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Emission comparison of short lived climate forcers over long term greenhouse gases from domestic and transport sector in Semarang city

H Huboyo*, B Samadiku and O Manullang

Environmental Engineering Department, Diponegoro University, Semarang, Indonesia

*huboyo@undip.ac.id

Abstract. Short-lived climate forcers (SLCF) controls are important because of their shorter impact and more immediate benefits in the short term than carbon dioxide controls that have a 100-year time horizon. In this study, we estimated the emission of SLCF from domestic and transport sector in Semarang city using emission factor from IPCC and CORINAIR. We also predicted the emission dispersion using AEMOD View. The total consumption of LPG domestic sector in Semarang city is 48,532 tons in 2017 and produces total SCLF emissions 0.537 tons/year and 11,538 tons/year for BC and CH_4 respectively. This corresponds to CO_2 emissions of 145,611 tons/year and 230.76 tons/year of N_2O emissions. While from transport sector, the motorcycle has the largest VKT i.e 18.282.061.600 km/year in 2017. The emission, based on VKT data combined with active vehicles data, reach 178.23 tons/year, 802.52 tons/year for BC and CH_4 respectively. Transport sector produces total CO_2 emissions almost 15 times to that of domestic sector. Based on emission model, the emission distribution was concentrated in the districts located in the city center. The pollutant was accumulated in the Northwest, city center and Southeast of the city.

1. Introduction

Anthropogenic climate change is largely driven by human induced changes in the composition of the atmosphere, including long-lived GHGs (that have lifetimes of approximately eight years or more) and short-lived climate pollutants removed from the atmosphere or transformed to CO_2 relatively quickly (i.e. a few weeks for BC to about 12 years for methane) [1]. Some short-lived climate pollutants such as black carbon (BC), tropospheric ozone (O_3), and methane (CH_4), are defined as gases and particles that have relatively short atmospheric lifetimes with significant warming impacts on the climate. short-lived climate forcers (SLCFs) have detrimental impacts on air quality, directly or via formation of secondary pollutants [2]. BC fluctuation, for example, could effect to chemical evolution and lead to disturbing Aerosol Optical Depth beyond the sources [3].

Climate change control through the control of greenhouse gas emissions included in the Indonesia's priorities in the next few years. Reductions in SLCFs have the potential to decrease the rate and degree of warming in the next few decades, with SLCF mitigation having a rapid effect on temperature [4]. To reduce SLCF precursor i.e. tropospheric ozon by reducing NOx and NMVOC, while to reduce the global radiative forcing, lessen CH4 emission could be an efficient way [5]. The relation of SLCF and CO2 could be approached by analyzing global-mean surface temperature with CO2, CH4, HFC, related-BC and SO2 mitigation [6]. The BC concentration also correlate well with

PM2.5, The ratio of BC/PM2.5 generally has consistent average of 5.29% during observation in China [7]. This observation indicates that PM2.5 measurement is important to know the BC concentration.

Many important sources emit more than one short-lived greenhouse pollutant, therefore, control of this SLCF is difficult e.g., black carbon and organic carbon from combustion of biomass, coal, and diesel fuel. The needs on emission inventory as stated by the Ministry of Environment and Forestry of Indonesia was to determine the comprehensive amount of pollutants from the source within areas and periods of time, with the ultimate objective is to enable the Municipal Government in Indonesia to make emission inventory result as a baseline for policy making and urban air pollution control strategy.

In this study we estimate the emission load of SLCFs from domestic and transport sector in Semarang city. We also compare them with CO_2 and N_2O emission from the same sources. The SLCFs we investigate comprise of methane (CH_4) and black carbon (BC). We predicted the hypothetical dispersion of these emissions using AERMOD View.

2. Methodology

2.1. Estimate the emission load from domestic sector

To calculate the emission load from household activities, we estimate from LPG consumption in the household. Calculation using Tier 1 method, adopting from IPCC using following equation [8]:

$$\text{Emission} = \sum_a [Fuel\ a\ x\ EF\ a]$$

where, Emission = Specific pollutant emission load (kg), Fuel a = fuel consumption of type a (GJ), EF a = emission factor (g / GJ).

We did survey (randomly) to 100 households consist of poor households, medium class households and affluent households to know the average LPG consumption based on household categories.

