

# Air source emissions inventory: A case for emissions calculation in Vietnam

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**Abstract.** Emission inventory is one of the measures to determine the amount of air causing pollution to the surrounding environment. This article calculates exhaust source in the area including: construction material stores, construction works, households, restaurants - eateries, gas stations, printing - photocopying shops, garages, temples, activities. straw burning activities from 9 cities/districts in Vinh Phuc province, Vietnam, thereby determining the contribution of each waste source as well as each district to the total emissions of the entire Vinh Phuc province. The results show that these emission sources have contributed to the gas resources of Vinh Phuc province in Vietnam as follows: NO<sub>x</sub>, CO, SO<sub>2</sub>, NMVOC, TSP, CH<sub>4</sub>, PM<sub>2.5</sub> are 372.08; 13242.50; 28; 1409.78; 2045.10; 1213.08; 1473.67 tons/year. The results also show that straw burning is the source with the largest load. Specifically, the load of CO, SO<sub>2</sub> and CH<sub>4</sub> accounts for over 70% of total emissions.

## 1 Introduction

Polluted air is one of the most serious environmental problems in urban areas [1]. The World Health Organization (WHO) has estimated that air pollution causes the deaths of more than 7,000,000 people per year in developing countries, and millions of people are found to have other respiratory diseases [2]. Therefore, air quality management should be urgently reviewed to protect human health.

Vietnam, a developing country, industrial activities have been developing throughout all provinces and cities. Vinh Phuc is one of the industrially developed provinces. As of the end of 2019, the population of Vinh Phuc province was 1,151,154 people. According to the Traffic Safety Committee of Vinh Phuc province, by the end of 2020, Vinh Phuc province had 55,342 cars and 635,985 motorbikes, nearly doubling compared to 2016; Not to mention motorbikes and cars of people from other provinces and cities coming to Vinh Phuc to make a living [9]. Currently, the whole province has a total of 19 industrial parks and 09 industrial clusters on an area of 5,228 hectares and many separate factories and enterprises [6]. The living activities of Vinh Phuc people and means of transport along with Industrial activities are emitting thousands of tons of emissions into the atmosphere every day [10]. In addition, with a relatively high population density, Vinh Phuc is currently ranked 10th among 63

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provinces and cities in Vietnam that are using fossil fuels for cooking and living, putting great pressure on the environment in general and on quality air in particular [6]. Emission calculation and inventory have been mentioned extensively in a number of recent studies in Vietnam. The traffic emission inventory method applied by author Ho.H.B is the EMISSEN model [3] or point source inventory methods used by author Pham.H.Q for point sources in Vinh Phuc Province [8]. But very little data is available on calculating area sources.

Area sources are defined as small, unidentified emission sources or multiple sources that are not considered point sources. However, Area sources make a large contribution to the total amount of pollution emissions in the city, sources of electrical emissions such as household cooking, restaurants, gas stations, straw burning activities, and construction works. , temples, small manufacturing establishments, printing establishments, car and motorbike repair establishments, etc. Area sources contain many small and widespread emission sources, so emissions inventory is very difficult. This article aims to provide methods and calculations for area sources and determine the contribution of this source to air pollution in Vinh Phuc province, Vietnam.

## 2 Research methods

The research was conducted by interviews with surveys. Interviewing staff will be allocated to localities and conduct interviews. Subjects providing information to answer questions. The content of the interview form is designed to meet all the contents such as total number of people, type of fuel used, total time spent using raw materials or fuel... Area sources include (1) household sources, restaurants - eateries; (2) gas station; (3) construction materials store; (4) construction works; (5) garage stores; (6) printing - photocopying shop; (7) pagoda; (8) straw burning activities. The amount of solar source emissions is calculated according to the general formula of US EPA 2005 and CORINAIR EU 2009. To calculate solar and biological sources, use the following formula:

$$E = AR \times EF \quad (1)$$

Where:

E = Emissions

AR= Product capacity, area or fuel consumption

EF = Emission factor

The results are surveyed using interview forms and then calculated based on the emission coefficient. Total number of source survey questionnaires: 1,010 questionnaires, of which the number of questionnaires are: Households: 800 questionnaires; Restaurants and eateries: 150 votes; Construction works: 15 votes; Construction material stores: 10 votes; Gas stations: 10 votes; Temple: 25 votes.

