MODELING AIR POLLUTION FROM VEHICLE EXHAUST AND APPLICATION TO STUDY AIR QUALITY FOR CAU GIAY DISTRICT, HANOI

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Abstract: *Cau Giay district serves as the gateway to Hanoi capital. Along with the infrastructure development and rapid population growth in recent years, the number of motor vehicles in the district has also increased sharply. These are the main reasons that affect air quality in the area. This study aims to use a pollutant propagation simulation model to evaluate the impact of traffic activity on neighboring regions. The results showed that most pollutant concentrations in the exhaust fumes of vehicles are within the permissible limits. However, some roads such as Pham Van Dong, Ho Tung Mau, and Cau Giay showed slight NO_2 pollution due to exhaust fumes of vehicles.*
Keywords: *simulation model, air pollution, Meti-lis, vehicles.*

МОДЕЛИРОВАНИЕ ЗАГРЯЗНЕНИЯ ВОЗДУХА НА ОСНОВЕ ВЫБРОСОВ ТРАНСПОРТНЫХ СРЕДСТВ, ПРИМЕНИТЕЛЬНО К ИЗУЧЕНИЮ КАЧЕСТВА ВОЗДУХА РАЙОНА КАУЗЯЙ, ХАНОЙ

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Аннотация: *район Каузяй служит воротами в столицу Ханоя. Наряду с развитием инфраструктуры и быстрым ростом населения в последние годы, количество автотранспортов в этом районе также резко увеличилось. Эта основная причина влияет на качество воздуха этого района. В данной статье изучается применение имитационной модели распространения загрязнителя для оценки воздействия транспортной деятельности на воздух. Результаты показали, что большинство концентраций загрязняющих веществ находится в допустимых пределах. Однако воздух на некоторых дорогах, таких как Фам Ван Донг, Хо Тунг Мау и КауЗяй, был загрязнен NO_2 в результате выбросов транспортных средств.*
Ключевые слова: *имитационное моделирование, загрязнение воздуха, Meti-lis, автотранспорт.*

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1. Introduction

Air pollution has been a significant problem in urban areas and major cities in Vietnam in recent years. Many reasons and factors that cause air pollution in big cities, but air pollution from road vehicles are the most severe air pollution factors. More than 200 different chemical compounds are included in vehicle emissions, such as carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter, and other smog-forming emissions. According to research reports [1], [2] the means of transport contribute about 65 - 70% to air pollution, and nearly half of the populations living in Ha Noi city live in polluting air.

Cau Giay is an important gateway to Hanoi with many significant intersections and streets like Cau Giay Street, Tran Thanh Tong Street, Mai Dich Street, Ho Tung Mau Street, etc.; therefore, there are a lot of vehicles in these areas every day. This is the main reason for the deterioration of the air quality in the Cau Giay region in recent years. Air pollution heightens the health risk of respiratory ailments, affects ecosystems, and increases environmental costs [3, 4]. However, there are still very few specific studies to assess the quality and zoning of pollutant emissions from road activities in the Cau Giay region.

The use of mathematical models to calculate emissions and dispersion of pollutants released from road traffic is quite common. The Meti-Lis model is one of the optimal options by its popularity and high reliability for calculating pollutant emissions from road sources. This model was planned and widely used by the Japanese Ministry of Economy, Trade and Industry [5].

2. Method

For the study, the method of collecting and processing information was used, as a result of which all information was obtained, including: area map, natural conditions, data of road network and data on meteorology of Cau Giay region.

As an example of calculating the pollution by exhaust gases of vehicles, on the main highways and streets will carry out measurements with specific data on the composition and intensity of vehicles.

In this paper we used model Meti-Lis version 2.03 in English to determine the state, zoning of atmospheric air pollution with dust and toxic gases from vehicle emissions in Cau Giay District. This model is based on the principle of Gaussian scattering and is applied to calculate emissions from any source. Sources with line-shaped characterics can be found by numerically integrating the point-source plume equation. [4]

$$C_{(x,y,z)} = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z-He)^2}{2\sigma_z^2}\right)+\exp\left(-\frac{(z+He)^2}{2\sigma_z^2}\right)\right]$$

With:

C – Concentration.

x, y, z – Coordinates.

