Calculate Road Traffic Air Emissions Including Traffic jam: Application over Hồ Chí Minh City, Vietnam

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Abstract: Road traffic emissions are the main sources of uncertainties in air quality numerical models used to forecast and define abatement strategies. Available models to calculate road traffic emission always require a big effort, money and time. So that in this research we used a model namely EMISENS model for calculation air emission inventories over Hồ Chí Minh City (HCMC), Vietnam. However, this model can not calculated air emission inventories in temporal and take into account the traffic jam. The first aim is to improve the calculation method including phenomena of traffic jam and integrated it in the EMISENS model. Then, study scenarios to reduce air pollution caused by road traffic activities for HCMC until 2020. The results shown that when calculating emissions we have to take into account traffic jam. Emissions calculated results taking into account traffic jams shown that motorcycle emissions occupy most emissions of CH_4, CO, NMVOC, SO_2 and NO_x (more than 88%, 85%, 82%, 70 % and 31.5% respectively, of the total emissions from road transport activities in HCMC). The first scenario is the reduction scenario for the year of 2020, its results shown that the emissions of the city will be increased very low (increasing 2-8% from 2012). The current vehicle technology is old and outdated techniques. Therefore, if we want to invest in buses to replace motorcycle, air pollution in HCMC will become aggravates.

Keywords: Traffic emissions; traffic jam; Hồ Chí Minh City; EMISENS model; Air Pollution.

1. Introduction

Hồ Chí Minh City (HCMC) is the highest population-concentrated city in Vietnam, with over six million people in 2006 and annual increases of 110,000 people. Located between southeastern region and southwestern region of Vietnam, it is an important center of economic, education and culture in Vietnam. According to

the GSO on 01/04/2010, the population of the city is 7,382,287 people. In 2010, HCMC has 2,912,825 motorcycles and 299,392 cars. Private transportation including mainly motorcycles accounts for 96.3% of total transportation in HCMC while public transportation only accounts for 3.7% [1]. Recently, along with high economic development, Vietnam is facing the problem of air pollution in general and particularly air pollution caused by transportation activities.

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Air pollution has deteriorated considerably the health of millions of people in HCMC due to high levels of emissions which caused more than 90% of children under the age of 5 years old suffered from various respiratory illnesses in the city. Other research showed that Viet Nam is listed amongst the top ten countries with the worst air pollution in the world [2] and traffic is the main air emission sources over HCMC [2]. Recently, the population and economy grow rapidly in HCMC. However, the infrastructure development cannot catch up this growth. Thus traffic jams occur all over the city every day. Emissions from cars and motorcycles are one of the major reasons that cause air pollution in HCMC. According to the measurement results at six air quality monitoring stations in the city, 89% of air samples excess the national technical regulation on ambient air quality QCVN 05:2013/BTNMT. Moreover, the amount of suspended particulate matter is a factor that causes serious pollution in HCMC. In addition, air pollution from lead is increasing rapidly. Particularly, lead concentration has been measured by monitoring stations from early 2009 until now ranges from 0.22 to 0.38 g/m^3. Air pollution is aggravated when traffic jam occurs. However, only EMISENS model is used in HCMC to access the pollution load, because other models are costly and request many input parameters. Therefore, the study focused on the developing a methodology to calculate air emissions of road traffic including traffic jam over Hồ Chí Minh City. First of all, the results of models show that traffic jam occurs mainly in two peak hours: 6am – 9am and 4pm – 7pm, when 45% of rush hours occur. Second, emission factor calculated matches the velocity of vehicle (0 – 5km/h). We integrated into EMISENS model in order to access the amount of air pollutants emissions. Combining

with GIS, it is shown that the emissions of air pollutants depend on space and time.

2. Methodology and data

2.1. Methodology

Introduction of EMISENS model:

EMISENS model is able to calculate the amount of road traffic emissions in several steps with different levels of complexity. It is developed by Dr. Quoc Bang Ho and Prof. Alain Clappier [3] at LPAS laboratory, Switzerland Federal Technology Institute in Lausanne (EPFL). The goal of the project is to use this model to calculate a road traffic emission in developing countries. EMISENS model has been applied successfully in many developing countries, such as Bogotá city of Colombia, Agadir city of Morocco, Bangalore City of India, Algiers City of Algeria, Ho Chi Minh City of Vietnam etc. It is also used in developed countries such as: Strasbourg City of France, Seoul Capital of Korea and Ispra of Italy etc [4].

