

Preliminary Results of Application Mobilev Traffic model to Calculate Air Emission and Assessing Policies for Reducing Air Emissions in an ASEAN City

Ho Quoc Bang¹, Vu Hoang Ngoc Khue²

1,2. Institute for Environment and Resources (IER) / Vietnam National University in Ho Chi Minh City, Vietnam, 142 To Hien Thanh Street, Dist.10, Ho Chi Minh, Vietnam.

†Email: bangquoc@yahoo.com Tel: +84.8.38651132; Fax: +84.8.38655670

Abstract

Traffic is one of the main air pollution source in urban cities, especially in Ho Chi Minh City. Annually, it emits a huge amount of pollutants into the atmosphere; and air quality in HCMC becomes worse due to circulation of outdated private vehicles. Therefore, clean air plan (CAP) is necessary for reducing air pollution level in the city and air emission inventory (EI) is an essential step to develop CAP. Mobilev model from Germany was chosen to conduct EI for HCMC. Objectives include of this study: (i) elaborating an air emission inventory (EI) from road traffic activities over HCMC; and (ii) assessing emission control policies and study abatement strategies to reduce air pollution level from traffic activities for HCMC in 2020. The results indicated that motorcycles are the main sources of air emission in HCMC. The emissions of CO are 3,586.707 tons/year, following is VOC, NO_x, CH₄, NO₂, SO₂ and particulate matter (PM). In addition, CO₂, which is one of the main greenhouse gases, also included and contributed 36,293.501 ton/year. These pollutants concentrated in the center which has crowded roads and population, affecting directly human health. Therefore, a replaced private vehicle with public transportation is necessary to reduce emissions. Two abatement strategies to 2020 for reducing emissions were performed and showed that if the HCMC government has severe policies on motor vehicles, the emission will be reduced until 60%, opposite emissions in 2020 will be increased to 200%.

Keywords: *Emission Inventory; Mobilev Model; Ho Chi Minh Transportation; Air Pollution; ASEAN Cities.*

1 INTRODUCTION

Ho Chi Minh City (HCMC), located at the South Vietnam with land area 2,056 km², has the highest population and is the biggest city in Vietnam. Traffic congestion is a big problem in the city due to dramatically increase in inhabitants and private vehicles, which will reach 10 million people in 2020 (Giang, 2015). Almost roads in the city are small and overloaded; while the number of vehicle has steadily increased annually, this causes traffic congestion during peak hours, making air pollution more worse. Annually, road traffic emits huge pollutants and directly affects the citizen's health, which is responsible for 3 to 4 percentages in total respiratory diseases (Tuan, 2014). In big cities such as HCMC, Ha Noi...), this percentage is higher from four to five times. Thus, air emission inventory is necessary to find out the main pollutants and main sources; and then relevant strategies to reduce air emission should be proposed.

In the condition of Vietnam, a developing country, there are many types of vehicles including motorcycles, heavy trucks, cars... originating from many different countries as China, Japan as well as Thailand; besides, outdated cars and trucks mainly originate from developed countries. As we are lack of study on vehicle emission which makes the emission inventory more difficult to be worked out. To solve the problem, Mobilev – a traffic emission model – was used for helping calculate emission factors as a tool. Mobilev was used for the same purpose in Thailand, Malaysia...

and showed the good result. This is the first study using Mobilev model in Vietnam in generally and in Ho Chi Minh City in particularly.

2 METHODS AND DATA

2.1 Methods

Mobilev model was selected to calculate emissions from traffic (on-road transport). It uses CORINAIR theory and emission factors database from Handbook Emission Factors for Road Transport version 3.1. The model and Handbook are provided by German Technical Cooperation (GIZ) under “Clean Air for Smaller Cities in the ASEAN Region” program. Vietnam is one of these cities and Ho Chi Minh City plays as the beneficiary city of the project which is possible to use the model and develop Clean Air Plan. The advantage of this model is the available emission factors database and we are able to modify the emission factor if available and also to modify/define a new scenario for study area. The scenario describes the traffic conditions including road network, vehicle categories and its share. Input of the model includes traffic conditions: road network information (length, speed limited, number of lanes), vehicle fleet composition, vehicle emission stage, the average daily traffic flows,... The calculation follows these steps:

