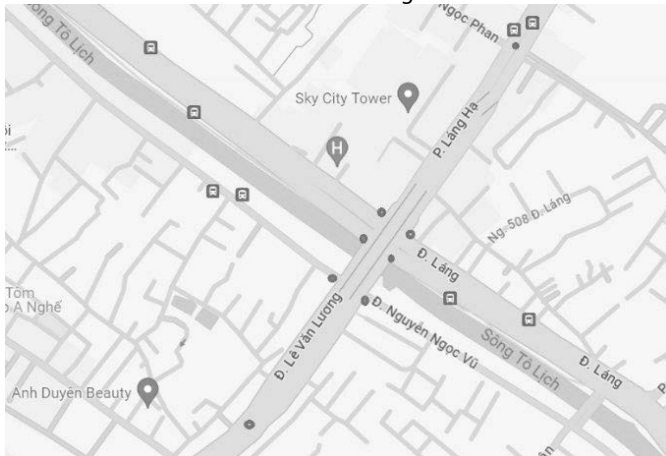


Figure 3. Vehicle counting locations

Vehicle counting time slots were 7:00-10:00 and 14:30-17:30, vehicle counting time was carried out for six consecutive days from October 30, 2023 to November 4, 2023. Vehicle counting results were calculated on average per hour (number of vehicles/hour) and then converted to vehicle groups corresponding to the air pollution load coefficients in Table 1. The research team used the method of calculating air pollution load coefficients to determine the level of pollution from vehicle operation.

Table 3: Survey results of average number of vehicles during rush hours in a day

Routes	Average number of vehicles (vehicles/h)						
	Motorbike	Car and light -duty truck <3.5 tons	Medium-duty truck 3.5-16 tons	Heavy-duty truck > 16 tons	Bus < 1400cc	Bus 1400-2000cc	Bus > 2000cc
Passing through the overpass	4506.8	1134.9	3.3	0.2	8.1	7.7	16.4
From Le Van Luong Road	5256.4	2261.7	10.7	0.0	51.7	22.6	20.9
From Lang Ha Street	2664.4	295.1	6.6	0.1	16.0	10.9	11.0
From Lang Street	8303.4	2097.6	3.1	1.3	139.2	87.9	56.2
From Nguyen Ngoc Vu Street	2701.2	483.6	2.6	0.1	3.9	6.2	15.5

Based on Sutton's modified model, the spreading of pollutants emitted from roads can be determined by the following formula:

$$C = 0,8E \left\{ \exp \left[\frac{-(z+h)^2}{2\sigma^2} \right] + \exp \left[\frac{-(z-h)^2}{2\sigma^2} \right] \right\} \frac{1}{\sigma_z u} \quad (*)$$

In which: C - concentration of pollutants in the air (mg/m³);
 E - emission source (mg/m/s); E=N*G/3.6
 Z - height of the calculation point (m);
 σ_z - diffusion coefficient in the z- direction (m) as a function of the distance x in the direction of the wind;
 u - average wind speed (m/s);
 h - height of the road surface compared to the surrounding ground (m).

N number of vehicles in 1 hour (vehicle/h)
 G Pollution load index

The value of the pollution diffusion coefficient σ_z in the vertical z direction in the case of a road source is determined according to the Slade formula (1968) with the atmospheric stability type "B" is calculated in accordance with formula (**):

$$\sigma_z = 0,53x^{0,73} \quad (**)$$

In which: x - distance (coordinates) of the calculation point from the emission source (calculated from the roadside) in the direction of the wind.

The air pollution load indexes from vehicles are determined according to WHO [6] with the load factor shown in Table 2

Table 2: Pollution load indexes by means of transport

Parameters	Indexes by means of transport (g/km)				
	Car	Light-duty truck	Heavy-duty truck	Bus	Motorbike
Dust	0.15	0.15	1.6	0.05	0
SO ₂	0.0042	0.0042	0.037	0.0074	0.0038
NO _x	0.55	0.55	24.1	1.43	0.3
CO	0.85	0.85	5.15	2.96	20
VOC	0.4	0.4	3	0.26	3

The sulfur content in the fuel is assumed to be 0.25%.