EMISENS model is based on three main functions: (i) EMISENS model is designed based on new approach to calculate emissions: EMISENS model combines the top-down and bottom-up approaches for generating road traffic emission inventories, reducing computational time by using vehicle groups instead of vehicle types; (ii) Authors built an interface for uncertainty and sensitivity analysis in using the Monte Carlo methodology. The Monte Carlo methodology has been used to evaluate the uncertainties in previous air quality studies [2, 5-7]; And (iii) Authors use the COPERT IV formulas in EMISENS model for calculation of emissions. The COPERT IV methodology [8] is based on theory of CORINAIR [9]. This is a classical methodology

developed in Europe. In the COPERT IV, the emissions are split in three: Hot emission, cold emission and evaporation emission. Total emissions are calculated based on equation:

$$E = E_{hot} + E_{cold} + E_{evap} \qquad (1)$$

The emissions are calculated based on the equation: $E_{ip,ie} = e_{ip,ie} A_{ie}$ (2)

E is total emissions

ip is the pollutant (CO, NO$_x$, PM10, NMVOC, CH$_4$)

ie is pollutants sources like a specific vehicle on specific street

e is emission factors

A is is the activity of the emitters

Hot emission (E_{hot}) is the emissions occurring under thermally stabilised engine and exhaust after treatment conditions.

Cold emission (E_{cold}) is the additional emissions due to the fact that a number of vehicles are driven with cold engine.

Evaporative emission (E_{evap}) can be estimated only for NMVOCs (Non Methane Volatile Organic Compounds) emissions and for gasoline passenger cars, gasoline light trucks and motorcycles because there are not enough data for others gasoline traffic and diesel vehicle [10,11].

Field study for EMISENS model:

The roads in HCMC are divided into 5 road categories based on regulation of Vietnamese [12-14]. The vehicles in HCMC are divided into 5 vehicle categories based on Vietnamese regulations and other studies [15-18] using GIS system [19].

After the field study, we determined traffic jam occurs at two peak time: 6am – 9am and 4pm – 7pm. Then average results are as follow: (i) From 6 am to 7 pm traffic jam occurs in 2

minutes (3.3%); (ii) From 7 am to 8 am traffic jams occur in 6 minutes (10%); (iii) From 8 am to 9 am traffic jam occurs in 4 minutes (6.6%); (iv) From 4 pm to 5 pm traffic jam occurs in 2 minute (3.3%); (iv) From 5 pm to 6 pm traffic jam occurs in 7 minutes (11.7%); (v) From 6 pm to 7 pm traffic jam occurs in 12 minutes (20%). The field study was conducted during 6 months from January to June of 2012.

During these 6 hours, traffic jam duration accounts for 9.16% of total time. In rush hour, speed of vehicle is in range of $0 \div 5$ km/h. Then we use the Fortran 90 running in the Linux operating system, Fedora Core 6 version. We added a loop called "Traffic jam calculation Loop". In this loop, we added a variable time (t_1) in the module of the MAIN.f of EMISENS model. The value of this variable is 24 hours in a day. If the value of t_1 is in ranges as 0 am – 6 am, 9 am -4 pm and 7 pm – 12 pm, the emission is calculated based on equation:

$$E_{ip,Ie,Istr} = e_{ip,Ie,Istr} F_{Ie,Istr} L_{Ie,Istr} \qquad (3)$$

Where ip is the pollutant (NO$_x$, CO, CH$_4$, etc)

I$_e$ is type of vehicle (heavy truck, light truck, bus, car and motorcycle)

I$_{str}$ is type of street (highway, rural, main urban street, sub urban street)

F and L are the vehicle flow and street length

If the value of t_1 is in ranges as 6 am – 9 am and 4 pm – 7 pm (traffic jam or rush hours), the emission is calculated based on equation:

$$E_{ip,Ie,Istr} = e_{traffic} F_{Ie,Istr} L_{Ie,Istr} 9.16\% + e_{ip,Ie,Istr} F_{Ie,Istr} L_{Ie,Istr} 90.84\% \quad (4)$$