- Step 1: Firstly, a scenario for HCMC needs to be defined. Information about vehicles in the area is required: vehicle categories and vehicle sub-categories available in the City and the shares of them, emission stage for each sub-category. Information on road data includes main road network, road sections, name of road, length, number of lanes, limited speed, road type/function, vehicle shares, average daily traffic (ADT). Road gradient and stop-go conditions are not considered in this study. A scenario for HCMC begins with choosing vehicle categories which are circulating in the city and its percentage. These vehicles are classified according to fuel use, emission standard, vehicle weight... After defining vehicle categories, emission factors for these vehicles are automatically aggregated by the model which is appropriate with the scenario that has been defined. These emission factors are provided as database for the model from HBEFA (Handbook Emission Factors for Road Transport) version 3.1 from Germany since Mobilev is integrated in access program. Mobilev also has a function for user to modify emission factors, but in this study, we used default emission factor database.
- Step 2: Traffic load variation curves are built for each road category. These curves demonstrate the variation of 5 main vehicle categories in 24 hours for weekdays and weekend. Road service is also considered. A table of the maximum number of vehicles in each road service per road category is available and possible to modify. In this study, we used the default value. Road service is automatically calculated and assigned to the road categories by determining the number of vehicles per hour per lane. In which light duty vehicle (LDV), heavy duty vehicle (HDV), bus/coach is considered as two vehicles and motorcycle is 0.5 vehicles.
- Step 3: EFs for each road are calculated with Mobilev model. Emissions are calculated per hour, then averaged in 24 hours and summed up to all vehicle layers. This is the output of the model, presented in g/km.h.

The total emissions are related to the driving pattern and traffic condition in 3 road categories as showed in Eq.(1) (CORINAIR, 2009): urban road, rural road and highway. These categories include sub-categories which are integrated in the model. For each category, total emissions of pollutant i are included the emission in three stages: hot emission (emission when vehicle runs with the thermally stabilized engine), cold emission (the emission from vehicle runs with warming-up duration) and evaporation emission (emission from fuel due to the difference between the engine and ambient temperature) Eq. (2) (CORINAIR, 2009). The total emissions are calculated for each pollutant in each road.

$$E_{TOTAL} = E_{URBAN} + E_{RURAL} + E_{HIGHWAY} \quad (1)$$

Where E_{TOTAL} is the total emission from different road types; E_{URBAN} , E_{RURAL} , $E_{HIGHWAY}$ is the total emissions of any pollutants for respective road category.

$$E_{t,i} = E_{h,i} + E_{c,i} + E_{e,i} \quad (2)$$

Where $E_{t,i}$ is the total emission of the pollutant i ; E_h is the hot emission of pollutant i ; E_c is the cold-start emission of pollutant i and E_e is the emission from evaporation of pollutant i .

Hot emission is calculated as Eq. (3) (CORINAIR, 2009) which is related to a number of vehicles and mileage, and it is also calculated by average daily traffic and road length.

$$E_{\text{hot}; i, j, k} = F_k \times L_{k, r} \times e_{\text{HOT}; i, k, r} \quad (3)$$

where $E_{\text{HOT}; i, k, r}$ is the hot exhausted emissions of pollutant i (g) produced in the period concerned by vehicles of technology k driven on roads of type r ; $e_{\text{HOT}; i, k, r}$ is the EF in (g/km) for pollutant i , relevant for the vehicle technology k , operated on roads of type r ; F_k is the average daily traffic load (veh); $L_{k, r}$ is the length of street (km).

Cold emissions are considered for vehicles which use gasoline such as passenger cars, motorcycle and LDV and calculated as showed in Eq.(4) (CORINAIR, 2009). Emissions from this stage depend on driving behaviour and ambient temperature to warm up the engine.

$$E_{\text{COLD}; i, k} = \beta_{i, k} \times F_k \times L_{k, r} \times e_{\text{HOT}; i, k} \times (e^{\text{COLD}}/e^{\text{HOT}}|_{i, k} - 1) \quad (4)$$

where $E_{\text{COLD}; i, k}$ is the cold start emissions of pollutant i by vehicle technology k ; $\beta_{i, k}$ is the fraction of mileage driven with cold engines or catalyst operated below the light-off temperature for pollutant i and vehicle technology k ; $e^{\text{COLD}}/e^{\text{HOT}}|_{i, k}$ is the proportion of cold and hot EF for pollutant i , relevant to vehicles of technology k .

Evaporation emission occurs when the engine thermal and the ambient temperature are different. There are three types of evaporation emissions: diurnal emission, running losses and the hot-soak emission, which are described in Eq.(5) (CORINAIR, 2009).

$$E_{\text{VOC}} = \sum D_s \times \sum N_j \times (H_{sj} + e_{d, j} + RL_j) \quad (5)$$

where E_{VOC} is the annual VOC emissions due to evaporative emission (g); D_s is the number of days for which the seasonal emission factor should be applied ($\sum D_s$ = total number of days in a particular year); N_j is the number of vehicles in category j ; H_{sj} is the average daily soak emissions (hot, warm, cold) of vehicle category j (g/day); $e_{d, j}$ is the average diurnal emissions of vehicle category j (g/day); RL_j is the average daily running losses (hot, warm and cold) of vehicle category j (g/day); j is the vehicle categories.

