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Research on CO Pollution Control of Motor Vehicle Exhaust

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Abstract: Carbon monoxide (CO) is harmful to our health, and even causes death. The main source of CO is automobile exhaust. Therefore, this article determines that CO is the emission factor, and finally the evaluation model is established. The model provides an important basis for the highway construction project design, traffic management, environmental pollution control, energy saving, environmental evaluation and so on. Compared with the traditional method that calculates the road traffic volume through the air emissions model, according to the total amount of air pollution control, this paper builds the emission diffusion model, which calculates the road traffic volume by road exhaust density. First of all, this paper measures CO emissions by testing 435 multifunction detectors from Shanghai typical roads, and compares the results with the national standard control. According to the standard in automobile exhaust emissions, the extreme values of the traffic volume over the road are calculated. Finally, the model's reasonableness and accuracy are validated through case study. The results from case analysis show that the evaluation model is of great practical significance.

Keywords: Highway transportation, traffic volume limit, emission control, carbon monoxide.

1 Introduction

Carbon monoxide (CO) is the largest and most widely distributed air pollutant and one of the main pollutants produced during combustion. Careful monitoring and controlling of CO emissions has been a national concern because it is harmful to health and can even kill people. The main source of CO is automobile exhaust. With the development of highway construction, the increase of highway mileage and the number of motor vehicles, the situation of natural environmental pollution caused by road traffic becomes increasingly serious. Especially in the case of heavy traffic, the impact of traffic pollution is the most serious. According to the investigation made by the environmental protection department, in Beijing, Shanghai, Guangzhou and other cities, the contribution rate of motor vehicles to CO, HC and NOx in the urban atmosphere has exceeded 50%, and even reached 90%, which means that motor vehicles have become the main pollution source of urban air pollution in China.

Therefore, this paper studies the relationship between CO emission and the traffic volume in tail gas, thus providing an important basis for highway construction project

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design, traffic control, environmental pollution control, energy conservation and emission reduction. CO was identified as the emission factor in this paper. Furthermore, transportation big data [Sun and McIntosh (2018)], data mining [Zhou, Liang, Li et al. (2018); Xia, Song, Jing et al. (2018)] and value capture [Liu, Wang and Wang (2018)] were also applied in such analysis. The traditional research on automobile exhaust emission is based on the automobile exhaust emission model and the gas diffusion model. This article uses the reverse thinking, total amount control of atmospheric pollution, and regional atmospheric environmental quality that meets the national standards for the purpose of exhaust emissions, and then, the deduction under the discharge standard road traffic is allowed.

2 The calculation method

2.1 The exhaust gas conversion model

The exhaust gas measurement device was the testosterone 435 multifunctional detector, and the measured unit was PPM [Gu and Li (2002)]. In order to facilitate the study, PPM was usually converted to mg/m^3 through the exhaust gas conversion model, and it stands for parts per million, or the percentage. For example, 1 PPM or 1,000,000 kg of solution contains 1 kg of solute. PPM is the same as the percentage (%), except that it has a larger percentage than the percentage.

There are two ways to express the concentration of pollutants in the environmental atmosphere (air): 1. 2. Volume solubility notation: the volume of pollutants contained in 1,000,000 volume air, i.e., PPM. However, the standard specifications of our country are also expressed in units of mass concentration (e.g., mg/m^3). Using the mass concentration unit (mg/m^3) as the expression method of air pollutant concentration is convenient for calculating the true amount of air pollutant. However, the mass concentration is related to the temperature and pressure environment conditions of the gas. It is necessary to measure the temperature and atmospheric pressure of the gas at the same time. When PPM is used to describe pollutant concentration, this problem will not occur because the volume ratio is adopted.

The conversion of concentration unit PPM and mg/m^3 is as follows:

$$\text{Mass concentration}_{\text{i}} = \frac{\text{M}}{22.4} \times ppm \times \frac{273}{373+T} \times \frac{B\text{a}}{101325} \tag{1}$$

where the mass concentration is that of gas I, mg/m^3; M is the molecular mass of gas; T is the gas temperature, and Ba is the atmospheric pressure.

The converted exhaust pollution value can be referred to whether the following table meets the standards. The first-order concentration limit is applicable to the first class zone, and the second-class concentration limit is applicable to the second class zone [China Academy of Environmental Sciences (2017)].

2.2 A value method of exhaust emission limit

To have a common evaluation benchmark in each city, it is specified that all cities must adopt a value method [The National Environmental Protection Bureau (1991)] to calculate the ideal atmospheric environment capacity of the city. The specific formula is as follows:

$$\text{p}_{\text{a}i} = A \times C_{st} \times \sqrt{S} \tag{2}$$

where Pai is the annual allowable pollutant emission of functional area i (unit g); A is the control coefficient, as shown in Tab. 3; S is the total area of the control area, (unit km^2); Cst is the hourly average concentration limit of a certain pollutant in region i, and g/m^3 can be found according to the environmental air quality standard. The specific value is shown in Tab. 2.

A is a range. In order to make the verification of the atmospheric capacity more comparable, a certain value is recommended to increase the difference by 10% on the basis of the minimum value. Recommended value A and the sharing rate are shown in Tab. 1. It is recommended that all cities calculate the air capacity according to the recommended value.