Where e$_{traffic}$ is emission factor of the vehicle which circulates with velocity in the range of traffic jam/rush hours.
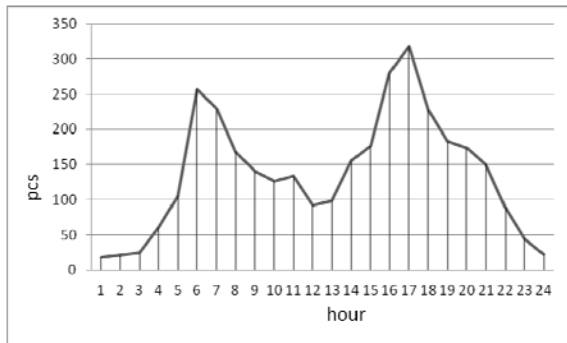
2.2. Input data

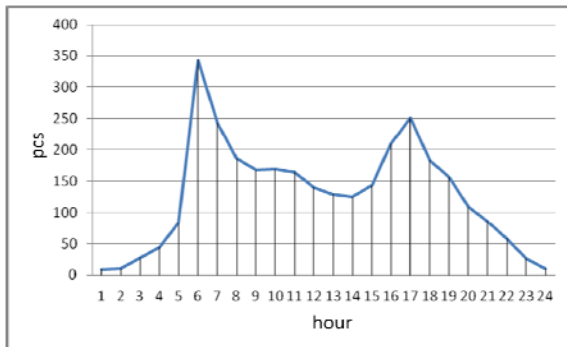Figure 1. Average traffic flow per hour on the Highway.

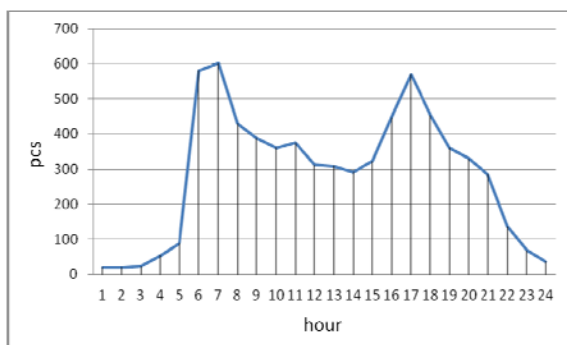Figure 2. Average traffic flow per hour on the Rural Street.

Figure 3. Average traffic flow per hour on the main Urban street.
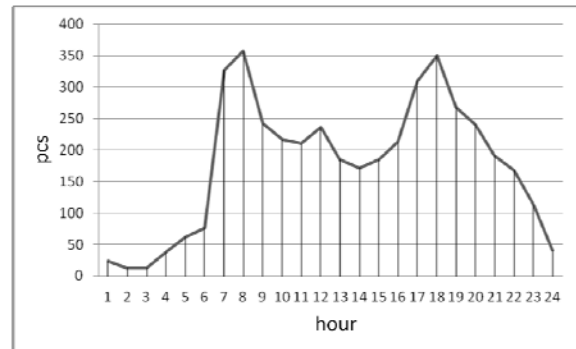

Figure 4. Average traffic flow per hour on the sub Urban street.

Counting vehicle traffic flow: in this research, we collected samples on four types of roads in Hồ Chí Minh City to determine the duration of traffic jam (Figure 1, Figure 2, Figure 3 and Figure 4). These four types of roads are highway, rural, main urban and sub urban streets. The vehicles were classified in 5 groups: car (all passenger cars and private cars), light truck (less than or equal to 2.5 tons), heavy truck (greater than 2.5 tons), bus (urban buses and coaches) and motorcycle (including 2 strokes and 4 strokes)
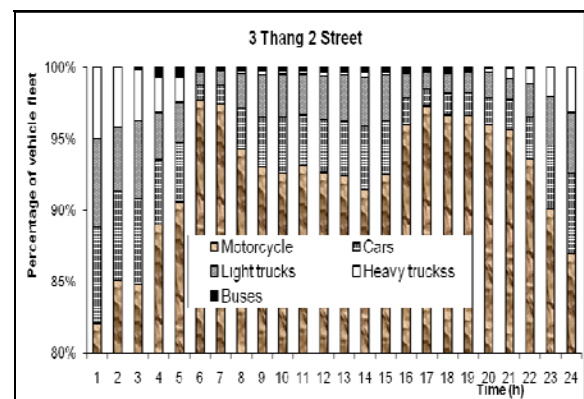