H_{sj} is average daily soak, which occurs by difference in temperature when a hot engine is turned off. Heat from the engine and exhaust system increases the temperature of the fuel in the system, especially from carburettor float bowls. $e_{d, j}$ is the average diurnal emissions from increasing in ambient temperature. And RL_j is average daily running losses, it's the result of vapour generated in the fuel tank during vehicle operation. They are three types of evaporation emission and can be calculated in equations below:

$$H_{sj} = x \{ c [p \times e_{s, \text{hot}, c} + (1 - p) \times e_{s, \text{warm}, c}] + (1 - c) \times e_{s, \text{hot}, fi} \} \quad (6)$$

$$RL_j = x \{ c [p \times e_{r, \text{hot}, c} + (1 - p) \times e_{r, \text{warm}, c}] + (1 - c) \times e_{r, \text{hot}, fi} \} \quad (7)$$

Where x is the mean number of trip per vehicle per day, averaged over the year (trips/day); c is the fraction of gasoline powered vehicles equipped with carburettor and /or fuel return system; p is the fraction of trips finished with hot engine (dependent on fuel volatility and average monthly ambient temperature); $e_{s, \text{hot}, c}$ is the mean hot-soak emission factor of gasoline (g/parking); $e_{s, \text{warm}, c}$ is the mean cold-and warm-soak emission factor of gasoline (g/parking); $e_{s, \text{hot}, fi}$ is the mean hot-soak emission factor of gasoline (g/parking); $e_{r, \text{hot}, c}$ is the mean emission factor for hot running losses of gasoline (g/trip); $e_{r, \text{warm}, c}$ is the mean emission factor for cold and warm running losses of gasoline (g.trip); $e_{r, \text{hot}, fi}$ is the mean emission factor for hot running losses of gasoline (g/trip).

2.2 Data Collecting and Processing

1) Road Data

First, typical roads were selected to create a road network base on its function. In Vietnam, roads are classified into four main types: national road, rural road, main urban road and sub-urban road. To compare road data with the road categories in the model, ID road and ID function are assigned to each road and road section. The example roads were

classified as in Table 1.

TABLE 1 ROAD TYPE CLASSIFICATION ACCORDING TO ROAD CATEGORIES IN MOBILEV
(EXAMPLE ROAD)

Street	ID road	Road category
Quoc Lo 1	22007	Urban / Main (Trunk Road) / SpLimit:70/ Suburbs, residential streets, inter city streets
Tinh Lo 10	11008	Rural / Motorway / SpLimit:80
Ba Thang Hai	23005	Urban / Distributor-District Connection / SpLimit:50/ Center outskirts, radial streets
Nguyen Tri Phuong	25004	Urban / Access-residential / SpLimit:40 City center, tangential streets, ring streets

TABLE 2 VEHICLE FLEET SHARES IN EACH ROAD TYPE (ON REPRESENTATIVE ROAD CATEGORIES)

Street	Length (m)	Speed limited (km/h)	ADT (veh /day)	HDV (%)	LDV (%)	Bus /coach (%)	Motor (%)	Car (%)
Quoc Lo 1	23,644	43.8	77,982	9.07	16.05	0.46	70.42	4.02
Tinh Lo 10	10,678	24.5	503,401	1.77	3.09	0	93.82	1.33
Ba Thang Hai	5,061	36.67	233,257	0.33	2.13	0.24	94.70	2.6
Nguyen Tri Phuong	2,949	32	185,512	0.27	2.17	0.14	95.65	1.78

TABLE 3 INPUT DATA FOR DIURNAL TRAFFIC LOAD CURVES ON WORKDAY FOR URBAN ROAD

Hour	Cars (%)	LDV (%)	HDV (%)	Bus (%)	Coach (%)	Motor (%)	Scooter (%)
1	1.09	1.10	3.09	0.00	0.00	0.55	0.55
2	1.09	1.10	2.99	0.00	0.00	0.65	0.65
3	0.97	0.96	3.29	0.86	0.86	0.76	0.76
4	1.11	1.10	4.88	3.52	3.52	1.86	1.86
5	2.36	2.36	4.56	6.55	6.55	3.20	3.20
6	2.85	2.84	2.71	7.85	7.85	7.80	7.80
7	4.05	4.04	3.46	6.26	6.26	6.95	6.95
8	6.27	6.26	4.21	6.64	6.64	5.11	5.11
9	7.02	7.01	5.17	6.05	6.05	4.26	4.26
10	7.13	7.13	5.44	4.35	4.35	3.85	3.85
11	6.42	6.43	5.18	5.85	5.85	4.04	4.04
12	5.88	5.87	4.68	4.60	4.60	2.79	2.79
13	6.63	6.63	4.99	4.70	4.70	2.99	2.99
14	7.48	7.47	5.44	5.49	5.49	4.71	4.71
15	8.40	8.40	5.58	7.80	7.80	5.35	5.35
16	6.03	6.03	4.80	6.81	6.81	8.50	8.50
17	5.70	5.71	3.95	6.50	6.50	9.62	9.62
18	4.58	4.59	3.73	6.16	6.16	6.88	6.88
19	3.29	3.29	2.42	5.74	5.74	5.55	5.55
20	3.20	3.20	4.59	2.78	2.78	5.26	5.26
21	2.65	2.65	4.31	0.94	0.94	4.55	4.55
22	2.28	2.29	4.10	0.55	0.55	2.71	2.71
23	2.04	2.04	3.30	0.00	0.00	1.36	1.36
24	1.49	1.50	3.14	0.00	0.00	0.70	0.70

