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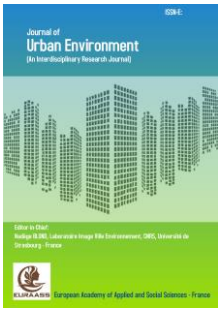

Research Article

Traffic air emission inventory and measures to reduce air pollution in Ho Chi Minh City, Vietnam

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Abstract

Together with the urbanization, industrial activities are increasing and transportation system is being rapidly developing. In 2017, the population of Ho Chi Min city (HCMC) is over 8.6 million. The city has 8 million vehicles including 637,323 automobiles and more than 7,339,522 motorcycles. Up to now, the city has a total of 2708 factories generating air emissions (including 3 processing zones (EPZs) and 16 industrial parks (IPs), with thousands of factories outside the IPs / EPZs), resulting in an increase in emissions from these activities and affecting the air quality of the city. Therefore, in this study (i) collect air emission data, evaluate and calculate of air emissions by applying EMISENS emission calculation models and survey and traffic counting methods; (ii) Develop clean air action plan and climate change mitigation for Ho Chi Minh City. The results showed that on-road activities are the major contributor, accounting for 88% of NOx, 99% of CO, 79% of SO_2, 99% of NMVOC, 88% of PM in total emissions from transportation activities. Key finding in this study is that harbour activities contribute up to 20% of total SOx and 10% of total PM. Other sources (airport, harbour, bus station, rail way) only accounting for negligible amount of emissions. Emission maps showed that emissions in harbours and in central areas of the city as District 1, district 10, district 3 and district 5 are higher than the other districts. This study has also developed 13 measures to effectively manage air quality and reduce GHG in Ho Chi Minh City.

Keywords:

Air Pollution; Traffic, air emission; Ho Chi Minh City; Measures.

1. Introduction

Air pollution is now a worrying issue for health. The large cities in the world are confronting with air pollution, and the main emission source from traffic activities. This emission source of London accounted for 50% (for NOx and PM) (London Council, 2018), Bangkok city

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was more than 60% (for substances except for SO_2) (Supat, 2013), Madrid was 39% ($PM_{2.5}$) and Paris was 29% ($PM_{2.5}$) (European Commission, 2017). HCM city has the highest number of vehicles in Vietnam with a total of 8 million active vehicles in April 2017, of which cars were 637,323 motorbikes were 7,33,5,522 vehicles (Excluding vehicles from other immigrants, an increase of 5.4% compared to 2016 (HCMC DOC, 2017). The number of vehicles is increasing, HCMC confront with an increase in air pollution levels. With AQI data many days in the year reaches high value. According to the statistics of GreenID, the annual average $PM_{2.5}$ concentrations of HCMC was 29.6 µg/m^3 in 2017 (Nguyen et al., 2018) higher than the Vietnamese standard QCVN 05: 2013/BTNMT (25 µg/m^3) and many times higher than WHO standards (10 µg/m^3). In 2017, the number of days the city had $PM_{2.5}$ concentrations higher than the WHO's standard (25 µg/m^3 24-hour) was 222 days and exceeded the Vietnamese standard (50 µg/m^3 24-hour) was 4 days (Nguyen et al., 2018), it directly affects to people's health.

Inventory of emissions is an indispensable step in the task of air quality management. Advanced countries inventoried emission for their cities and the European is implementing $PM_{2.5}$ map for the whole region. In Vietnam, the emission inventory has been carried out for Bac Ninh and Can Tho cities with the support of the German Development Cooperation (GIZ) and Clean Air Asia (Clean Air Asia). These studies have carried out a comprehensive emission inventory for the city including transport, industrial and household ...

In this study including: i) To develop a database on air emission in Ho Chi Minh City for efficient air quality management and determine air receiving zones for Ho Chi Minh City; (ii) To develop of a Clean Air Action plan and reducing Greenhouse gases (GHG) for HCMC.