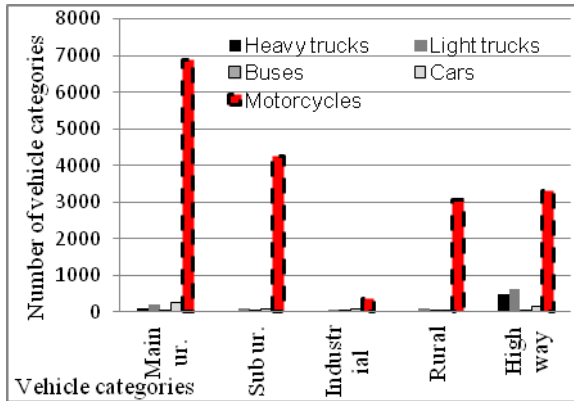Figure 5. Percentage of vehicle fleet in 3 Thang 2 street, HCMC, Vietnam.

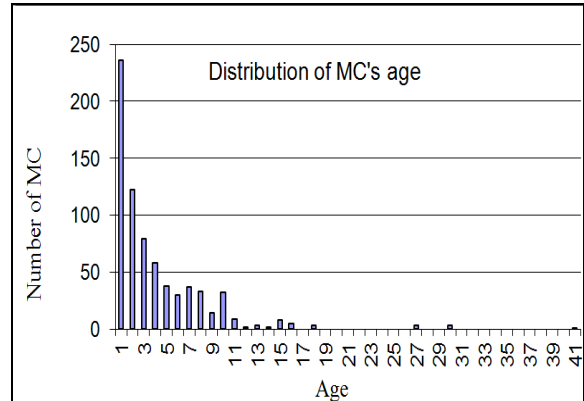Figure 6. Average number of vehicle groups in each street categories in HCMC, Vietnam.

Figure 7. Distribution of Moto's age in HCMC.

3. Results

3.1. Average emission results

Table 1. The average emissions of each vehicle groups in rush hour/traffic jam (ton/year)

Vehicle groups	NO_x	CO	SO_2	NMVOC	CH_4
Heavy truck	6.985	686	763	22.883	297
Light truck	5.966	186.382	403	4.020	901
Bus	6.054	39.549	389	5.611	382
Car	4.884	48.671	452	10.891	843
Motorcycle	10.999	1.667.430	4.789	200.549	18.242

From table 1, we calculated the percentage of each vehicle emissions compared with total emissions. The results show that main pollution source comes from motorcycles because of its large amounts.

Table 2. The average emission of all parameters when traffic jam occurs

Pollutants	Emission (g/h)	Emission (ton/year)	Hot emission (%)	Cold emission (%)	Evaporative emission (%)
NO_x	$0.3071.10^7$	26906.34	83.97	16.03	0
CO	$0.2644.10^9$	2315749.8	88.29	11.71	0
SO_2	$0.3694.10^6$	3235.99	82.02	17.98	0
NMVOC	$0.5948.10^8$	521001	51.27	0.86	47.87
CH_4	$0.2861.10^7$	25064.99	77.79	22.21	0

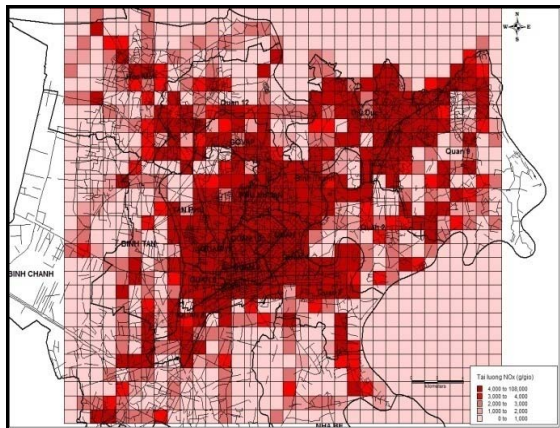*3.2. Spatial and time distribution*

a) NO_x
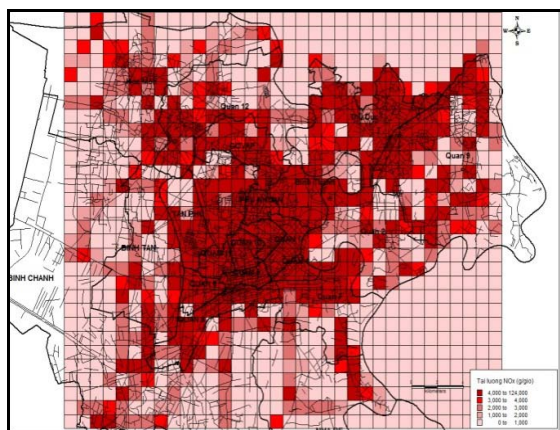

Figure 8. Emission of NO_x during 7am – 8am.