2.2. Estimate the emission load from transport sector

To calculate the emission from transportation, we used Tier-2 method i.e. using vehicle kilometer traveled-VKT (vehicle kilometer traveled-VKT). The term VKT is intended to know the mileage of the vehicle in a given time (day/ week/month/year). The emissions are treated as area sources based on district. Total VKT of mobile source is the number of multiplication of vehicle population and average mileage per year for each vehicle category/sub-category.

The equations for estimating the total VKT of a mobile source are:

$$\mathbf{VKTb,c} = \mathit{VKTb,c}\ \text{odo} . \text{Nb,c}$$

Where: *VKTb*,c odo = VKT vehicle category b and fuel c based on odometer survey (km/year); **VKTb,c** = VKT of all motor vehicles category b using fuel c (km/year); Nb,c = number of motor vehicle category b using fuel c

2.3. Emission factor

To calculate the emission from domestic sector, we used emission factor from CORINAIR [9] for each parameter as follows: BC: 11 mg/kg, CO_2: 63.1 g/MJ, CH_4: 5 g/MJ, N_2O: 0.1 g/MJ.

The emission factor for transport sector we use and adopt from Ministry of Environment and Forestry and EPA guideline as follows:

Table 1. Emission factor used in this study.

Vehicle Types	Parameters			
	CO2 (g/kg)	CH4	N2O	BC (g/kg)
Motorcycle	3.180	0,26	0,002	0.0510
Gasoline Personal Car	3.180	0,07	0,005	0.2800
Diesel Personal Car	3.172	0,01	0,014	0.7900
Bus	3.172	0,06	0,031	0.4000
Truck	3.172	0,01	0,031	0.6400

3. Results and discussion

Based on statistical data in Semarang City in 2017, the population of the city reaches 1,701,172 inhabitants. The population growth rate during 2010-2016 was 10.85% due to rapid urbanization. The average city density of Semarang was 4,628 residents/sqkm. Based on government classification, approximately 9% of the population of Semarang is categorized poor people, the middle class is around 17-43% while the affluent people reaches 11%. Our survey confirmed the poor household generally has less than 1 million rupiahs/month income, while affluent households collect more than 4 million rupiahs/month.

Figure 1. Semarang city map.

3.1. Domestic activities and emission load

Based on our survey, the average consumption of domestic LPG for affluent households is 9.92 kg/month/households, while for middle class household is about is 9.34 kg/month/household. Last, for poor people is 5.83 kg/month/household. This shows that for the poor, they less consume domestic LPG. However, the number of household member also affects the LPG consumption. The average cooking duration was dominantly at 2-3 hours/day for all household categories. The affluent households usually use 12 kg LPG cylinder, while for the poor generally use 3 kg LPG cylinder. While the middle class shows combination of using LPG 12 kg and 3 kg cylinder.

Based on data from the Ministry of Energy and Mineral Resources (2018), the city of Semarang has 52 LPG cylinder distributors and based on our observation it was found that approximately 200 cylinders were distributed daily. If we assume that each distributor distributes the same number of LPG, then based on top-down calculation, the amount of LPG distributed in 2017 was 3,796,000 cylinders. It was quite different if we calculate based on bottom-up approach which shows 2,734,172 cylinders. Several distributors sold the LPG to the Semarang periphery inhabitants that might be live administratively to neighboring cities such as Demak, Kendal and Semarang Regency.

Our estimation, the total consumption of LPG domestic sector in Semarang City is 48,532 tons in 2017 and produces total SCLF emissions 0.537 tons/year and 11,538 tons/year and for BC and CH_4

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respectively. This corresponds to CO_2 emissions of 145,611 tons/year and N_2O emission of 230.76 tons/year. The distribution of emission loads for each district (represented by CO_2) is shown in Figure 2.

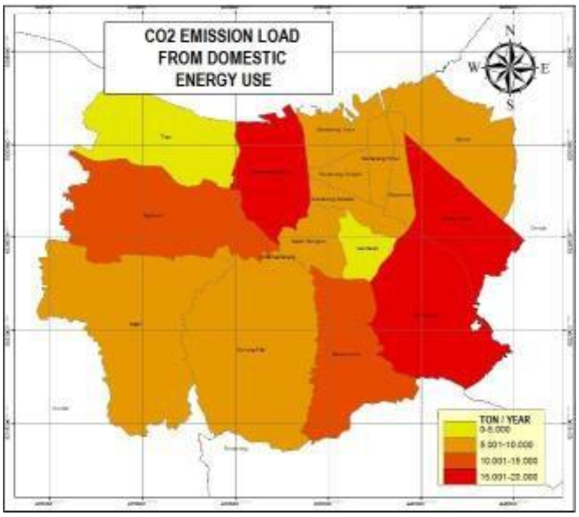

Figure 2. CO_2 emission load from domestic sector.