Processing survey data The number of votes surveyed is calculated according to Yamane's formula:

$$n = N / (1 + N (e)) \quad (2)$$

Where:

n = Number of samples to be investigated or surveyed

N = Total number of samples within the research scope

e = Allowable error, %

– Calculating emissions from households and restaurants

The following formula:

$$E = \frac{AR \times EF}{10^6} \quad (3)$$

Where:

E: Amount of emissions emitted (tons/year)

AR: Fuel consumption per source (kg/year)

EF: Emission factor for each substance by each type of source (g/kg)

The exhaust emission factor EF (g/GJ) from the use of coal, firewood, oil and gas when burning is referenced in the 2013 European emissions inventory guideline.

- Calculate emissions from gas stations

$$E = \frac{AR \times EF}{TVP \times 10^6} \quad (4)$$

Where:

E: NMVOC emissions (tons/year)

AR: Fuel consumption of gas station (m<sup>3</sup>/year-kpa TVP)

EF: VOC emission factor (g/m<sup>3</sup>)

TVP: True vapor pressure is the real vapor pressure that depends on the Reid vapor pressure (RVP)

Emission coefficients are referenced from liquefied fuel emission coefficients, European emission coefficient reports.

and temperature according to the following formula:

$$TVP = RVP \times 10^{AT+B} \quad (5)$$

Where:

RVP is Reid Vapor Pressure - Reid vapor pressure for gasoline

Therefore:

$$A = 0.000007047 \times RVP + 0.0132 = 0.013636914$$

$$B = 0.0002311 \times RVP - 0.5236 = -0.5092718$$

T is the average temperature of Vinh Phuc province.

- Calculate emissions from construction material stores

$$E = EF \times AR \quad (6)$$

Where:

E: Amount of dust emitted (tons/year)

EF: Dust emission factor for storage activities (tons/ha.year)

AR: Storage area (ha)

TSP generation coefficient for construction materials in storage and loading activities respectively: 16.4 tons/ha.year; 12g/ton

- Calculating emissions from the garage

$$E = \frac{EF \times AR}{10^6} \quad (7)$$

Where:

E: Amount of NMVOC emitted by paint (tons/year)

EF: NMVOC emission factor of paint (g/kg)

AR: Amount of paint consumed by the garage (kg/year)

- Calculating emissions from printing and photocopying shops

$$E = \frac{EF \times AR}{10^6} \quad (8)$$

Where:

E: Amount of NMVOC emitted (tons/year)

EF: NMVOC emission factor of printing ink (g/kg)

AR: Amount of ink consumed by photocopying - printing shop (kg/year)

- Calculating emissions from pagodas

$$E = \frac{EF \times AR}{10^9} \quad (9)$$

Where:

E: Amount of dust/pollutants emitted (tons/year)

EF: Emission factor of pollutants (mg/g)

AR: Amount of incense used (g/year)

The emission coefficients of incense burning activities at pagodas are: MNVOC 8.1 mg/g; CO 156.2 mg/g; TSP 72.8mg/g; NOx 1.3 mg/g; CH<sub>4</sub> 7.3mg/g; PM<sub>2.5</sub>: 7,3mg/g.

### 3 Research results and discussion

#### 3.1 Emissions from households

Total household emissions of 9 administrative units of Vinh Phuc province are in Table 1. The results show that people in Vinh Phuc mainly use gas for cooking. Some Tam Duong districts, City. Phuc Yen, Song Lo, Binh Xuyen use a lot of charcoal, so CO<sub>2</sub> emissions are quite large, especially Tam Duong district with 1,470.60 tons/year. That is why the emissions of all pollutants of interest in research in Tam Duong district are also very high. Compared to Ho Chi Minh City, Vietnam, Vinh Phuc province has a much higher rate of using charcoal in cooking [4,7]

**Table 1.** Emissions from households in Vinh Phuc province.

District/city	Emission load (tons/year)						
	NOx	CO	SO <sub>2</sub>	NMVO C	TSP	CH <sub>4</sub>	PM <sub>2,5</sub>
Phuc Yen	19.83	618.92	1.69	90.79	119.29	31.97	108.91
Vinh Yen	15.48	456.65	1.20	64.97	83.39	24.30	74.42
Yen Lac	8.61	43.04	0.15	6.13	8.11	2.61	7.53
Vinh Tuong	9.45	4.72	0.05	0.31	0.35	0.79	0.35
Tam Duong	34.93	1.470,6	4.06	220.36	293.77	73.86	271.75
Tam Dao	4.41	52.91	0.16	7.80	10.37	2.84	9.60
Song Lo	7.05	114.00	0.33	16.90	22.49	5.98	20.82
Lap Thach	7.87	3.94	0.04	0.26	0.29	0.66	0.29
Binh Xuyen	9.36	123.41	0.36	18.22	24.24	6.58	22.44
<b>Total</b>	<b>116.99</b>	<b>2888.20</b>	<b>8.04</b>	<b>425.74</b>	<b>562.30</b>	<b>149.58</b>	<b>516.10</b>