Figure 9. Emission of NO_x during 2pm – 3pm.

When traffic jam occurs, vehicles move with velocity of 0 - 5 km/h due to the high density of vehicles. Therefore at the rush hours emission of NO_x is lower than emission of NO_x in normal time. However, at the rush hour, the number of vehicles is very high. So emission distributions of NO_x in both of map (Figure 8 and Figure 9) are similar.
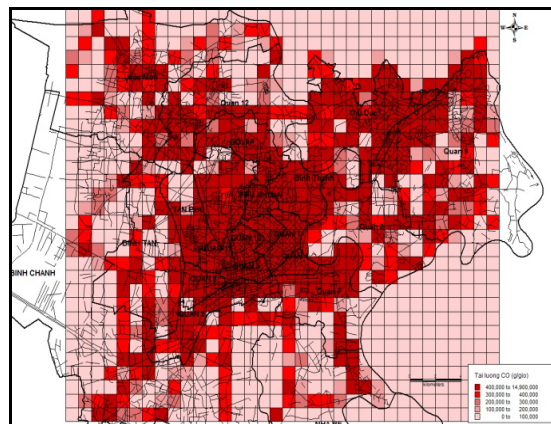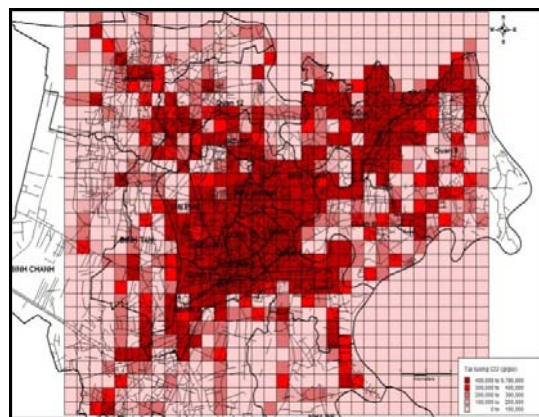
b)CO

Figure 10. Emission of CO during 7am – 8am.

Figure 11. Emission of CO during 2pm – 3pm.

Emission of CO during 7am – 8am is higher than emission during from 2pm – 3pm in some areas such as Hoc Mon district, district 12, Thu Duc district, and district 9, where trafiic jam often occurs at the rush hour (Figure 10 & 11).
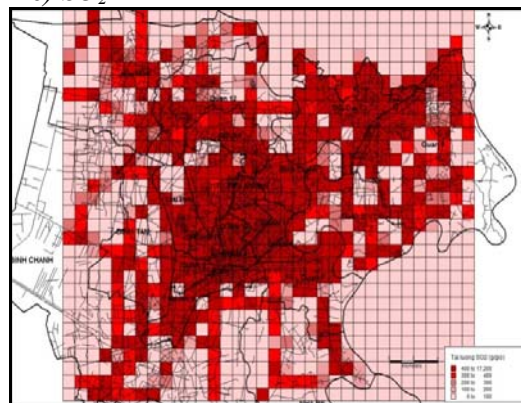
c) SO_2

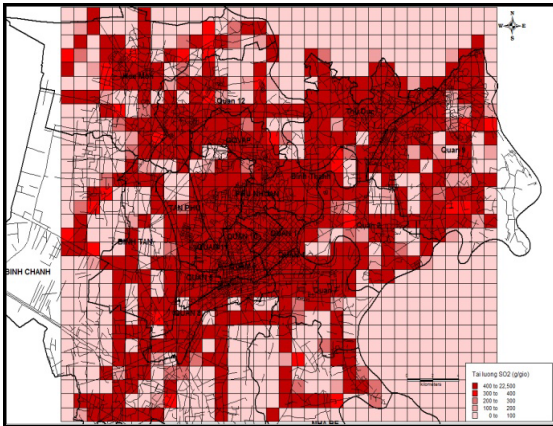Figure 12. Emission of SO_2 during 7am – 8am.