He – Effective plume-rise height (With line sources the height and their effective height are both assumed to be 0).

Q – Volume of emission per unit distance and unit time (g/(km.h)).

U – Wind speed (m/s).

σ_y, σ_z – Horizontal and vertical dispersion width from Pasquill-Gifford curves. As the given in the ISC 3 line-source calculation released by the US Environmental Protection Agency, model Meti-Lis sets the initial vertical dispersion width to 3,5 meters and the horizontal dispersion width by the target line width divided by 2,15 [5].

The method to integrate the point-source plume equation used in model is the Simpson formula of finding numerical integrals. The Simpson formula approximates the value of a definite integral by using quadratic functions.

$$\int_{x_1}^{x_2} f(x)dx \approx \int_{x_1}^{x_2} P_2(x)dx = \frac{x_2-x_1}{6}\left(f(x_1)+4f\left(\frac{x_1+x_2}{2}\right)+f(x_2)\right)$$

With $f(x_1), f\left(\frac{x_1+x_2}{2}\right), f(x_2)$ – the values of the function at the corresponding points (the segment's endpoints and center point).

To calculate the emissions, we have used the value of emissions operating for different vehicle groups in accordance with the studies [6, 7, 8] applied to Vietnam and the value of emissions by inventory guidebooks European Environmental Agency air pollutant emission [9, 10]. In this paper, we use three main parameters, including: hot exhaust (E_h) and cold exhaust gas (E_c).

$E_{total} = E_h + E_c$

The emission factors of vehicle for road traffic are shown in Table 1 for the substances to calculate for hot emissions and Table 2 is the emission factors for calculating cold emissions.

Table 1. Emission factor for road traffic – hot emission (g /km.vehicle) [6, 7, 9]

Vehicle category	**Hot emission (g/km)**		
	NO_x	**CO**	**SO_2**
Heavy trucks and buses	19,7	11,1	0,18
Cars	1,9	34,8	0,018
Motorcycles	0,05	21,85	0,03

Table 2. Emission factor for road traffic – cold emission (g /km.vehicle) [6, 8, 10]

Vehicle category	**Cold emission (g/km)**		
	NO_x	**CO**	**SO_2**

Heavy trucks and buses	0,0	0,0	0,0
Cars	0,02294	0,0	0,00871
Motorcycles	0,0023	1,7086	0,00138

3. Results and discussions

This is the first study on emissions inventory for Cau Giay Distric, therefore the data of air pollutants from traffic is limited. Data of this emission inventory are described as follows: (1) traffic counts were performed at intervals of 30 min for 12 streets; (2) The composition of each vehicle category is constant for the entire area under consideration; (3) The emission factor are constant in each streets and in time; (4) the selected road network consisting of 12 highways and main streets is shown in figure 1.