The results show that Tam Duong contributes from 30% - 53%, followed by Phuc Yen city (about 17% - 21%) and Vinh Yen city (13% - 16%) of the total emissions of each pollutant. Lap Thach district only contributes about 0.5% to the emissions of NMVOC, TSP, CH<sub>4</sub>, PM<sub>2,5</sub>

#### 3.2 Emissions from food and beverage services

The survey results in Table 2 show that, on average, each food service business consumes more fuel than a normal household because they spend more time cooking during the day. The results show that the largest emissions from cooking activities at food service establishments in Vinh Phuc province are CO (65%), NMVOC, TSP and PM<sub>2,5</sub> contribute about 9% - 10%. total emissions.

**Table 2.** Emissions from food and beverage services in Vinh Phuc province.

Emission load (tons/year)						
NO <sub>x</sub>	CO	SO <sub>2</sub>	NMVOC	TSP	CH <sub>4</sub>	PM <sub>2.5</sub>
3.23	68.44	0.17	9.09	11.03	3.90	10.14
Ratio (%)						
3.05	64.57	0.16	8.58	10.41	3.68	9.57

### 3.3 Emissions from gas station, construction material stores, Garage, photocopying shops

In Vinh Phuc province, there are currently 140 operating gas stations. The amount of emissions from these stores is 2.11 tons of NMVOC/year. According to investigation and survey results, there are currently about 143 construction material stores doing business throughout the province, so the amount of dust emission from stores for the whole province is 156.08 tons of TSP/year and 7.80 tons of PM<sub>2.5</sub> per year. In Vinh Phuc province, there are about 46 car painting garages operating. The total amount of NMVOC emissions from garage operations in the province is 124.60 tons of NMVOC per year. There are about 43 large photocopy shops in operation. The total amount of NMVOC emissions from printing and photocopying activities in the province is 74.47 tons of NMVOC per year.

### 3.4 Emissions from pagodas

Emissions from temple activities are calculated based on the volume of incense burned during the year at the temples. Emissions on festival days will be higher than on normal days of the year because the number of visitors can increase on average about 9 times. In addition to CO, the incense burning activity generates a relatively large amount of dust (reflected by parameters TSP and PM<sub>2.5</sub>).

**Table 3.** Emissions from pagodas in Vinh Phuc province.

District/city	Emission load (tons/year)					
	NO <sub>x</sub>	CO	NMVOC	TSP	CH <sub>4</sub>	PM <sub>2.5</sub>
Phuc Yen	0.02	2.52	0.13	1.17	0.12	1.09
Vinh Yen	0.02	2.39	0.12	1.12	0.11	1.04
Yen Lac	0.02	2.39	0.12	1.12	0.11	1.04
Vinh Tuong	0.02	2.39	0.12	1.12	0.11	1.04
Tam Duong	0.02	2.02	0.10	0.94	0.09	0.88
Tam Dao	0.02	2.77	0.14	1.29	0.13	1.20
Song Lo	0.01	1.39	0.07	0.65	0.06	0.60
Lap Thach	0.01	1.13	0.06	0.53	0.05	0.49
Binh Xuyen	0.01	1.76	0.09	0.82	0.08	0.77
<b>Total</b>	<b>0.16</b>	<b>18.77</b>	<b>0.97</b>	<b>8.75</b>	<b>0.88</b>	<b>8.16</b>

### 3.5 Emissions from straw burning activities

The total cultivated area in 2019 of Vinh Phuc province is 54,072 hectares. Rice output for the whole year is about 313,241.8 tons. According to the calculation results, emissions from straw burning account for a high proportion of the total emissions from land sources. Straw is regularly burned in fields after harvest. Straw may not be completely dry when burned, creating clouds of smoke that cover a large area, affecting environmental quality and the health of people living in the area (Table 4). The coefficient to calculate exhaust emissions is referenced from the author's research on straw burning activities in the Northern Delta and Hanoi [4, 3].