3.2. Domestic emission dispersion

Emission dispersion estimation was simulated using AERMOD View program with ISCST3 modes. We simulated the model input derived from standardized gas stove parameters (emission rate, height of emissions) for each household using area sources category. The average wind velocity based on meteorological data provided by Meteorological and Geophysics Agency in 2017 is 1.81 m/s with the highest wind speed is 11.10 m / s and the lowest wind speed is less than 0.5 m/s. The dominant wind direction of Semarang city in 2017 comes from the northwest and southeast direction as depicted in the Figure 3.

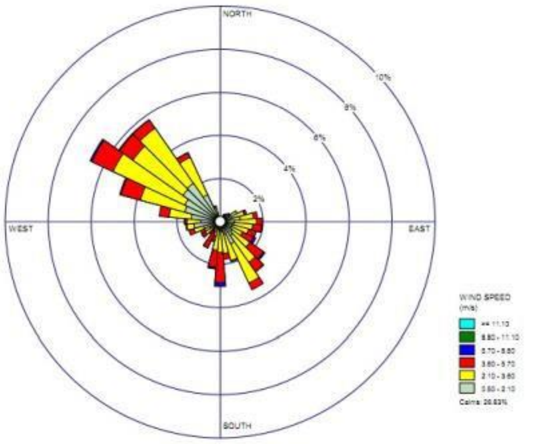

Figure 3. Prevailing wind at Semarang city throughout the year.

The simulation results of the distribution emission from domestic sector (represented by CO_2 emission) is shown in the Figure 4 below.

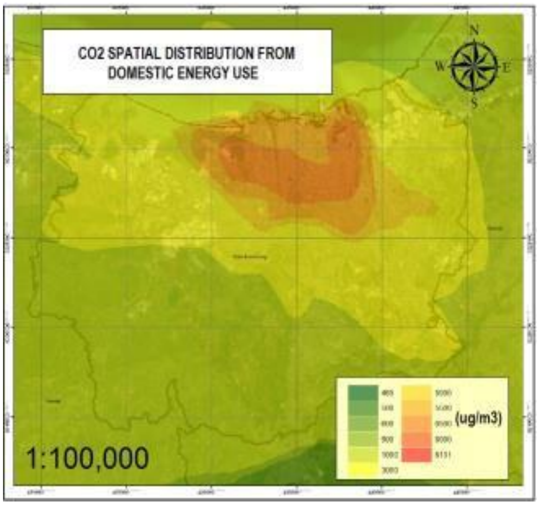

Figure 4. CO_2 emission dispersion from domestic sector.

From the above figure, the emission distribution was concentrated in the districts lied in the city center. The pollutants were accumulated in the northwest, at the city center and southeast of the city. Thus, if we compare Figure 2 and Figure 4, it be concluded that higher emission in the Northwestern and Southeastern of the city will accumulate in the city center. This might be caused, not only by the prevailing wind which come from Northwest and Southeast, also caused by the land terrain in the southern of the city which has higher elevation than in the city center.

3.3. Transport activities and emission load

In this study, we focus on transportation on road transportation i.e. from highways and road networks. We collected current vehicles data from Local Income and Management Agency at province level. These vehicles data reflect the active vehicles that still in use. Active vehicles here are vehicles that are still registered by paying taxes therefore are considered still actively producing emissions on the road.

Table 2. Number of active vehicles in Semarang city.

Year	**Vehicle types**			
	PC	***Truck***	***Bus***	***MC***
2012	156,614	56,666	2,345	822,700
2013	136,191	52,289	1,917	696,086
2014	141,669	49,748	1,675	661,180
2015	178,542	65,825	2,394	1,067,815
2016	176,964	53,788	1,728	728,824
2017	226,073	78,448	3,271	1,252,196

PC: Personal Car, MC: Motorcycle

Based on table above, the vehicle in Semarang City is dominated by two-wheeled vehicles or motorcycles that are 80% in the proportion followed by passenger cars by 15%.

Transport sector emissions calculations are calculated based on the mileage of each vehicle type or Vehicle Kilometer Traveled (VKT). In this study the type of vehicle is divided into trucks, buses, motorcycles, passenger cars fueled by gasoline, and diesel-fueled passenger cars. The fraction between gasoline and diesel passenger cars in Semarang City based on previous research was equal to 97% and 3% [10].