2. Methodology and material

Transport in this research include: on-road source emission from vehicles (motorcycles, cars) and non-road source are harbours, airway (the activity of aircraft), railway (the activity of train), and emission from bus stations. These are typical pollution of city.

Calculating emissions for these activities, we need to collect raw data and then aggregate. And emission inventory is using the model method and the emission factor method. After having emission data, we distributed emission according to space using ArcGIS software. The pollutions are CO, and NMVOC, and NOx, and SO_2 and TSP.

2.1 Sea port

For seaport, carry out a survey on the anchoring of vessels and cargo-handling equipment at Saigon Port system, and emission inventory using the formula of US.EPA guidelines for port operations.

Ocean going vesels (OGVs):

$$E = P \times LF \times A \times EF \quad (3)$$

Cargo-handling equipment (CHE):

$$E = N \times P \times LF \times A \times EF \quad (4)$$

$$LF = (AS/MS)^3 \quad (5)$$

Where: LF: Load factor (%); AS: Actual speed(knots); MS: Maximum speed (knots); E: Emissions (g); N: Number of items; P: Maximum continuous power rating (kW); A: Activity (hour); EF: Emission factor (g/Wh);

2.2 Bus station

For bus station, HCMC has 8 large bus stations: Mien Dong bus station, Mien Tay bus station, Cu Chi bus station, Ben Thanh bus station, bus station in District 8, Cho Lon bus station, Nga Tu Ga bus station, An Suong bus station. Emissions due to this activity often overlooked in emissions inventory, but this is also an interesting source of emissions, especially for local emissions. Collecting information on the number of vehicles in a year for each bus station, and at the same time we survey the driver's behaviour of drivers to fuel consumption during the waiting process for passengers and idling berth (not including emissions due to vehicles traveling on the road). The equation for emission from bus station is shown:

$$E = (A \times EF)/10^6 \quad (7)$$

Where: E: Emissions (ton/year), A: Fuel consumption (kg/year) calculated according to the number of trip per year and consumption per trip, EF: là Emission factor (g/kg fuel) in Table 1.

Table 1: Emission factors for vehicle in bus station and train.

Pollution	NOx	CO	MNVOC	PM	SO_2
Bus station* (g/kg)	33.37	7.58	1.92	0.94	0.5
Railway ** (kg/ton)	63	18	4.8	1.8	0.01

*EMEP / EEA emissions guidelines for 2013, Section 1.A.3.b, Tables 3-5 and Table 3-6.

** EMEP / EEA emissions guidelines for 2013, Section 1.A.3.c, Tables 3-2.

2.3 Air way

The number of flights for each aircraft category is collected by 2017 for all national airlines and international airlines. Emission factor is collected in inventory flight operation guidelines of ICAO (International Civil Aviation Organization). The equation for emission is shown below:

$$E = (LTO \times EF)/1000 \quad (8)$$

Where E: Emissions (ton/year), LTO: Number of flight per year (for each aircraft category), EF: Emission factor (kg/flight) in Table 2.

Table 2: Emission factor for aircraft category (kg/flight).

Aircraft	NOx	SO_2	CO	NMVOC	TSP
Airbus A318	6.71	0.6	10	2.0	0.06
ATR72	2.34	0.2	2	0.0	0.00
Boeing B787	17.15	1.3	15	0.5	0.09
MD-11	38.17	2.2	18	1.4	0.17
B77W	69.79	2.6	48	5.1	0.21
B788	17.15	1.3	15	0.5	0.09
…	…	…	…	...	…

Source: 1.A.3.a CORINAIR for airway and ICAO, 2011: Airport Air Quality Manual, Table B-1

