Establishment of Taxi Driving Conditions and Emission Inventory in Tangshan City

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Abstract: The project team selected 3 taxis in the built-up area of Tangshan City to conduct emission tests under actual road conditions, systematically and comprehensively evaluated, analyzed and compared the test results. They established the VSPbin emission rate database and emission factor list of typical urban Taxis in the built-up area based on the actual driving characteristics of Tangshan city. To analyze the driving conditions of taxis in Tangshan City, this study selected four operating conditions: acceleration, constant speed, deceleration, and idle. The research results showed that as the emission standards became increasingly strict, the emission of single-vehicle pollutants decreased, and in particular NOx emissions were reduced by more than 90%. Compared with gasoline fuel, CNG fuel taxis’ CO2 and NOx emissions showed a downward trend. When natural gas was used as fuel, the CO emissions of taxis could be reduced by 27.2% ~ 92.0%, and the CO2 emissions by 19.5% ~ 32.1%. The CO and CO2 emission factors of taxis both decrease with the increase of speed. For particulate matter, the quantity and quality emission factors both decrease first and then increase with the increase of speed, and the rising speed is obviously accelerated during the high-speed phase.

1. Introduction
Establishing vehicle emission inventory and analyzing the overall emission characteristics of city vehicles are the basis for managing and controlling city vehicle emissions.\textsuperscript{[1]} Controlling vehicle exhaust emissions has become one of the most important tasks to improve the quality of urban atmospheric environment\textsuperscript{[2]}. Different vehicles have different emission characteristics, and the emission characteristics of the same vehicle under different working conditions are also inconsistent. In-depth study of the emission characteristics of vehicle exhaust pollutants under actual roads is of great significance for the management department to formulate targeted exhaust control measures and traffic management strategies. It can also lay the foundation for improving urban air quality and solving regional complex air pollution problems\textsuperscript{[3]}. This study used methods such as field study, data and statistical yearbook queries to investigate the main types of taxis in Tangshan City. Based on the selection of typical taxi vehicles, combined with the actual road characteristics of Tangshan, it selected representative roads, and investigated the driving characteristics and emissions of actual roads by using the Portable Emissions Measurement System (PEMS).
This study is expected to deepen our understanding of the characteristics of regional or local taxi pollution, and to scientifically formulate targeted improvement measures for taxi pollution control [4].

2. Test method and data processing

2.1. Test general situation
Vehicle exhaust emission test is to use a Portable Emission Measurement System (of PEMS) installed directly in a vehicle traveling in the actual road, collect the vehicle driving parameters and the exhaust pollutant concentration by second [5], and provide reliable data for the analysis of vehicle exhaust emission characteristics [6].

This article uses SEMTECH on board emission tester to test the emission of gaseous pollutants (CO, NOx, THC, CO2, etc.) on actual roads [7]. The position of the vehicle are measured and recorded by GPS. The vehicle speed is read by the OBD. At the same time, an Electrical Low Pressure Impactor (ELPI+) is used to record the number and concentration of PM.

This article investigates the types of vehicles in Tangshan City, and through field investigation. Three taxis are selected according to the emission standards. Considering that most taxis in Tangshan city are transformed into natural gas fuel vehicles, we selected vehicles which burn gasoline and natural gas.

Table 1 Detailed parameters of test vehicles in Tangshan City

| Serial number | Fuel            | Total mass (kg) | Displacement (L) | Emission Standards | Mileage (km) |
|---------------|-----------------|-----------------|------------------|--------------------|--------------|
| No.1          | Gasoline /CNG   | 1.646           | 1.6              | National V         | 127,978      |
| No.2          | Gasoline /CNG   | 1.646           | 1.6              | National III       | 723,303      |
| No.3          | Gasoline /CNG   | 1.767           | 2.0              | National III       | 677,896      |

2.2. Test routes
The regulations stipulate the test route, which shall include urban roads, suburban roads, and highways, allowing the actual composition ratio to have a deviation of ±5%. The difference in altitude between the starting point and the ending point of the test shall not exceed 100 m, and the cumulative positive altitude increase of the test vehicle shall not exceed 1200 m/100 km. The taxi test routes fully cover typical expressways, trunk roads, secondary trunk roads, branch roads, and intersections at various types or levels of roads.