Figure 13. Emission of SO₂ during 2pm – 3pm.

SO$_2$ is emitted mainly from diesel vehicles. However at the rush hour, most vehicles are cars and motorcycles. So Emission of SO$_2$ during 7am – 8am is lower than emission during 2pm – 3pm (Figure 12 & 13).
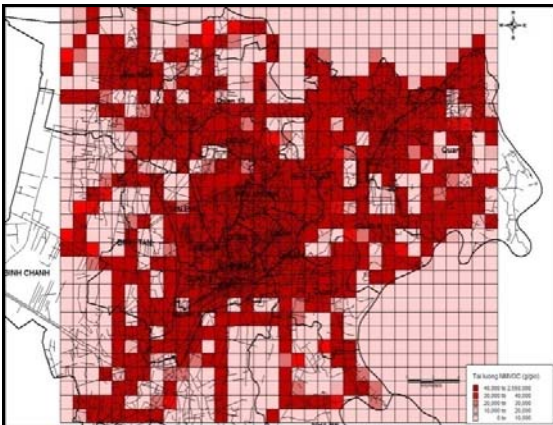
d) NMVOCs

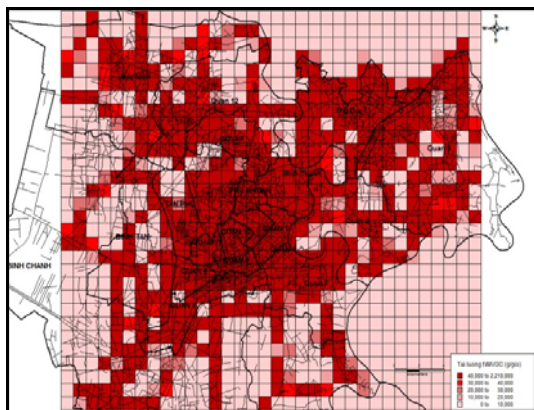Figure 14. Emission of NMVOCs during 7am- 8am.

Figure 15. Emission of NMVOCs during 2pm- 3pm.

Emission of NMVOC during 7am – 8am is higher than emission of NMVOCs during 2pm – 3pm, due to the high density of vehicles (Figure 14 & 15).

e) CH$_4$
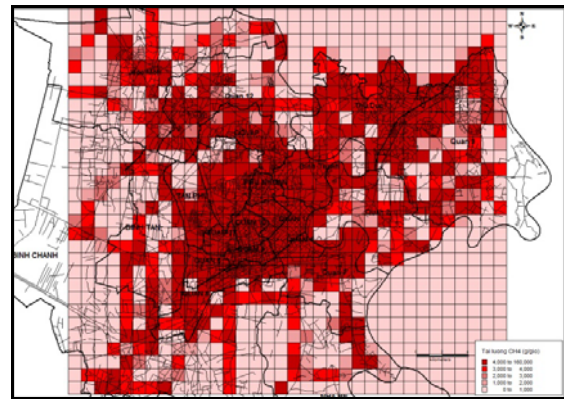
Figure 16. Emission of CH4 during 7am – 8am.
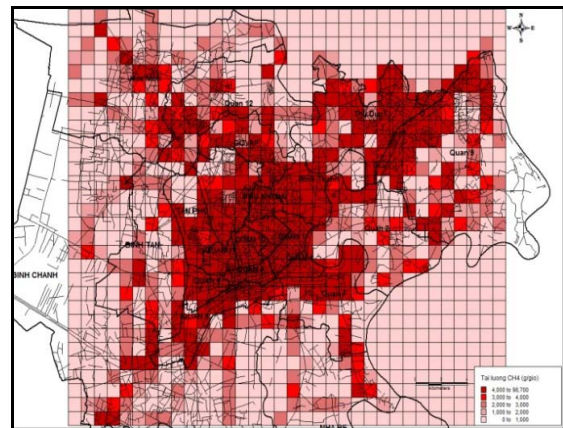

Figure 17. Emission of CH$_4$ during 2pm – 3pm.

As one of NMVOCs, the emission of CH$_4$ and emission of NMVOCs are similar (Figure 16 & 17).