2.4 Road traffic

With road traffic, the research team has carried out a traffic inventory for Ho Chi Minh City since 2010, and so far this data is no longer relevant to the city's traffic situation. Therefore, it is necessary to update the current status of new emissions. Counting vehicles at 92 routes in the city area, for 5 main road types are main urban roads (connecting districts), sub-urban roads (connecting wards and roads in residential areas), provincial highway (connecting provinces) and national highways (including highways and existing National highways). To effectuate the new survey and re-survey of available routes to update data. At the same time, we conduct random surveys of behaviour of vehicle users (for 5 vehicles category are motorcycles, cars, light trucks, heavy trucks and bus) to know the information on vehicle life, vehicle usage frequency in the day and average length of vehicle that the vehicle operation. From the collected data, we analyse the flow for each type of vehicle for 5 types of roads as well as the vehicle technology being used in Ho Chi Minh City according to Euro standards on engine emissions.

There is a basis to set the emission factor set for the vehicle categories are close to the current state of the vehicle system currently circulating in the city road. EMISENS model was applied to conduct air emission inventory for transportation sector, was developed in 2006 - 2010 by Prof. Dr Clappier và Assoc. Prof. Dr. Ho Quoc Bang in Laboratory of Air Pollution and Soil-EPFL, Switzerland. EMISENS uses emission inventory theory from CORINAIR (EEA), it allows shortening of calculation time and error calculated by Monte Carlo simulation technique. The EMISENS model is selected because this model was developed for emission inventory from road traffic and it applies to developing countries (where data conditions are inadequate by combining bottom-up methods and top-down methods) with

conditions like Vietnam (Bang et al., 2010). Input data of the EMISENS model requests: number of each vehicles category, length of each road type, flow of each vehicles category as of each road type, emission factor is calculated according to the vehicle system in circulation, Emission inventory for road traffic by EMISENS model is classified into 3 types of emissions: hot emissions (Ehot), cold emissions (Ecold) and evaporation emissions (Eevap)according to the equation is shown below:

$$E_{Total} = E_{Cold} + E_{Hot} + E_{Evap} \quad (1)$$

Where: E_{hot}: hot emissions, E_{cold}: cold emissions, E_{evap}: evaporation emissions

Each emission category follows a general equation in EMISENS is shown below:

$$E_{ip, ie} = e_{ip, ie} \times A_{ie} \quad (2)$$

In which E: total emission; ip: pollution i; ie: vehicle category; e: emission factor in Table 3; A: Activity rate.

Table 3: Emission factor for road traffic - hot emissions (g/km. vehicle).

	NOx	CO	SO_2	CH_4	PM10
Heavy trucks	19,7	11,10	1,86	0,17	0,13
Light trucks	1.90	34,80	0,18	0,40	0,045
Bus	19,7	11,10	0,18	0,12	0,178
Cars	1,90	34,80	0,18	0,40	0,016
Motorcycles	0,05	21,85	0,03	0,20	0,0088

(Source: a) Ho et al., 2010; b) China (DOSTE, 2001); c) Calculated from CORINAIR 1999).

2.5 Railway

For railway, Ho Chi Minh City has Hoa Hung Station which is the final terminal of the North-South railway. The team collects and surveys the number of annual trains and interviewing the driver about the fuel consumption, the length of the railway section that the train travels in HCMC. The equation for emission from railway is shown below:

$$E = (A \times EF)/10^3 \quad (6)$$

Trong đó: E: Emissions (ton/year), A: fuel consumption (ton/year), EF: Emission factor (kg/ton fuel).

3. Investigation and the survey for collecting data

In this study, the team conducted an additional survey of 1,099 questionnaires on the status of vehicle use, and calculated based on the data for 2,924 questionnaires surveyed from 2010 up to now. According to statistics, Motorcycles on roads with engines respond to Euro 3 emissions standards are 24% and Euro 2 standards are 63%, the rest are those with Euro 1 standard of 10%. For cars, most of them are respond to Euro 4 emission standards with 75%, and Euro 3 and Euro 5 with each accounting for about 10%. Most trucks and buses (diesel-powered vehicles) are circulating with Euro 2 emissions standards of more than 50%, the rest are Euro 3 and Euro 1. The study also counted cars of 92 city routes for representative roads. Proceeding manual vehicles counting method from 6 am to 19 pm and combined with 24-hour camera rotation to establish vehicle load curve for each route category. According to the survey results, motorcycles have the highest number of vehicles on the roads with the highest average load of 14,000 motorcycles, accounting for 80% of vehicles 10 times higher than the number of cars). Only 10% are cars and 10% for the remaining vehicles, the time of high traffic is from 6 am to 18 pm, especially heavy trucks operating in residential areas have peaked at night.