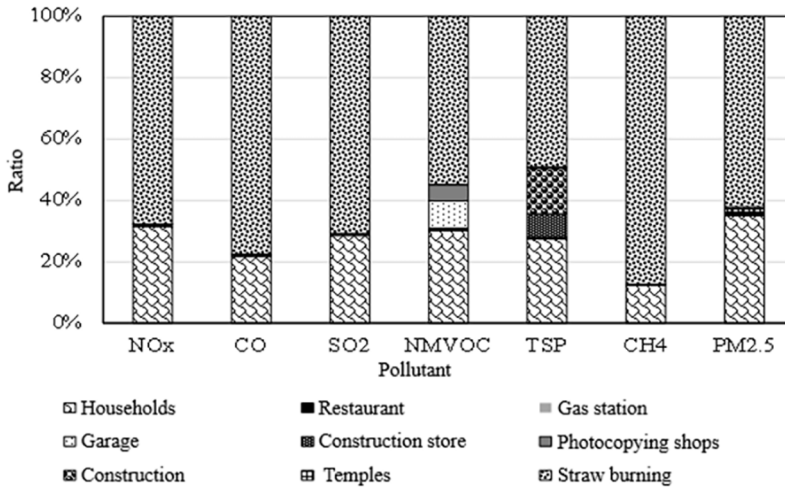
**Table 4.** Emissions from straw burning activities in Vinh Phuc province.

District/city	Emission load (tons/year)						
	NO <sub>x</sub>	CO	SO <sub>2</sub>	NMVOC	TSP	CH <sub>4</sub>	PM <sub>2.5</sub>
Phuc Yen	17.75	724.16	1.40	54.51	70.86	74.67	64.63
Vinh Yen	9.86	402.15	0.78	30.27	39.35	41.47	35.89
Yen Lac	43.96	1793.03	3.47	134.96	175.45	184.89	160.02
Vinh Tuong	46.38	1891.84	3.66	142.40	185.12	195.08	168.84
Tam Duong	28.87	1177.53	2.28	88.63	115.22	121.43	105.09
Tam Dao	17.90	730.20	1.41	54.96	71.45	75.30	65.17
Song Lo	23.82	971.51	1.88	73.12	95.06	100.18	86.70
Lap Thach	31.57	1287.82	2.49	96.93	126.01	132.80	114.93
Binh Xuyen	31.60	1288.86	2.49	97.01	126.11	132.90	115.03
<b>Total</b>	<b>251.71</b>	<b>10267.1</b>	<b>19.87</b>	<b>772.79</b>	<b>1004.63</b>	<b>1058.73</b>	<b>916.31</b>
Can Tho	1.907	77.768	151	5.853	7.610	8.019	-

Comparison with emissions from straw burning activities of Can Tho city, Vietnam conducted in 2015 shows that: Can Tho's rice output is 4.5 times higher than that of Vinh Phuc, however emissions from Straw burning in Can Tho is about 7 times higher than Vinh Phuc. This difference may be due to the higher rate of straw burning in the fields in Can Tho compared to provinces in the Northern region of Vietnam [4, 5,7].

### 3.6 Total surface source emissions in Vinh Phuc province

For surface sources, most pollutants arise mainly from straw burning activities, partly from household cooking activities. (Figure 1). Straw burning activity has a load of CO, SO<sub>2</sub> and CH<sub>4</sub> accounting for over 70% of total air source emissions, NMVOC and dust accounting for 55% because in Vinh Phuc, people still have the habit of burning straw after harvest directly on the ground. Because of its large area, exhaust gas emissions account for a very large load. Emissions are mainly concentrated in districts with large rice output such as Yen Lac and Vinh Tuong.



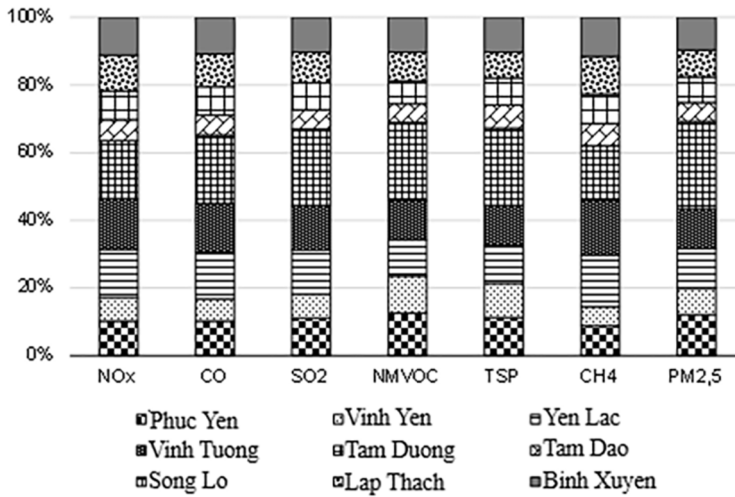
**Fig. 1.** Total emissions by source in Vinh Phuc.

