Characteristics and Estimation
Analysis of CO$_2$ and CH$_4$ Emission from Vehicle in Nanjing

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Outline

- Background
- Materials and Methods
- Results and Discussion
- Conclusion
Background

- **CO₂** and **CH₄** are the most important greenhouse gases. Vehicles are their common source of emission (IPCC, 2013). Greenhouse gas emission from vehicles account for more than **70%** of total traffic emission (He, 2005).

- In recent years, the number of vehicles in China is growing rapidly (Li, 2013), particularly **the rapid growth of the number of natural gas vehicles** (Lu, 2015), further exacerbated the CH₄ emission of urban traffic.

- This paper aimed to clear the characteristics of **CO₂ and CH₄ on the road** and its influencing factors, and analysis the reliability of methods by contrasting two estimation methods.
Materials and Methods

Observation site

1. Main roads (Figure 1)

2. Tunnels

(Changjiang River Tunnel, Yangtze River Tunnel, Xuanwu Lake tunnel, Jiangshan Street Tunnel, Drum tunnel, Tongji-men tunnel and Jiqing-men tunnel)

Fig.1 Image of the observation route
Materials and Methods

**Experimental date:**
1. October 17, 18, 20, 23, 2014
2. September 11, 2015
   April 18, 2016

**Time:**
- 06:00 - 07:30 (morning rush hour)
- 11:30 - 17:30 (evening rush hour)
- 22:00

**Instrument:** LGR gas analyzer, computer, GPS, video camera

*Fig. 2 Schematic of instrument installation and calibration*
Materials and Methods

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>Formula</th>
<th>Method</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Bottom-up”</td>
<td>$F_i = \sum_{1}^{n} f_i \times E_i$</td>
<td>CH$_4$:CO$_2$</td>
<td>WRI/WBCSD,2009...</td>
</tr>
<tr>
<td>“Top-down”</td>
<td>/</td>
<td>ΔCH$_4$:ΔCO$_2$</td>
<td>Hsu et al., 2010、Wang et al., 2004、Pataki et al. 2005...</td>
</tr>
</tbody>
</table>

IPCC method:

$f_i = W_i = P_i \times T_i \times M_i / g_i$

$E_i = e_i \times q_i$

- $f_i$: the activity data;
- $W_i$: the amount of vehicle fuel consumption;
- $P_i$: vehicle ownership;
- $T_i$: fuel type coefficient of vehicle;
- $M_i$: annual average mileage of vehicle;
- $g_i$: fuel economy of vehicles;
- $E_i$: proposed emission coefficient;
- $e_i$: original emission coefficient;
- $q_i$: calorific value of china.
Results and Discussion

◆ Temporal variation of CO$_2$ and CH$_4$ on main road

Fig. 3 Diurnal variation of mean CO$_2$ and CH$_4$ concentration on the main roads
Results and Discussion

◆ Spatial variation of CO₂ and CH₄ on main road

Fig. 4 Bar graph of mean CO₂ and CH₄ concentration on the different main road
Results and Discussion

◆ Variation of CO₂ and CH₄ in Tunnel

Fig.5 Time series of CO₂ and CH₄ concentration in Changjiang River Tunnel
Results and Discussion

◆ Variation of CO₂ and CH₄ in Tunnel

Fig. 6 Time series of CO₂ and CH₄ concentration in Nanjing Tunnel
Results and Discussion

◆ Influential factors of CO$_2$ and CH$_4$ on main road

Fig. 7 Time series of CO$_2$ and CH$_4$ concentration on the traffic main road in the 11:30 period of October 20, 2014
Results and Discussion

◆ Influential factors of CO$_2$ and CH$_4$ on main road

Fig. 8 Relationship between ΔCO$_2$, ΔCH$_4$ and traffic volume, taxi / traffic volume on the road
Results and Discussion

◆ ΔCH₄:ΔCO₂ and its diurnal variation

![Graph showing the relationship between ΔCO₂ and ΔCH₄ concentrations.](image)

![Graph showing the diurnal variation of ΔCH₄ and ΔCO₂ concentrations on traffic main road.](image)

○、△、☆ represent road 1, road 2, road 3; hollow and solid means weekday and weekends

Fig.9 Fitting diagram of mean ΔCH₄ concentration and mean ΔCO₂ concentration on the traffic main road and its diurnal variation
Results and Discussion

**ΔCH\textsubscript{4}:ΔCO\textsubscript{2} in Nanjing Tunnel**

![Graph showing CH\textsubscript{4} and CO\textsubscript{2} concentrations in Nanjing Tunnel.

### ∆CH\textsubscript{4}:∆CO\textsubscript{2} in Nanjing Tunnel

<table>
<thead>
<tr>
<th>Tunnel</th>
<th>ΔCH\textsubscript{4}:∆CO\textsubscript{2}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yangtze River Tunnel</td>
<td>0.0028</td>
</tr>
<tr>
<td>Xuanwu Lake tunnel</td>
<td>0.0043</td>
</tr>
<tr>
<td>Jiangshan Street Tunnel</td>
<td>0.00064</td>
</tr>
<tr>
<td>Drum tunnel</td>
<td>0.0062</td>
</tr>
<tr>
<td>Tongji-men tunnel</td>
<td>0.0035</td>
</tr>
<tr>
<td>Jiqing-men tunnel</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