In addition, this study also collects air emission inventory for point source and area sources. Results are presented in the next section.

4. Results and discussion

4.1 For total sources

- Traffic is main contribute to air pollution in HCMC, responsible for more than: 99% of total CO, 97% NMVOC, 94% NO_x, 81% SO_2, 48% TSP and 64% CH_4 (in Table 4)
- Industrial source contributes a small amount of pollutants (19% in total SO_2 and 19% of TSP)
- Area sources (including households, harbor and construction) contribute 30% emission of TSP
- Biogenic responsible for 32% emission of CH_4

4.2 Only for traffic source

Emissions due to traffic source in the city are generally ample because HCMC has many types of traffic as airway, seaport, bus station, railway and road traffic. However, road traffic is still the main source of high density and the main emission source of the city. Emissions from road traffic accounted for 88% of NOx, 99% CO, 79% SO_2, 99% of NMVOC, 88% of TSP compared to the total traffic emissions in HCMC (Figure 1). Meanwhile transportation source (line source) play an important part in emitting a significant amount of pollutants compared to the other sources, except for TSP emissions (Figure 2).

Table 4: The results of total emission.

NO_x		**CO**	
Motorcycles	27,9%	Motorcycles	90%
Cars	21,5%	Cars	5.7
Harbour	11,5%	Light trucks	2.6
Light trucks	10,6%		
Heavy trucks	9,0%		
NMVOC		**TSP**	
Motorcycles	68%	Brake wear and road surfaces	36,5
Cars	14	Households	11,0%
Light trucks	6%	Construction sites	8,8%
Bus and heavy trucks	5%	Harbour	7,8%
		Building materials vendors	7,6%
SO_2		**CH_4**	
Motorcycles	35,5%	Motorcycles	63%
Harbour	23,7%	Biogenic	32%
Cars	9,6%	Households	2%
Textile industry and heavy trucks	5,6%		
Food processing	3%		
Paper and electricity plant	2%		

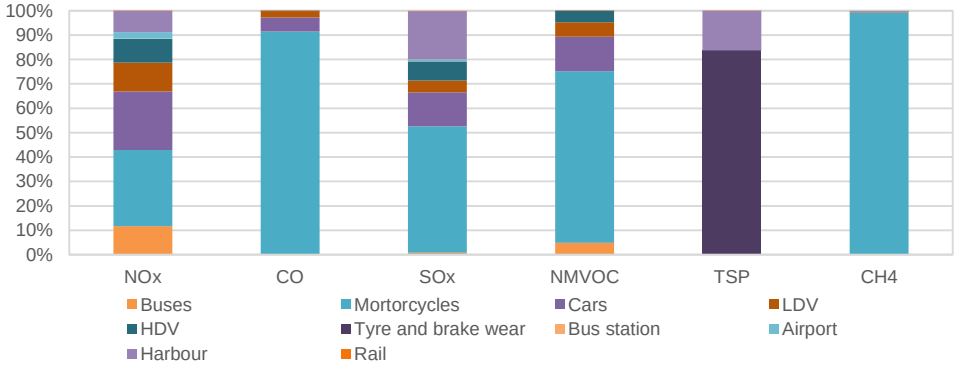

Figure 1: Shares of the emission sources.