Second, traffic flows were obtained by manual counting for each road from 7 a.m. to 18 p.m. Only four main road categories were observed in 24 hours by using camera. In this study, for convenience, we divided vehicle into 5 categories: light duty vehicle (LDV) (truck that ≥ 3.5 tons), heavy duty vehicle (HDV) (truck that < 3.5 tons), car, bus/coach and motorcycle. Each of them could include several subcategories based on the current transport in the City. ADT is the number of each vehicle category in a day (as shown in Table 2). The traffic load curves are the

variation of the vehicle categories in 24 hours, which demonstrates the number of vehicle in 24 hours and peak hours as shown in Fig.2 and Table 3 (Bus and coach, motor and scooter were considered the same). Each road category has specific curves, based on which we can obtain the remaining data for uncounted hour. The shares of vehicles categories are also different for each road categories, which are shown in Table 2.

2) Vehicle Characteristic

Vehicle data include vehicle sub-categories and its emission stage information. Vehicle sub-categories which are available in HCMC are chosen in the model. We conducted surveys at parking plots, sidewalks to get vehicle register information. To compare this information with the emission standard regulation in Vietnam and the day, it became effective, and emission stages for each vehicle sub-categories were determined. A combination of vehicle sub-category and emission stage creates a vehicle layer (ex: motorcycle 4-strokes with emission stage Euro II). Weighting factor is a percentage of an emission stage in a category, which is calculated and assigned to each vehicle layer.

Despite the Road map of vehicle standard in Vietnam regulated that Euro 2 was adopted in 2007 (QD No. 249/2005/QD-TTg), many vehicles in HCMC still did not meet any Euro standards according to the survey result.

3) Fuel Data

Fuel data were also considered in survey to find out the percentage content of sulphur due to the different fuels used in each country. Then the emission of sulphur dioxide was calculated by Eq.(7) (CORINAIR, 2009). In Vietnam, the %S content in fuel is 500 mg/kg for both petrol and diesel.

$$E_{SO_2} = 2 \times k_S \times FC \quad (7)$$

Where E_{SO_2} is the emission rate of sulphur dioxide (tons/year); k_S is the elemental sulphur content (% by weight); FC is the fuel consumption rate which was calculated by model (tons/year).

3 RESULTS AND DISCUSSION

3.1 Vehicle Fleet and Traffic Characteristics

As shown in Fig. 1, the main vehicle circulated in HCMC was motorcycle with 89%. The results shown in Fig. 3 demonstrate the emission stage, all most vehicles meet the Euro 1 and Euro 2 (according to Vietnam vehicle emission standard Road map) except for the small number of HDV and LDV. While Euro 6 has been released in 2014 in Europe, Vietnam only planed to apply Euro 3 for motorcycle and Euro 4 for car in 2017. With the old engine, vehicles in HCMC release a huge amount of pollutants into the air.

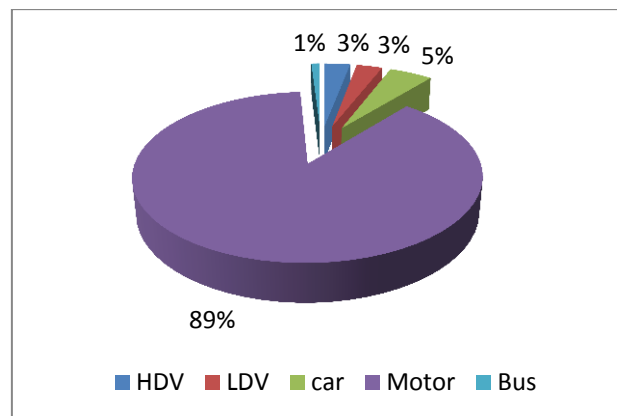


FIG. 1 VEHICLES SHARE IN HCMC

Fig. 2 shows the traffic load curves for four represented road categories. Highway has the highest number of vehicles with peak hour reach nearby 35,000 veh/hour. Rural way has the lowest vehicles with peak hour reach closely to 7,000 veh/hour. Urban and sub-urban streets also had heavy traffic, ranging from 20,000 to 25,000 veh/hour in peak hour. Generally, peak hours extend from 6 a.m. to 8 a.m. and from 16 p.m. to 18 p.m.