Household sources have a substance load of about 12 - 35%, which is the second source contributing to surface source emissions. According to current surveys, people still use a lot of firewood for cooking. The amount of firewood used for cooking in Vinh Phuc province is about 45,776.16 tons per year, while the total number of households is about 320,787 households. Compared to Ho Chi Minh City, the rate of firewood usage in cooking is 47,865.37 tons per year while the total number of households is about 4 times that of Vinh Phuc (1.3 million households). Therefore, the amount of firewood used for cooking in Vinh Phuc accounts for a high proportion and causes high emissions.

Emissions are unevenly distributed among the districts of the province. Due to population distribution and different emission activities. Looking at the results table, we see that the largest emission is CO, followed by TSP, PM<sub>2.5</sub>, and NMVOC. The lowest emission is SO<sub>2</sub> with 28.09 tons/year. For each pollutant, the chart Figure 1,2 shows the contribution rate of each city/district. The results show that Tam Duong is the district that contributes the largest proportion of most pollutants (about 17 - 26%), especially PM<sub>2.5</sub> dust (~26%). Vinh Tuong district also contributes a high proportion to NO<sub>x</sub> and CH<sub>4</sub> emissions (16%).

**Table 5.** Emissions from surface sources (excluding biological sources) by each city district.

District/city	Emission load (tons/year)						
	NO <sub>x</sub>	CO	SO <sub>2</sub>	NMVOC	TSP	CH <sub>4</sub>	PM <sub>2.5</sub>
Phuc Yen	37.93	1352.69	3.11	176.68	228.11	107.16	177.47
Vinh Yen	25.66	867.49	2.00	153.86	208.37	66.24	116.47
Yen Lac	52.91	1845.26	3.63	152.94	231.09	188.00	171.87
Vinh Tuong	56.08	1903.95	3.72	161.49	241.08	196.27	173.66
Tam Duong	64.26	2659.45	6.37	325.82	466.70	195.90	381.86
Tam Dao	22.91	798.09	1.60	78.94	140.10	78.97	80.54
Song Lo	31.26	1094.99	2.23	96.78	161.81	106.69	111.45
Lap Thach	39.73	1298.76	2.55	119.01	158.07	133.84	118.10
Binh Xuyen	41.34	1421.82	2.88	144.25	209.76	140.01	142.26
<b>Total</b>	<b>372.08</b>	<b>13242.5</b>	<b>28.09</b>	<b>1409.78</b>	<b>2045.10</b>	<b>1213.08</b>	<b>1473.67</b>



**Fig. 2.** Emissions of pollutants from surface sources (excluding biological sources) by city/district in Vinh Phuc province.

Comparing the total emissions of all pollutants of the districts, the results show that Tam Duong is the province that emits the most land source emissions (4,100.36 tons/year) because there is a high rate of use of firewood in cooking. higher than other areas. Next are Vinh Tuong and Yen Lac with emissions of 2,736.25 tons/year and 2,645.7 tons/year, respectively. These are the two localities with the highest cultivated area and rice output in Vinh Phuc province.

## 4 Conclusion

Calculation of surface source emissions shows that mainly pollutants arise from straw burning activities. Straw burning activity has a load of CO, SO<sub>2</sub> and CH<sub>4</sub> accounting for over 70% of total air source emissions, NMVOC and dust accounting for 55% because in Vinh Phuc, people still have the habit of burning straw after harvest directly on the ground. Because of its large area, exhaust gas emissions account for a very large load. Emissions are mainly concentrated in districts with large rice output such as Yen Lac and Vinh Tuong. A part from cooking activities in households accounts for 12 - 35%, making the second contribution to surface source emissions. Because according to the current survey, people still use a lot of firewood for cooking. The amount of firewood used for cooking in Vinh Phuc province is about 45,776.16 tons/year, while the total number of households is about 320,787 households. Compared to Ho Chi Minh City, the rate of firewood usage in cooking is 47,865.37 tons/year while the total number of households is about 4 times that of Vinh Phuc (1.3 million households). Therefore, the amount of firewood used for cooking in Vinh Phuc accounts for a high proportion and causes high emissions.

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