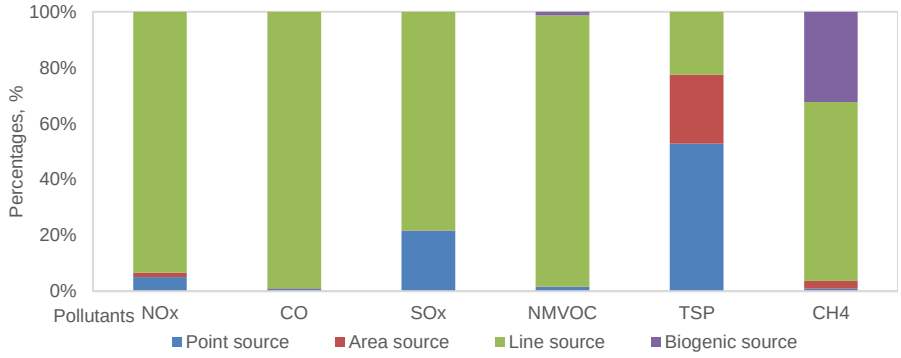

Figure 2: Contribution of transportation sources in total emissions of HCMC, 2017.

4.3 Clean Air Action Plan

Table 5. Air pollution control solutions in 2019-2025.

No.	Name of task/project	Content	Time	Host/ Coordinate agency	budget (USD)
1	Air smoke checking automobile randomly on road	- Establishment of "Motor Vehicle Inspection Working Group" (VITF) includes representatives from the Department of Transportation (DOT), Vietnam Register (VR), HCMC People's Committee, and traffic police.	2019	Host agency: DOT Coordinate agency: VR-DOT, Ho Chi Minh Environment Protection Agency (HEPA),	20,000

		- Develop and agree on the content of "Terms of Reference (ToR) for VITF - Air smoke checking automobile randomly on road - Note: HCMC has checked a few days for buses: As a result, 22% of the buses were checked for air smoke exceed the allowable standard. It is necessary to carry out both random and continuous exercises with all of the cars			
2	Air smoke checking for motorcycles	○ Using Motor Vehicle Inspection Working Group" (VITF) ○ Develop a plan to check motorcycle exhaust emissions in circulation. ○ Air smoke checking for motorcycles Note: HCMC has measured in several of motorcycles: As a result, the emission from motorcycles will be reduce 30%.	2020	Host agency: DOT Coordinate agency: VR-DOT, HEPA, Traffic police and consultants	1,000,000
3	Develop project for public transportation	○ Reviewing and assess the short-term financial support needed to establish new bus teams and routes; ○ DOT will draft the necessary regulations to facilitate the financial support for new routes; ○ New regulations approved by the HCMC People's Committee; ○ Implementation and inspection; ○ Developing a plan to expand the bus network.	2019	DOT. Vietnamese experts, international experts	40,000
4	Bike sharing system	○ DOT established "Transport reorganization working group" (RTTTF). The working group will start with the signing of a Cooperation Agreement (MoU) between RTTTF members; ○ Preparing ToR for the Working Group. ○ Determining the role of NMT in the future	2021-2022	DOT Pilot implementation in District 1, District 3, Vietnamese experts, international experts support technical	45,000