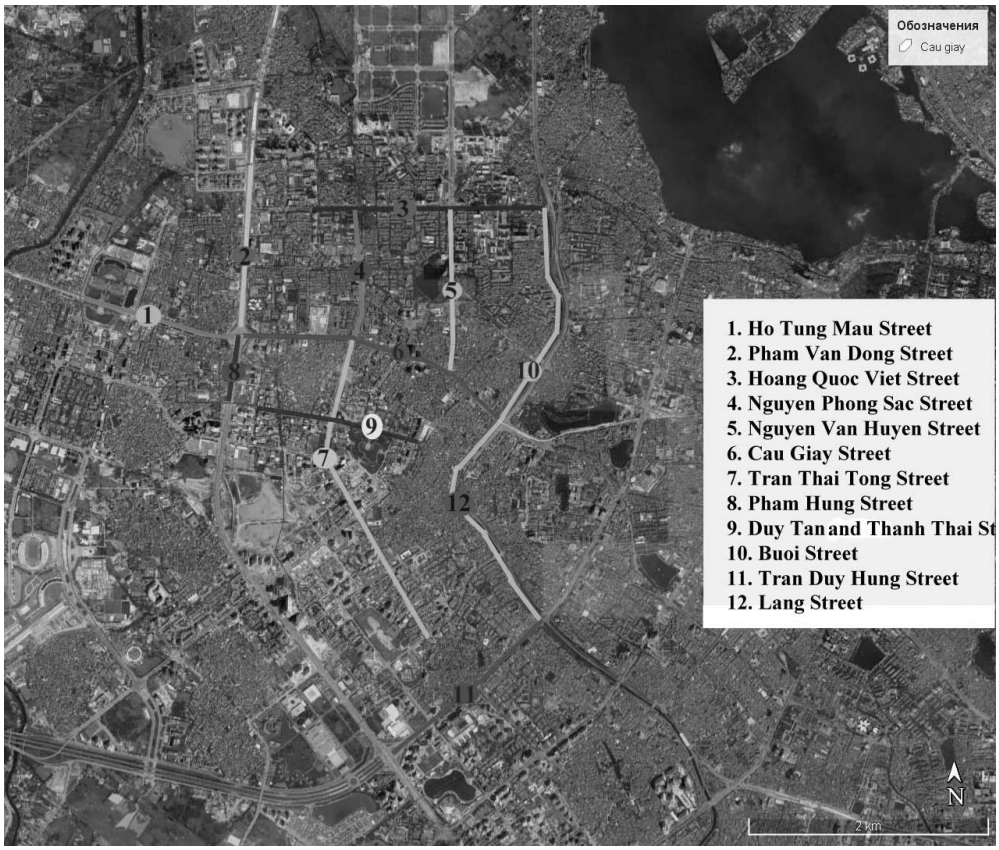


Fig. 1. The selected road network on region Cau Giay

The map of this paper is 8 km x 7 km including all road network of Cau Giay District. The resolution of each grid is 160 m x 140 m.

The basis for internal processing of meteorological data are described as follows: the meteorological conditions obtained by a series of meteorological data collected from Cau Giay meteorology station in winter (February to March) and summer (July to August) in 2020. The archive formatted to directly enter into and processed by the model.

From the meteorological data collected at Cau Giay, the prevailing wind directions of the study area in winter were Northeast (NE), East (E) and Southeast (SE) (Figure 2a); and in summer were East (E) and Southeast (SE) (Figure 2b).

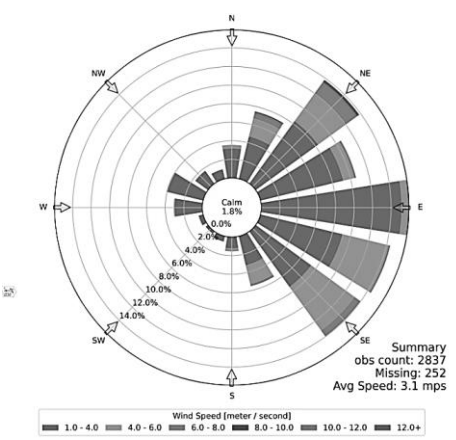


Fig. 2a. Wind direction and wind speed (m/s) in winter (February to March)

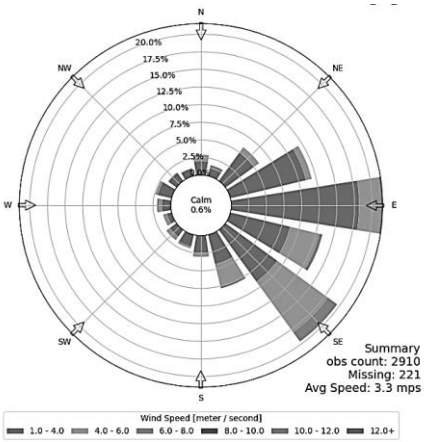


Fig. 2b. Wind direction and wind speed (m/s) in summer (July to August)

Table 3 shows the final results of pollution emissions from traffic flows on the selected road network per hour. With the results obtained, the intensity of the emission of individual impurities can be represented.