In this study the VKT data was derived from odometer readings observation for each vehicle type using the results of previous research that can be seen in following table 3.

Table 3. Vehicles VKT based on vehicles types.

Vehicles Types	Number (units)	Average of VKT (km/year)
Bus	3,271	43,435 [10]
Truck	78,448	10,115 [11]
Gasoline Personal Car	219,291	15,330 [10]
Diesel Personal Car	6,782	15,330 [10]
Motorcycle	1,252,196	14,600 [10]

Based on above table, the motorcycle has the largest VKT i.e. 18.282.061.600 km/year in 2017. The emission, based on VKT data combined with active vehicles data, reach 178.23 tons/year, 802.52 tons/year and 88.78 tons/year for BC, CH_4 and N_2O respectively. This transport sector produces total CO_2 emissions of 2,123,302 tons/year (almost 15 times to that of domestic sector). The distribution of emission loads for each district (represented by CO2) is shown in Figure 5.

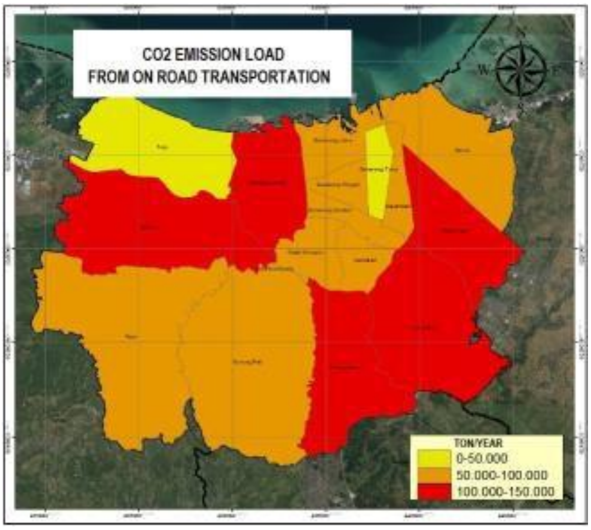

Figure 5. CO_2 emission load from on road transport sector.

3.4. Transport emission dispersion

Likewise, in domestic emission, the estimation of emission dispersion from transport sector was simulated using AERMOD View program with ISCST3 modes. We modified the model input to accommodate for transport emission. We still use historical meteorological data collected from Meteorological and Geophysics Agency in 2017. Likewise, from domestic sector, the emission distribution was concentrated in the districts located in the city center. The pollutants spread from transport sector was more outward rather than those from domestic sector. However, it was still accumulated in the Northwest, city center and Southeast of the city.

The simulation results of the distribution emission from domestic sector (represented by CO_2 emission) is shown in the Figure 6.

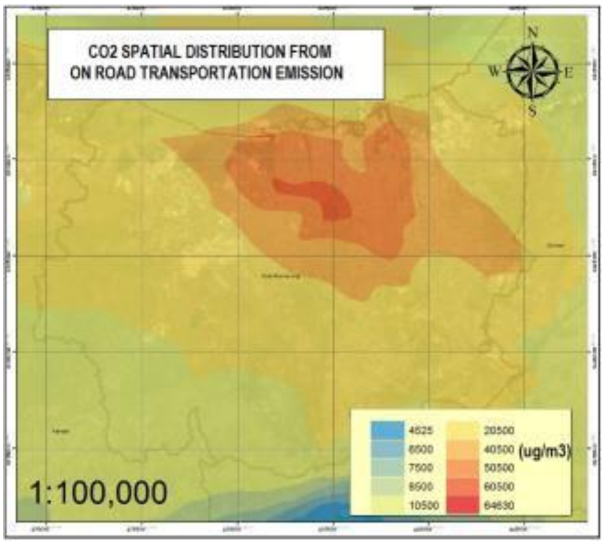

Figure 6. CO_2 emission dispersion from on road transport sector.

3.5. Comparing with other cities

We compare the transport emission (represented by CO_2) in Semarang city with those in other cities. Based on Fig. 7, the population is directly proportional to the amount of GHG's produced. Denpasar City which has a population of 880,600 in 2015 produces CO_2 pollutants as much as 984,280 tons/year. While the city of Semarang which has a population of 1,729,428 people in 2017 produces CO2 emission as much as 2,123,302 tons/year. The Jakarta city which has the largest number of city population i.e. 9,057,632 inhabitants in the year 2009 produces CO_2 emission of 11,744,480 tons /year.