		○ Determining the goals of the NMT Action Plan ○ Evaluating achievements. Note: Piloting the central area of HCMC		guidance	
5	Inspection outdate motorcycles and remove	○ Investigate and review statistics on the number of motorcycles, three-wheeled motorcycles, four-wheelers transporting passengers and goods; ○ Developing regulations to suspend the vehicles have not warranted technical safety	2021-2022	DOT Vietnamese experts, international experts support technical guidance.	250,000
6	Replace cleaner and cook stove for households	○ Using data from emissions inventories estimates potential emission mitigation, and the corresponding cost ○ Experts drafted an assessment of the potential for emissions reduction using the experience of smaller cities in Vietnam; ○ Encouraging organizations and donors to provide cleaner stoves for low-income households. Goals: 200 cleaner stoves for each district or 1000 cleaner stoves for 5 districts in the city (Binh Chanh, Hoc Mon, Cu Chi, Nha Be, Can Gio). Note: Suburban area of HCMC	2022-2024	Department of Agriculture and Rural Development (DARD), Department of Natural Resources and Environment (DONRE),CFA	35,000
7	Study boilers using in industry and fuel burning	○ Overall assessment of fuel burning operations using boiler in Industry HCMC (5 billion dong) ○ Supporting the plant in the efficient operation of the boiler (reducing emissions) and continuing to support the technical consultancy of the expert group 2019-2024 (2 billion dong/year)	2019-2024	DONRE, HEPA, CEM, Institutes	650,000
8	Provide smoke checking equipment for DONRE inspection	○ Equipping chimney automatic measurement equipment for DONRE to regularly as well as irregular inspection of industrial sources	2019-2022	DONRE, HEPA, CEM	100,000

		○ Strengthening inspection for establishments that have not complied with the emission regulations. Note: Currently, the city has 812 factories, of which 764 factories (94%) have treatment systems; 48 factories (6%) do not have a treatment system			
9	Public raise aware on air pollution	○ Developing communication strategies and other activities ○ Hiring consultants ○ Developing and implement strategies	2016-2020	DONRE, HEPA, CEM	20,000
10	Air quality monitoring automatically system: 9 stations	○ For automatic monitoring stations : continuous automatic monitoring of all air pollutants according to QCVN 05:2013.	2017-2018: 2 stations 2018-2022: 7 stations	DONRE, CEM, HEPA	5,470,000
11	Invest for air quality monitoring lab	○ Every year, selection and monitoring of hot spots on air pollution; passive monitoring 1 month/point. Season; Monitoring 2 seasons/year. To enough assessment data according to QCVN 05:2013	2018-2022	DONRE, CEM, HEPA	500,000
12	Re-EI every 5 years	○ Every 5 years, update the emissions inventory of HCMC	2022	DONRE, HEPA, CEM, Institutes	75,000
13	Study air emission receiving zone	○ Mapping of the air pollution reception area for HCMC. ○ serving as a basis for the city's socio-economic development planning	2020	DONRE, DOST, HEPA, CEM, Institutes	150,000

5. Conclusion

Air in Ho Chi Minh city is polluted. This research developed a database on air emission in Ho Chi Minh City for efficient air quality management and developed of a Clean Air Action plan and reducing Greenhouse gases (GHG) for HCMC. In this research we did an detail air emission inventory for traffic sources. EMISENS model is applied to calculate road traffic emission. For other traffic sources, we used the emission factor method to calculate air emission. After having emission data, we distributed emission according to space using ArcGIS software. Traffic is main source contribute to air pollution in HCMC, responsible for more than: 99% of total CO, 97% NMVOC, 94% NO_x, 81% SO_2, 48% TSP and 64% CH_4. Key finding in this study is that hahour activities contribute up to 20% of total SOx and 10% of total PM. Other sources (airport, habour, bus station, rail way) only accounting for negligible amount of emissions. Emission maps showed that emissions in harbors and in central areas of the city as District 1, district 10, district 3 and district 5 are higher than the other districts. Air quality in HCMC is polluted by O3, TSP, NOx. The research also developed 13 measures for Air pollution and climate change

mitigation to sustainably development 2019 - 2024 is developed as follow: Air smoke checking automobile randomly on road; Air smoke checking for motorcycles; Develop project for public transportation; Bike sharing system; Inspection outdate motorcycles and remove; Replace cleaner and cook stove for households; Study boilers using in industry and fuel burning; Provide smoke checking equipment for DONRE inspection; Public raise aware on air pollution ; Air quality monitoring automatically system: 9 stations; Invest for air quality monitoring lab; Re-EI every 5 years; Study air emission receiving zone map. With total cost 184,97 billion VND (9,2 mil USD).

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