The highest monthly average wind speed in Hanoi is taken from QCVN 02:2022/BXD- National technical regulation on Natural physical and climatic data for construction of Vietnam. In October, the wind speed is 2.4m/s, the height of the calculated point is 1.5m (according to the height of an adult) and the height of the pollution source is 1m when calculating for vehicles traveling in the lower lane and 4m for vehicles traveling over the overpass.

3. RESULTS AND DISCUSSIONS

3.1 Results on the vehicle counting

The survey results of the number of vehicles (average per hour) at the Lang - Lang Ha interchange along the Lang Ha - Le Van Luong route are shown in Table 3. This route restricts heavy trucks at certain times of the day but allows buses to operate.

3.2 Results of pollutant spreading in the air



Figure 4. Area for calculating the spread of pollutants

Based on the data on the number of vehicles and the pollution load of dust, SO₂ and VOC, the research team used the Sutton model to calculate the spread of pollutants from traffic activities on the research route to residential areas on both sides of the road, the calculation of diffusion was limited by the intersection angle with Lang and Lang Ha streets (Figure 4). The calculation results are shown in the Figures 2, 3, and 4.

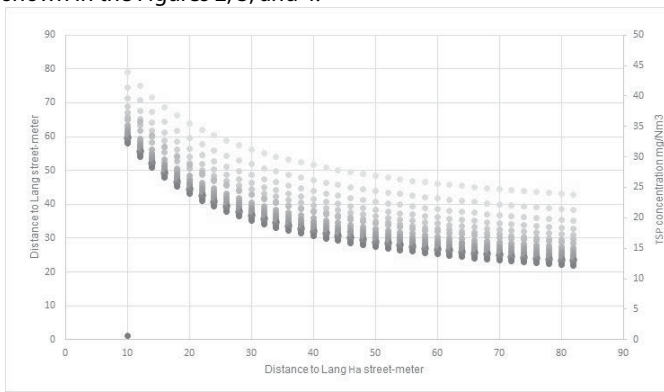


Figure 5. Calculation results of TSP spreading from traffic activities to surrounding residential areas

Calculation results show that the dust pollution concentration during the morning and afternoon rush hours in both directions of Lang and Lang Ha streets are in the range of 11 - 45 mg/ Nm³, exceeding QCVN 05:2023/BTNMT (0.3 mg/ Nm³) with the highest level exceeding 150 times, especially, at a distance of 90 m from the roadside to residential areas, the dust concentration is still very high, environmental pollution still occurs, then affecting people's health. A particulate can penetrate deep into the human body, damaging organs, especially the respiratory system. Exposure to dust causes acute respiratory diseases such as asthma, bronchitis, chronic obstructive pulmonary disease. In addition, fine particles moving into humans can cause heart disease, liver disease, dysfunction, and affect the central nervous system.

Similarly, with the regulation on SO₂ content in the air being 0.35 mg/ Nm³, in the locations at 90m far from the source, SO₂ content exceeded the regulation (the lowest value is 1.06

mg/ Nm³ in the morning and 0.54 mg/ Nm³ in the afternoon). Thus, it can be seen that the traffic flow when passing Lang Ha overpass at the Lang-Lang Ha intersection has negatively affected the air quality of the area. With the characteristics of being an acidic and hydrophilic gas, SO₂ can directly affect human health, cause acid rain to destroy the environment, or it can also indirectly affect through photochemical transformation in the atmosphere.

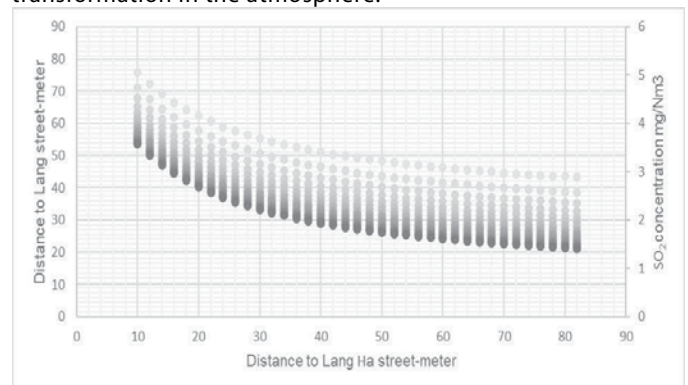


Figure 6. Results of calculation of SO₂ spreading from traffic activities to surrounding residential areas

From the chart above, it can be seen that the VOC concentration in the air reaches a minimum of 852.44 mg/ Nm³ and a maximum of 3072.34 mg/ Nm³, even at a distance of 80m far from the source. According to the regulations of the Ministry of Environmental Protection of the Federal Republic of Germany, when the VOC concentration value in a room is between 1000 - 3000 mg/ Nm³, the room is only allowed to be used for a limited period of time (no more than 12 months) and ventilation must always be ensured. Such VOC concentration does not ensure health conditions for people in residential areas around the intersection. VOCs are very harmful to the eyes and skin, respiratory diseases such as nose, throat, etc. If we are exposed to VOCs regularly and for a long time, it can cause headaches, even more seriously, organs are gradually weakened and damaged.