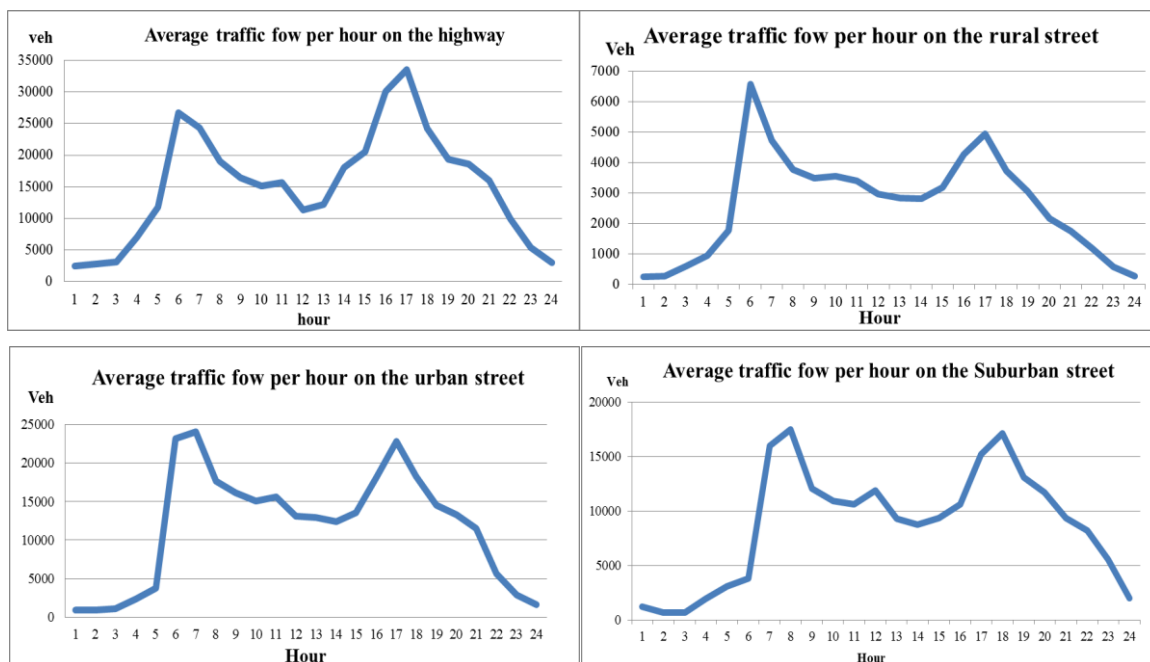


FIG. 2 DIURNAL TRAFFIC LOAD CURVES FOR ROAD CATEGORIES

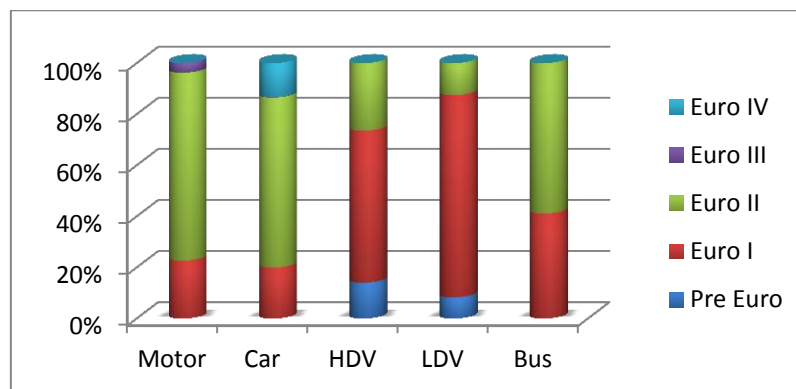


FIG. 3 EMISSION CONTROL TECHNOLOGIES OF HCMC VEHICLE FLEET

3.2 Emission Inventory Results

TABLE 4 EMISSION FROM ROAD TRANSPORT IN HCMC 2015

Unit: Ton/year

	CO	CO ₂	VOC	NO _x	PM	SO ₂
Car	51.745	2.731.346	9.758	7.090	283	937
Bus	110.402	1.435.183	667	13.564	262	440
HDV	10.269	4.705.644	2.256	40.164	943	1.480
LDV	28.505	3.064.609	3.892	12.472	1.725	975
Motorcycle	3.385.787	24.356.719	805.900	28.406	1.405	7.444
Total	3.586.707	36.293.501	822.473	101.695	4.618	11.276

The results in Table 4 indicate that the amount of CO emission is 3.586.707 tons/year, the following constituents are VOC, NO_x, CH₄, NO₂, SO₂ and Particle Matter (PM). In addition, CO₂ is a greenhouse gases with 36.293.501 tons/year (as shown in Fig.4). Detail of main source emission was demonstrated in Fig.5, pointing out that motorcycles were the main sources of CO, CO₂, VOC and SO₂ because they have a huge number (90% in total vehicles). And the fuel used is gasoline which mainly releases a lot of VOC and SO₂. Almost all of them are old engines with incomplete combustion technology, responsible for high emissions of CO. Emissions of NO_x and PM are mainly from diesel vehicles (HDV and LDV) which emit about 40% NO_x, and 60% PM (while motorcycle emit

about 30% in both pollutants).