Figure 1 PEMS test route
2.3. Driving parameters

In this study, average speed (V), acceleration (a) and relative positive acceleration (RPA) are used as statistical characteristic parameters describing the driving of motor vehicles.

The working conditions experienced by the vehicles when driving on the actual road are complex and changeable, which can be roughly divided into the following four working conditions: acceleration working condition, deceleration working condition, constant speed working condition and idle working condition.

In this study, the criteria for acceleration conditions, deceleration conditions, constant speed conditions and idle conditions are as Table 2.

| working condition          | Acceleration (a) / Velocity (v) |
|----------------------------|---------------------------------|
| Acceleration working condition | a ≥ 0.14m/s^2                   |
| Deceleration working condition | a ≤ -0.14m/s^2                 |
| Constant speed working condition | a < 0.14m/s^2, v ≥ 1km/h       |
| Idle working condition     | a < 0.14m/s^2, v < 1km/h       |

3. Analysis of driving characteristics

The distribution of the speed and acceleration of the taxi in the actual driving process is shown in the figure 2.

![Figure 2 The acceleration distribution condition](image1)

![Figure 3 The RPA distribution condition](image2)

The driving state of taxis is more complicated, with the highest speed of about 110 km/h and the widest acceleration distribution, which is concentrated in [-4.5,4.5]m/s^2. Considering the parameters that affect fuel consumption and emissions of the vehicle's engine acceleration during an operating cycle, RPA can reflect the acceleration performance of vehicle in actual driving. Figure 3 shows the distribution of speed and relative positive acceleration during driving. It can be seen from Figure 3 that the relative positive acceleration of taxis has a wide distribution, It can be seen that it is very obvious in the low speed stage, there are more frequent acceleration and deceleration behaviors, so the driving behavior is more intense.

4. Research on actual road emission factors of motor vehicles

In this study, the emission characteristics of motor vehicles are expressed by the pollutants emitted per unit distance. The average emission factor of this working condition can be obtained (G/km) by calculating the pollutant emission amount (g) for a certain distance, and dividing it by the distance or the driving mileage (km) of this working condition. This method can directly express the characteristics of the relationship between pollutants and vehicle driving conditions.
4.1 Calculation of basic emission factors

Regarding CO, the value of national III standard taxis using gasoline as fuel is higher (7.1 ~ 17.2 g/km), which is about 6.5 ~ 15.8 times of national V standard taxis. When natural gas is used as fuel, its CO value can be significantly reduced by 87.8% ~ 92.0%. However, for taxis with national V standard, when natural gas is used as fuel, CO emission is also slightly reduced by 27.2%. For CO₂, Taxi National V No.1 and National III No.2 have no significant difference in emissions, but both of their emissions are significantly lower than that of No.3 National III vehicles, indicating that taxi CO₂ is related to vehicle displacement and vehicle quality, and No.3 taxis have the largest displacement and total mass (see Table 2-2). In addition, when taxis use natural gas, their CO₂ is obviously degraded, and No.1, No.2 and No.3 are decreased by 19.7%, 19.5% and 32.1% respectively, compared with that of taxis using natural gas, indicating that the CO₂ reduction effect of large displacement taxis is more obvious. For NOx, taxi emission is the lowest (1.17 g/km), and the emission of national V vehicle (0.08 g/km) is obviously lower than that of national III vehicle (1.72 g/km), which is about 95.1% lower. At the same time, the use of natural gas has no obvious effect on NOx in taxis.

Among the taxis, the particulate matter emissions of National V vehicles have not been lower than those of National III vehicles following the tightening of emission standards. However, when using natural gas, the emissions of the No. 3 taxis have increased, and the emissions of the other two taxis have been significantly reduced. This may be related to the engine control technology of the taxi brand.