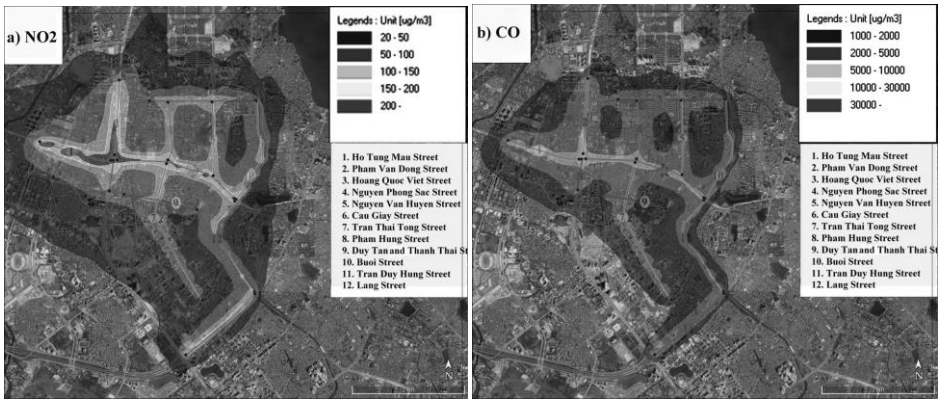
Table 3. The total of emission factors on the selected road network

№	Street	The values of emissions from vehicles (g/km.h)		
		NO_2	CO	SO_2
1	Ho Tung Mau	16963	461073	660
2	Pham Van Dong	16424	361068	507
3	Hoang Quoc Viet	7847	248957	334
4	Nguyen Phong Sac	5127	219797	275
5	Nguyen Van Huyen	8139	169072	254
6	Cau Giay	11596	367769	506
7	Tran Thai Tong	4393	186132	238
8	Pham Hung	11191	328545	434
9	Duy Tan	2746	34123	56
10	Buoi	6704	169672	243
11	Tran Duy Hung	10392	268118	318
12	Lang	6704	169672	243

Finally, run the Meti-Lis model for all selected pollutants and meteorological data. The model simulates concentration pollutants average hour at the calculated height of 1.5 m (average breathing range) for each pollutant.

The results obtained when running diffusion simulation models of substances from the exhaust fumes of vehicles on the roads of Cau Giay district are the concentration values in 1 hour and the average value of the entire data sequence hourly.

Figure 3 shows the average hourly concentrations of pollutants during winter, and Figure 4 shows the results obtained for average hourly pollutant concentrations during the summer period.



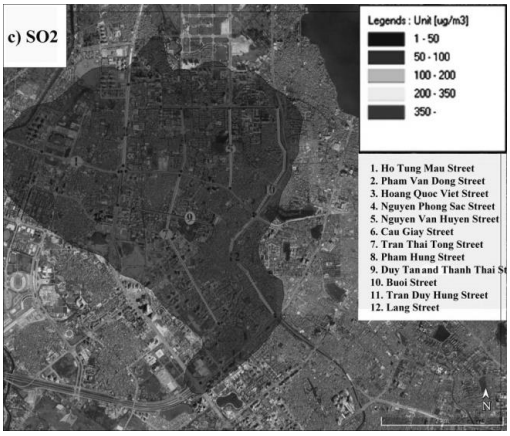


Fig. 3. The average 1-hour concentration of pollutants from road vehicle exhaust during the winter period