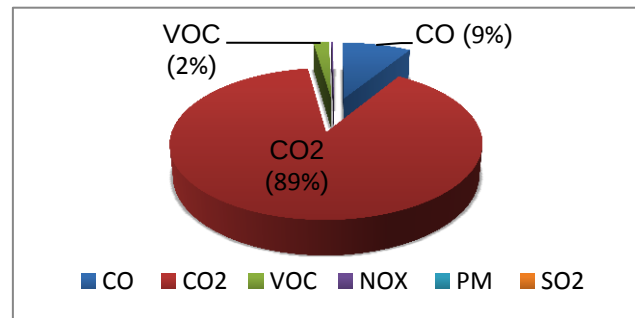


FIG. 4 POLLUTANTS RATE

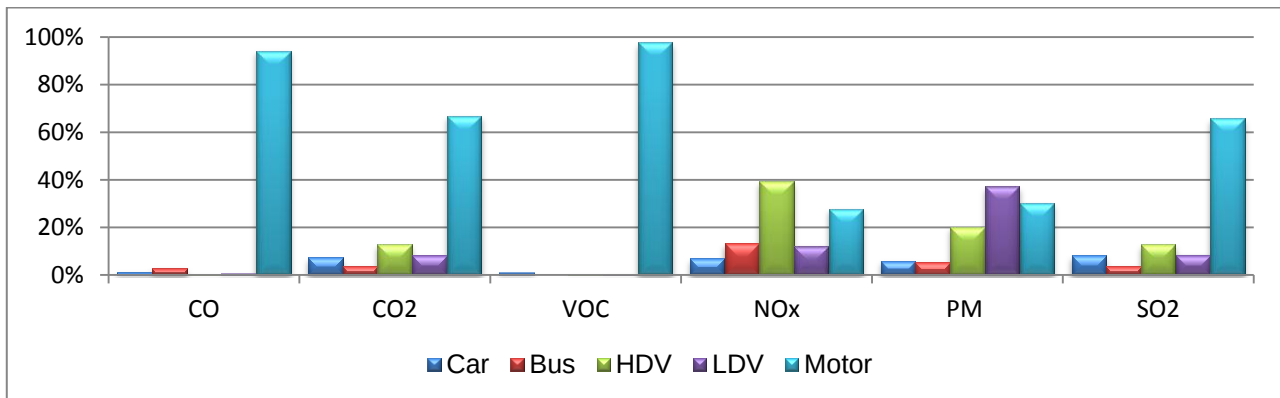


FIG. 5 POLLUTANTS RATE BY VEHICLE CATEGORIES IN HCMC – USING MOBILEV

3.3 Spatial Distribution

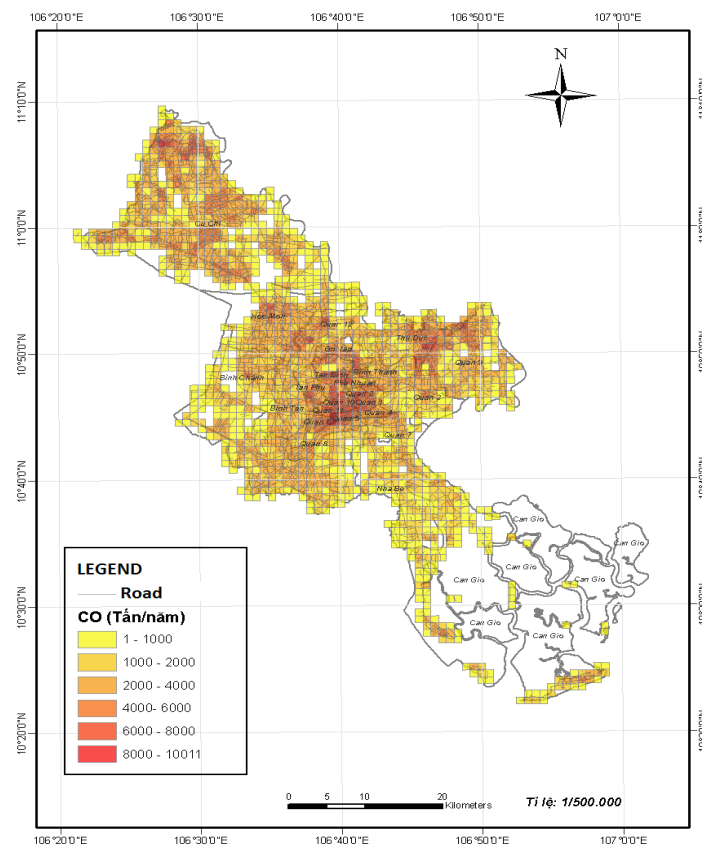


FIG. 7 DISTRIBUTION OF CO (SIMILAR FOR NO_x AND PM)

Fig.7 demonstrates pollutant distribution in space. The centre had the highest emission due to populated and dense road network. CO₂ with the highest load and emission in each grid cell at the centre reached 100,000 tons/year, following by CO, VOC, NO_x, SO₂ and PM with the annual emission of 10,000; 2,300; 290; 32 and 13 tons/year, respectively. The emission concentrated in the residential area, which directly affected people's health.