5. Analysis of specific power emission rate of motor vehicles

5.1. Motor vehicles specific power VSP

Referring to the IVE model and MOVES model, according to the vehicle running state (deceleration, idling, acceleration, constant speed) and VSP size, the transient condition of motor vehicle is divided into 38 VSP bin (Table 3). Each VSP-bin corresponds to one emission level, based on which the corresponding
relationship between the transient operating conditions of the motor vehicles and the emission can be established.

Table 3 38 VSP bin classification criteria based on the operating state of the vehicle and VSP

| VSP (Kw/t) | Low speed (1.6 km/h<ν<40 km/h) | Middle speed (40 km/h<ν<80 km/h) | High speed (ν≥80 km/h) | Idling (0≤ν<1.6 km/h) | Deceleration (a<1 m/s²) |
|------------|---------------------------------|---------------------------------|-----------------------|-----------------------|------------------------|
| ≤-8        | bin2                            | bin14                           | bin26                  |                       |                        |
| (-8,-6]    | bin3                            | bin15                           | bin27                  |                       |                        |
| (-6,-4]    | bin4                            | bin16                           | bin28                  |                       |                        |
| (-4,-2]    | bin5                            | bin17                           | bin29                  |                       |                        |
| (-2,0]     | bin6                            | bin18                           | bin30                  |                       |                        |
| (0,2]      | bin7                            | bin19                           | bin31                  |                       |                        |
| (2,4]      | bin8                            | bin20                           | bin32                  |                       |                        |
| (4,6]      | bin9                            | bin21                           | bin33                  |                       |                        |
| (6,8]      | bin10                           | bin22                           | bin34                  |                       |                        |
| (8,10]     | bin11                           | bin23                           | bin35                  |                       |                        |
| (10,12]    | bin12                           | bin24                           | bin36                  |                       |                        |
| >12        | bin13                           | bin25                           | bin37                  |                       |                        |

Note: a is acceleration, ν is speed

5.2. Emission rate based on VSP

Figure 5 The change of emission rate of pollutants in different VSP intervals of taxis
The variation of taxi gaseous and particulate emission rates with the VSP interval is shown in Figure 5, respectively. The discharge rate of different pollutants increases with the increase of speed in low speed, medium speed and high speed regions.

For CO, the change of national III gasoline vehicle is the most obvious, and the increase rate with the increase of VSP speed is the highest in different speed ranges; for CO₂, the changes of the four cars are more consistent, and in different speed ranges, with the increase of VSP, they all increase rapidly; For NOx, its changing trend is mainly related to emission standards, the two National III vehicles are more consistent, while the two National V vehicles are more consistent.

For the quality of particulate matter, the four vehicles became more consistent; but for the quantity of particulate matter, the change in the national III gasoline vehicles is the most obvious.

6. Conclusion
The project team selected three taxis in the built-up area of Tangshan to conduct actual road emissions and chose gasoline and CNG, National III and National V taxis to carry out actual road emission tests. The study found that with the tightening of emission standards, single-vehicle pollutant emissions were reduced, and NOx emissions were reduced by more than 90%. Compared with gasoline fuel, CO₂ and NOx emissions of CNG fuel taxis showed a downward trend. The CO emissions of National III taxis were the highest, which were 6.5 to 15.8 times that of the National V taxis. With the tightening of emission standards, the emissions of the National V vehicles (0.08 g/km) were significantly lower than those of the National III (1.72 g/km) vehicles, which were about 95.1% lower. When natural gas was used as fuel, it could reduce CO and CO₂ emissions from taxis by 27.2%-92.0% and 19.5%-32.1%.

Both the CO and CO₂ emission factors of taxis decreased with the increase of speed, and the emission of National III gasoline was relatively high. In different speed ranges, the NOx emissions of National III taxis were significantly higher than those of National V. But as the speed increased, National III natural gas taxis showed a trend of first rising and then falling, while National III gasoline taxis showed a downward trend and then rose. For particulate matter, both the quantity and quality emission factors showed a trend of first decline and then increased with the increase of speed, and the rising speed was obviously accelerated in the high-speed stage.

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