**Fig.10 Fitting diagram of CH\textsubscript{4} and CO\textsubscript{2} in Nanjing Tunnel**
Results and Discussion

◆ Influential factors of ΔCH₄:ΔCO₂

Table 1: Atmospheric ΔCH₄:ΔCO₂ of Nanjing roads under different conditions

<table>
<thead>
<tr>
<th>Road</th>
<th>Starting or braking</th>
<th>Smooth running</th>
<th>No NGV</th>
<th>Only NGV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0098</td>
<td>0.0062</td>
<td>0.0054</td>
<td>0.0124</td>
</tr>
<tr>
<td>2</td>
<td>0.0120</td>
<td>0.0056</td>
<td>0.0056</td>
<td>0.0072</td>
</tr>
<tr>
<td>3</td>
<td>0.0115</td>
<td>0.0063</td>
<td>0.0033</td>
<td>0.1387</td>
</tr>
</tbody>
</table>
Results and Discussion

◆ Influential factors of $\Delta CH_4: \Delta CO_2$

Fig. 11 Relationship between $\Delta CH_4: \Delta CO_2$ and traffic volume, taxi / traffic volume on the typical road

$\text{R} < 0, \text{P} > 0.01, \text{n} = 66$

$y = 0.00048x - 0.0023$

$R = 0.68, \text{P} < 0.01, \text{n} = 66$
Results and Discussion

◆ Estimating CH4 emissions by IPCC method

Table 2: List of CH4 emission of vehicle in Nanjing in 2014

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Fuel</th>
<th>Total fuel consumption (L or m³)</th>
<th>Proposed emission coefficient of CH4 (KgCH4/(L or m³))</th>
<th>CH4 emission (10⁴ ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger</td>
<td>Gasoline</td>
<td>9.27 × 10⁹</td>
<td>8.16 × 10⁻⁴</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>5.14 × 10⁶</td>
<td>1.44 × 10⁻⁴</td>
<td>0.000074</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>1.21 × 10⁸</td>
<td>3.81 × 10⁻³</td>
<td>0.046</td>
</tr>
<tr>
<td>Cargo</td>
<td>Gasoline</td>
<td>5.37 × 10⁸</td>
<td>8.16 × 10⁻⁴</td>
<td>0.044</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>1.19 × 10⁹</td>
<td>1.44 × 10⁻⁴</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>0</td>
<td>3.81 × 10⁻³</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>Gasoline</td>
<td>5.06 × 10⁷</td>
<td>8.16 × 10⁻⁴</td>
<td>0.0041</td>
</tr>
<tr>
<td></td>
<td>Diesel</td>
<td>5.63 × 10⁷</td>
<td>1.44 × 10⁻⁴</td>
<td>0.00081</td>
</tr>
<tr>
<td></td>
<td>CNG</td>
<td>0</td>
<td>3.81 × 10⁻³</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>0.87</td>
</tr>
</tbody>
</table>
Results and Discussion

◆ Estimating CH₄:CO₂ emission ratio by IPCC method

Table 3 List of CH₄:CO₂ emission ratio of vehicle in Nanjing

<table>
<thead>
<tr>
<th>Year</th>
<th>CO₂ (10⁴ ton)</th>
<th>CH₄ (10⁴ ton)</th>
<th>CH₄:CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1215.04</td>
<td>0.40</td>
<td>0.00090</td>
</tr>
<tr>
<td>2011</td>
<td>1682.64</td>
<td>0.54</td>
<td>0.00089</td>
</tr>
<tr>
<td>2012</td>
<td>1934.24</td>
<td>0.63</td>
<td>0.00090</td>
</tr>
<tr>
<td>2013</td>
<td>2240.42</td>
<td>0.74</td>
<td>0.00091</td>
</tr>
<tr>
<td>2014</td>
<td>2601.17</td>
<td>0.87</td>
<td>0.00092</td>
</tr>
</tbody>
</table>
Results and Discussion

◆ Comparative analysis of estimation methods

（1）Atmospheric concentration observation

➢ Regional representation
➢ Natural gas leakage
➢ Other emission sources

（2）IPCC method

➢ Method applicability
➢ Emission coefficient
➢ Statistical data
Conclusion

- The diurnal variation of CO$_2$ concentration in the main road in Nanjing showed bimodal distribution, and the two peaks appeared in 07:30 and 17:30. The spatial variation of CH$_4$ concentration was higher than the spatial difference of CO$_2$ concentration on the road. Due to the "piston wind" in the tunnel, the CH$_4$ concentration in tunnel was gradually increased from the inlet to the outlet.

- There was a significant linear correlation between CH$_4$ concentration and CO$_2$ concentration on the road. The atmospheric $\Delta$CH$_4$: $\Delta$CO$_2$ value on the main road was 0.0090. The diurnal variation showed "W" type; The range of atmospheric $\Delta$CH$_4$: $\Delta$CO$_2$ value in Nanjing experiment tunnels was 0.00064-0.0062.

- Traffic volume was the main factors for the increase of CO$_2$ and CH$_4$ concentration on road. There was a significant positive correlation between the atmospheric $\Delta$CH$_4$: $\Delta$CO$_2$ value and the proportion of natural gas taxis, but the traffic volume was not.

- For CH$_4$ emission, the difference analysis of the two methods shows that the estimation of the IPCC method was underestimated, and the estimation of the atmospheric concentration observation method was credible.
Thank you