3.4 Emission Reduction Scenario for 2020

After estimating emissions from traffic in HCMC, abatement strategies to reduce air pollution to 2020 were proposed. There are two scenarios: one is to implement emission control policies and to replace private vehicle with public transport; another is to keep business as usual. In 2020, the regulation of controlling vehicle emission will become effective (Phung, 2015), and the first metro line will be in the operation. This will change the vehicle composition. The scenario 1 is described as following:

- If we control all vehicles according to relevant regulation, for example motorcycle vehicles must meet the Euro 3 standard, so emission will reduce 6.5% CO, 52% HC and NO_x. And passenger cars, trucks (included HDV, LDV, Bus/coach) must meet the Euro 4 which will reduce 73% CO, 46% HC and NO_x and 95% PM (as compared with the emission reduce from Euro 1 and Euro 2 as the recent standard).
- The first metro line will be in operation in 2020 and replace about 25% private vehicles (mainly motorcycle) according to the regulation No.568 by the Minister. It indicates the objective that public transport responsible from 20% to 25% transportation in 2020 and private vehicles are about 72% to 77%.
- According to the research of traffic trend, from 2005 to 2050, the average growth rate will be 3% for motorcycles, 12% for passenger cars/buses and 5.3% for trucks (Tuan, 2013). There are 1,500 buses which will be added from 2015 to 2020 (Anh, 2014).

Scenario 2 is the business as usual scenario. There is no metro and no vehicle emissions control regulation, but the increase annual number of vehicles. Comparing this scenario with the other will show the effectiveness of scenario 1 and how many pollutants will be reduced.

Emission trend in 2020 of scenario 1 was described in Fig. 8. It showed that if we follow scenario 1, we will be able to reduce a lot of emissions of CH₄, CO, HC, NO_x, PM (as compared with the emission in 2015) due to the reduction of motorcycles and controlling vehicle emissions. CH₄, CO will be decreased more than 10% and about approximately 60% for HC, NO_x, and PM. Only CO₂ and SO₂ will slightly increase (about 5%) because of the increasing number of vehicles in 2020.

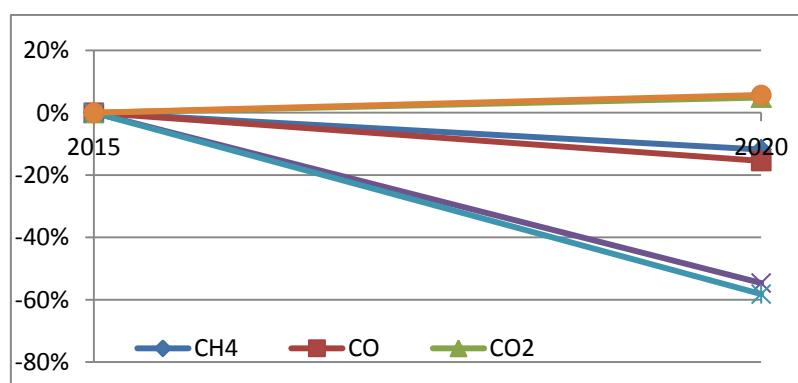


FIG. 8 SCENARIO 1 – PERCENTAGE DIFFERENCE BETWEEN THE EMISSIONS OF POLLUTANTS OF 2015 AND 2020 FOR SCENARIO 1 EMISSION, EMISSION COMPARISON (%) = $100 \times (\text{EMISSION SCENARIO 2020} - \text{EMISSION SCENARIO 2015}) / \text{EMISSION SCENARIO 2015}$

Fig. 9 demonstrates the emission trend in scenario 2 with the annual increase of vehicle without any control vehicle emission and the number of vehicle. Consequently, the emission in 2020 will dramatically increase from 150% to 200% (as compared with that in 2015).

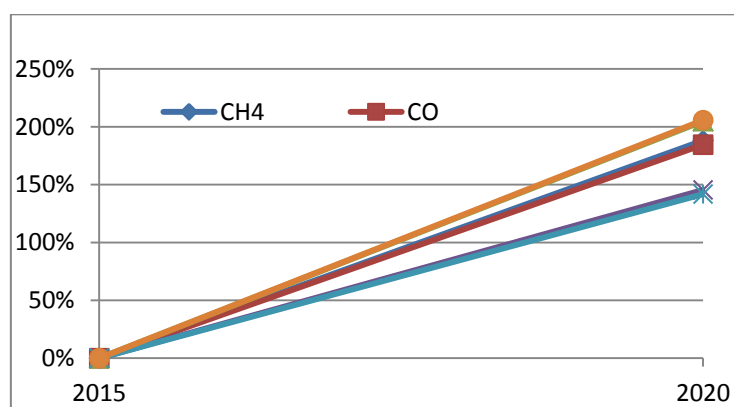


FIG. 9 PERCENTAGE DIFFERENCE BETWEEN THE EMISSIONS OF POLLUTANTS OF 2015 AND 2020 FOR SCENARIO 2 EMISSION

4 CONCLUSIONS

Mobilev model from Europe has been successfully applied to calculate air emission from transportation in HCMC after being adjusted the scenario for study area. The result indicated that air pollution in HCMC has been affected strongly by traffic, mainly from motorcycles. The highest emissions were from CO₂, released into the air as greenhouse gases with 36 million tons/year. The second was CO with 3.5 million tons/year and the least was PM with 102 tons/year. These pollutants concentrated in the centre of city, where there is high population density, such as many roads and high traffic loads.