3.3. Suggestions to reduce air pollution

a) Social solutions

- Planning transportation routes pass through the city. Constructions of ring road around the city that avoid heavy trucks, light trucksentering inner city when they transport

goods. Therefore, planning transportation routes scientifically helps to reduce traffic jams during rush hours, as well as reduce harmful pollutants emissions.

- Solutions to reduce the amount of dust released in the air: (i) Increase water spraying; (ii) Sweep the roads during the dry seasons; (iii) Wash the cars before they enter the city.

- Inspect and control the quality of petroleum because the components, as well as the ratio between the chemical in gasoline will affect the load of pollutant emission of transportation.

- Adjust the working hour to restrict the traffic jams.

- Prohibit certain types of vehicle entering the city during rush hours

- Strictly implement the provisions of law that relate to emissions of vehicles.

- Increase funding for air environment management to carry out suitable management policies to improve air environment.

-To manage air quality in the city, we need to collect and calculate all emission sources. This is an effective way to determine the cause of air pollution and propose reasonable control solutions.

b) Technical solutions

- Restrain from using personal vehicles, increasing use of public transport and green vehicles.

Support the price and expand fuel distribution sector.

- Improve techniques of motorcycles; Turn off your vehicle if you have to stop more than 30 seconds.

- Plug in calculation module to calculate emission load when traffic jams occur, which can reduce deviation of EMISENS model results.

4. Conclusion

Improving the methodology for air emission calculation helps to calculate pollutants emission of Hồ Chí Minh City more exactly.

Most emissions are found in the areas with high vehicle density. Emission of SO_2 in some areas at the rush hour is lower than at normal time. When traffic jam occurs, vehicles accrue to some areas. So the number of vehicles decreases in remaining areas of city.

To manage air quality in Hồ Chí Minh City, we need collect air emission data and calculate all air pollution sources. It's an effective solution to find the cause of air pollution and propose effective control solutions.

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Tính toán phát thải khí thải do hoạt động giao thông bao gồm kẹt xe: Áp dụng cho Thành phố Hồ Chí Minh

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Tóm tắt: Tính toán phát thải khí thải từ hoạt động giao thông đường bộ là nguồn gây ra sai số chính trong các mô hình hóa chất lượng không khí. Mô hình không khí được sử dụng để dự báo và xác định chiến lược giảm thiểu. Mô hình có sẵn hiện nay để tính toán phát thải giao thông đường bộ luôn luôn đòi hỏi tốn rất nhiều thời gian, tiền bạc và khó khăn. Vì vậy, trong nghiên cứu này chúng tôi sử dụng một mô hình cụ thể là EMISENS tính toán khí thải cho thành phố Hồ Chí Minh (TP HCM) , Việt Nam. Tuy nhiên, mô hình này không thể tính toán khí thải trong trường hợp kẹt xe . Mục đích đầu tiên của mô hình là hoàn thiện phương pháp tính phát thải kẹt xe và tích hợp nó trong mô hình EMISENS. Sau đó, nghiên cứu các kịch bản để giảm thiểu ô nhiễm không khí do hoạt động giao thông đường bộ cho TP Hồ Chí Minh đến năm 2020. Kết quả chỉ ra rằng khi tính toán lượng khí thải, chúng ta phải

đưa vào yếu tố kẹt xe. Lượng khí thải tính toán có tính đến ùn tắc/kẹt xe chỉ ra rằng lượng khí thải xe máy chiếm phần lớn lượng khí thải CH_4, CO, NMVOC, SO_2 và NOx (hơn 88 %, 85% , 82% , 70% và 31,5 % tổng lượng khí thải từ đường hoạt động giao thông đường bộ ở TP.HCM). Kịch bản đầu tiên là kịch bản giảm phát thải cho năm 2020, kết quả của nó chỉ ra rằng lượng khí thải của thành phố sẽ tăng lên rất thấp (tăng 2-8 % so với năm 2012). Công nghệ xe buýt hiện nay quá cũ và lỗi thời. Do đó, nếu chúng ta đầu tư xe buýt để thay thế xe gắn máy, ô nhiễm không khí tại TP.HCM sẽ trở nên trầm trọng thêm.

Từ khóa: Phát thải giao thông; kẹt xe; Thành phố Hồ Chí Minh; Mô hình EMISENS; Ô nhiễm không khí.