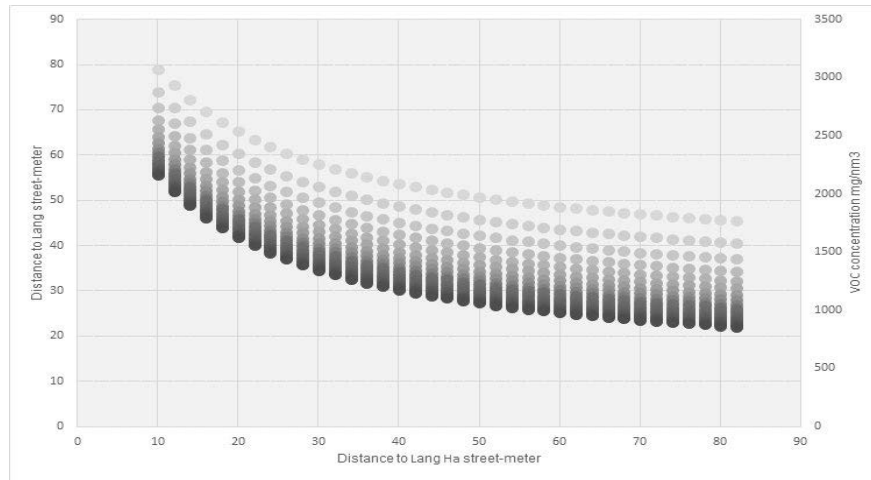


Figure 7. Results of calculation of VOC pollution spreading from traffic activities to surrounding residential areas

3.3 Conclusions

The research has shown the relationship between the number of vehicles, concentrations of dust, SO₂ and VOC according to the Sutton's modified model. Thereby, it shows that the area of the route from Lang Ha Street to Le Van Luong Street at the Lang - Lang Ha intersection has a large number of vehicles participating in traffic, this area is an interchange with pollution sources at different heights, which causes the pollutants spreading further and wider along both routes from the intersection. In residential areas closed to the interchange, dust, SO₂ and VOC levels exceed the permitted standards. To overcome this, in the near future, the Hanoi government needs to have solutions to reduce the number of vehicles participating in traffic by strengthening the public transport network such as buses, urban railways, etc.

In the Hanoi Urban Economic Development Plan, 33 priority tasks and programs have been proposed, including the Project "Zoning to restrict motorbike operations in accordance with the infrastructure and service capacity of the public passenger transport system, towards the complete ban of motorbikes in 12 districts of Hanoi by 2030". Banning motorbikes will reduce environmental pollution provided that there is no increase in other private vehicles and people traveling by public transport. In the case that the number of people traveling by public transport does not increase and they switch from motorbikes to private cars, pollution will be more serious because the amount of emissions from cars is higher than that of motorbikes, at the same time the road capacity will not be able to serve a large number of cars, which will lead to more serious traffic jams, and the travel time through the intersection will increase many times. Therefore, the most suitable solution for the area is to strengthen the public transport system combined with limiting private vehicles. Public transport needs to be prioritized in movement such as elevated railways, avoiding conflicts with other means of transport.

The research was only conducted in two time slots during the rush hours in the morning and afternoon, and ignored the influence of the terrain of the residential area as well as the weather. To assess the pollution situation more comprehensively, it is necessary to conduct more extensive research by hour of the day and at different times of the year. At the same time, using monitoring tools to assess the error level of the calculation model, as well as putting pollution parameters on the map to see the spreading level of dust, SO₂ and VOC to serve the environmental impact assessment reports of urban transport projects. The research conducted can be used to

calculate the health risks of people due to the impact of vehicle emissions, helping assess the pollution level and the spreading of pollutants in areas near traffic routes more objectively and accurately.

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