Compared with the result in 2010 calculated by EMISENS model (Bang, 2010), motorcycles are still the main transports with a huge number, emit more than 50% of total emissions. Therefore, reducing private vehicles and replacing with public transportation such as buses, metro line, and electric golf cars are necessary. Besides, policies of controlling vehicle emissions are also important to reduce emissions. In 2020, as the regulation has recently issued and become effective in 2020, emission will be reduced as the proposed scenario. According to the scenario 1, we will be able to reduce a lot of emission if the government put it into implementation.

Though scenario and emission factor has been recalculated based on traffic fleet in HCMC, these data are from Europe where there has the different weather from Asia in generally and from HCMC in particularly. This causes uncertainty for the result. Thus, an emission factors database for Asia region in general and for HCMC in particular should be studied, serving as the model input database.

ACKNOWLEDGMENTS

Authors thank to Vietnam National University - Ho Chi Minh City (VNU-HCM) for providing the fund under program: "Vietnam National University - Ho Chi Minh City (VNU-HCM) provides funding under the framework of tasks TXTCN codes TX2015-24-09".

REFERENCES

- [1] Anh, L., HCMC decided to investing 1680 bus, 2014. Last Access: 27 May 2015,
- [2] <http://www.thesaigontimes.vn/115426/TPHCM-quyet-dinh-dau-tu-them-1680-xe-buyt.html>
- [3] Bang, Q.H. Optimal Methodology to Generate Road Traffic Emissions for Air Quality Modelling: Application to Ho Chi Minh City, PhD. Thesis, EPFL, 2010.
- [4] Bang, Q.H. and Alain, C. Road traffic emission inventory for air quality modelling and to evaluate the abatement strategies: A case of Ho Chi Minh City, Vietnam. *Atmospheric Environment*. 45: 3584–3593, 2011.
- [5] EMEP/EEA air pollutant emission inventory guidebook, 2009.
- [6] Giang, T., HCMC: Population may reach over 10 million people in 2020, 2015. Last Access: 08 June 2015. <http://www.thesaigontimes.vn/125900/TPHCM-Dan-so-co-the-tren-10-trieu-nguoi-vao-2020.html>

- [7] Khahornsak, S., Somporn, C., Sirichai, K., Poon, T., Noratep, P. Chiang Mai Municipality Atmospheric Emission Inventory, GIZ. 2012.
- [8] Tuan N.D., “Disaster” health from air pollution, 2014. Last Access: 23 May 2015,
- [9] <http://www.donre.hochiminhcity.gov.vn/tintuc/Lists/Posts/Post.aspx?List=f73cebc3-9669-400e-b5fd-9e63a89949f0&ID=4059>
- [10] Tuan, L.H., A study of Long-term transport action plan for ASEAN, The Nippon Foundation, 2013
- [11] <http://cleanairasia.org/portal/sites/default/files/vietnam.pdf>, Last Access: 01 June 2015.
- [12] Phung, T., Controlling motorcycle emission: Experiment in Da Nang, 2015. Last Access: 05 June 2015.
- [13] <http://tuoitre.vn/tin/chinh-tri-xa-hoi/moi-truong/20150505/nam-2018-lam-truoc-tai-da-nang/741983.html>,

AUTHORS



Ho Q. Bang was born on 17/12/1979. He got Docteur ès Sciences (Ph.D.) degree on Environmental Science (Emission inventories and air quality modelling) at the Swiss Federal Institute of Technology in Lausanne (EPFL), Switzerland in 2010. He is doing research on Climate Change,

Energy and Air quality fields.

From 2001 to 2010 he worked for several Labs at IER, EPFL (LPAS, LASIG) and also in French National Center for Scientific Research, France (CNRS) on Emission inventory, Modelling of Meteorology and Air pollution, monitoring of air quality and water quality. He is doing as a National and Regional consultant on Air emission inventories for German Technical Cooperation (GIZ).

Dr. Ho is currently a head of Air Pollution and Climate Change Department/IER/Vietnam National University, HoChiMinh City (VNU/HCM).



Vu H.N. Khue was born in Ho Chi Minh City, Vietnam on 13/04/1993. She got Bachelor of Environmental Science at Sai Gon University in Ho Chi Minh City, Vietnam in 2015. Her major field of study is air quality management and environmental

modelling. She has been working for Air Pollution and Climate Change Department/Institute for Environment and Resource (IER)/Vietnam International University, Ho Chi Minh City since 2014. She is now researching on air quality management and environmental modelling.