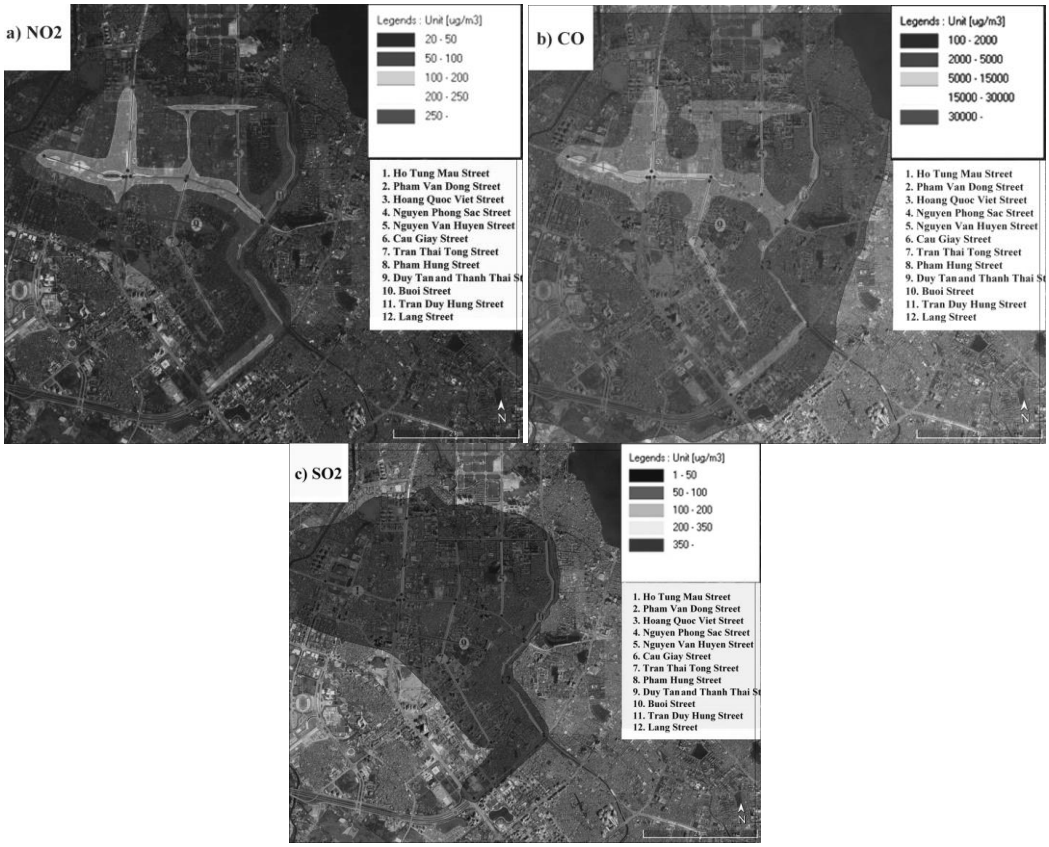


Fig. 4. The average 1-hour concentrations of pollutants from road vehicle emissions over the summer period

From the results received, it can be seen that there are signs of NO2 pollution in the Cau Giay district due to emissions from vehicles on some main roads such as Pham Van Dong, Cau Giay, Ho Tung Mau. The concentrations of other pollutants such as CO and SO2 are much lower than the allowed concentration values for 1 hour. It can be seen that exhaust gas from heavy trucks and buses is the leading cause of air pollution in the Cau Giay district. The pollutant concentration values in the area along the main roads are higher in winter than in summer, which can be explained by the fact that there is less solar radiation in winter than in summer. Therefore, the dispersal of pollutants takes place more slowly.

4. Conclusion

In this work, a computational model of the transport of pollutants from road traffic emissions in the Cau Giay district area is used for two seasons: winter and summer respectively. Specific emissions parameters are calculated

based on the total number of vehicles, classification of different vehicles and the emission factor corresponding to each vehicle type.

According to the calculation results simulating the spread of air pollutants from the Meti-Lis model, it can be seen that in the traffic area between Pham Van Dong, Ho Tung Mau, Pham Hung, and Cau Giay streets, there are NO2 pollution occurs.

Theo các kết quả tính toán mô phỏng lan truyền các chất ô nhiễm không khí từ mô hình Meti-Lis có thể thấy rằng tại khu vực giao thông giữa đường Phạm Văn Đồng, đường Hồ Tùng Mậu, Phạm Hùng và Cầu Giấy có sự xuất hiện ô nhiễm của khí NO_2. This can be explained because these routes pass through the My Dinh bus station area and these are the main roads connecting to the city center, so there are many passenger cars and buses daily, and heavy trucks move through these routes.

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