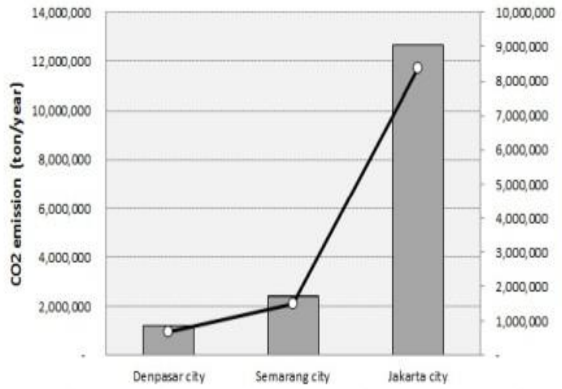

Figure 7. Comparing CO_2 emission load from on road transport sector in other cities.

4. Conclusion

Short-lived climate forcers (SLCF) controls are important because of their shorter impact and has immediate benefits in the short-term period. Based on this study results, the total consumption of LPG domestic sector in Semarang City is 48,532 tons in 2017 and produces total SCLF emissions 0.537 tons/year, 11,538 tons/year and 230.76 tons/year for BC, CH_4 and N_2O respectively. This is corresponding to CO_2 emissions of 145,611 tons/year. While from transport sector, the motorcycle has the largest VKT i.e. 18.282.061.600 km/year in 2017. The emission, based on VKT data combined with active vehicles data, reach 178.23 tons/year, 802.52 tons/year and 88.78 tons/year for BC, CH_4 and N_2O respectively. Transport sector produces total CO2 emissions almost 15 times to that of domestic sector. Based on emission model, the emission distribution was concentrated in the districts located in the city center. The pollutants were accumulated in the Northwest, city center and Southeast of the city. Comparing to the other cities, the emission of CO_2 from transport sector is directly proportional to the number of the population.

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References

[1] IPIECA.org. 2014 *Understanding short-lived climate forcers* (United Kingdom: Blackfriars Road London SE1 8NL)
[2] Kirtman B, Power S B, Adedoyin A J, Boer G J, Bojariu R, Camilloni I and Prather M 2013 *Near-term climate change: projections and predictability*
[3] Sadiq M, Tao W, Liu J and Tao S 2015 Air quality and climate responses to anthropogenic black carbon emission changes from East Asia, North America and Europe *Atmospheric Environment* **120** 262-276
[4] Myhre G, Samset B H, Schulz M, Balkanski Y, Bauer S, Berntsen T K and Easter R C 2013 Radiative forcing of the direct aerosol effect from AeroCom Phase II simulations *Atmospheric Chemistry and Physics* **13** 1853-1877
[5] Akimoto H, Kurokawa J I, Sudo K, Nagashima T, Takemura T, Klimont Z and Suzuki K 2015 SLCP co-control approach in East Asia: Tropospheric ozone reduction strategy by simultaneous reduction of NOx/NMVOC and methane *Atmospheric Environment* **122** 588-595
[6] Rogelj J, Schaeffer M, Meinshausen M, Shindell D T, Hare W, Klimont Z and Schellnhuber H J 2014 Disentangling the effects of CO2 and short-lived climate forcer mitigation *Proceedings of the National Academy of Sciences* **111**(46) 16325-16330
[7] Zha S, Cheng T, Tao J, Zhang R, Chen J, Zhang Y and Du J 2014 Characteristics and relevant remote sources of black carbon aerosol in Shanghai *Atmospheric research* **135** 159-171
[8] IPCC (Intergovernmental Panel on Climate Change) 2006 Guidelines for national greenhouse gas inventories *Task force on national greenhouse gas inventories (TFI)*
[9] CORINAIR 2009 *Atmospheric Emission Inventory Guidebook 3th Edition* (European Environment Agency)
[10] Buanawati T 2017 *Estimation of Conventional Air Pollutants (SOx, NOx, CO, AND PM) From Personal Vehicles Based On International Vehicle Emission (IVE) Method in Semarang City Road* (Semarang: Diponegoro University)
[11] Huboyo H S, Sutrisno E, Sutrisno A M and Tiarani V L 2018 Spatial Distribution of Conventional Air Pollutant and GHGs from Land Transportation in Two Developing Cities and Main Co-Benefit Actions For Reducing It In *E3S Web of Conferences* **31** 09005