Table 1: Capacity control coefficient A of China

No.	Province (city) name	A	Recommended value	α
1	Xinjiang, Tibet and Qinghai	7.0-8.4	7.14	0.15
2	Heilongjiang, Jilin, Liaoning, Inner Mongolia (north of Yinshan)	5.6-7.0	5.74	0.24
3	Beijing, Tianjin, Hebei, Henan, Shandong	4.2-5.6	4.34	0.15
4	Inner Mongolia (South of Yinshan), Shanxi, Shaanxi (north of Qinling), etc.	3.5-4.9	3.64	0.20
5	Shanghai, Guangdong, Guangxi, Hunan, Hubei, Jiangsu, Zhejiang, Anhui, etc.	3.5-4.9	3.64	0.25
6	Yunnan, Guizhou, Sichuan, Gansu (south of Weihe), Shanxi (south of Qinling)	2.8-4.2	2.94	0.15
7	Calm area (average annual wind speed less than 1 m/s)	1.4-2.8	1.54	0.25

Note: from the preparation outline of the technical report on urban air environmental capacity assessment.

2.3 Establishment of the automobile exhaust emission model

Based on the traffic volume of small cars, medium cars and large cars on the route, the pollutant emissions of traffic flow were calculated by multiplying the emission factors of each type of vehicle by the respective traffic volume. The air pollutant emission of highway vehicles is calculated in the following formula [He, Ping and Liu (2012)]:

$$P_i = \sum_{j=1}^{3} E_{ij} \times F_j \times L \tag{3}$$

where Pi is the emission of class I atmospheric pollutants, g; Eij is the emission factor of class I air pollutants of type j vehicle, $g/(km^2)$, as shown in Tab. 2; Fj is type j vehicle flow, vehicle /h, j=1,2,3, which means small cars, medium cars and large cars respectively, and L is the length of the line, km.

Table 2: Recommended values of vehicle emission factor (g/km·vehicle)

Average speed (km/h)		50.00	60.00	70.00	80.00	90.00	100.00
Small car	CO	31.34	23.68	17.90	14.76	10.24	7.72
	THC	8.14	6.70	6.06	5.30	4.66	4.02
	NOX	1.77	2.37	2.96	3.71	3.85	3.99
Medium car	CO	30.18	26.19	24.76	25.47	28.55	34.78
	THC	15.21	12.42	11.02	10.10	9.42	9.10
	NOX	5.40	6.30	7.20	8.30	8.80	9.30
Large car	CO	5.25	4.48	4.10	4.01	4.23	4.77
	THC	2.08	1.79	1.58	1.45	1.38	1.35
	NOX	10.44	10.48	11.10	14.71	15.64	18.38

Note: The value comes from the environmental impact assessment standard for highway construction projects [The Institute of Highway Science, the Ministry of Communications (2016)].

3 Establishment of the evaluation model

Obviously, the following equation can be established through an equation, such as the allowable emission limit of atmospheric pollutants and the traffic exhaust emission model.

$$P_{ai} = P_{ai} \tag{4}$$

$$\sum_{i=1}^{3} A \times (C_{si} - C_{bi}) \times \sqrt{S} = \sum_{j=1}^{3} E_{ij} \times F_j \times L \tag{5}$$

$$F = \sum_{j=1}^{3} F_j \tag{6}$$

Through derivation, the traffic volume can be obtained:

$$F = \sum_{j=1}^{3} F_j = \frac{P_{ai}}{\sum_{j=1}^{3} E_{ij} \times L} = \frac{A \times C_{st} \times \sqrt{S}}{\sum_{j=1}^{3} E_{ij} \times L} = \frac{A \times C_{st}}{\sum_{j=1}^{3} E_{ij}} \bullet \sqrt{\frac{\mathrm{m}}{L}} \tag{7}$$

Note: this traffic volume is the mixed traffic volume

In formula (4), it can be seen in a particular section of the road, if road highway mileage L and width m are already known, vehicle emission factor Eij, control factor A and emission limit Pai can be checked by the table, and then F can be solved.

4 Case analysis

The main trunk road of Yangpu District, Shanghai, has a length of 10 km, and the research scope is 1 km, from Zhoujiakou Road to Guanjiang Road, with two-way 8 lanes and 4 expressways, with a total width of 40 m, which is in the second-level standard evaluation area. When calculating the allowable traffic volume of this section, the exhaust emission will not exceed the limit. Through Testo435 multifunctional detector measure, the region’s actual CO value is: CO emission of 6 PPM, gas temperature of 8.9°C and atmospheric pressure of 102700 pa.

The solution: substitute into Eq. (1), and the mass concentration of CO is:

$$\text{Mass concentration}_{CO} = \frac{28}{22.4} \times 6 \times \frac{273}{373+8.9} \times \frac{102700}{101325} = 5.43\text{g}/m^3 \quad (8)$$

According to the survey on the average speed of 60 km/h in this region, the CO emissions of large, medium and small models can be obtained from Tab. 3 (g/(km)), and they are 4.48, 26.19 and 23.68 accordingly. The values of A and Cst can be found in the table, and the traffic volume at the concentration of 3.62 g/m^3 can be obtained by substituting into Eq. (4):

$$F = \frac{3.64 \times 5.43}{4.48 + 26.19 + 23.68} \times \sqrt{\frac{40}{1000}} = 261\text{veh / h} \quad (9)$$

The traffic volume under the level 2 standard of concentration limit of basic environmental air pollutants is:

$$F = \frac{3.64 \times 10}{4.48 + 26.19 + 23.68} \times \sqrt{\frac{40}{1000}} = 480\text{veh / h} \quad (10)$$

According to the calculation results, 3.62 mg/m^3 is much smaller than 10 mg/m^3, the environmental air quality monitoring standard (Tab. 2). The area of automobile exhaust CO emissions meets environmental construction quality inspection specifications with 10 g/m^3. Through the calculation of average hourly concentration of measured 3.62 g/m^3, the traffic is: 261 pcu/h that maximally satisfies the speed 480 m/h. After the peak hour field survey, the traffic volume is 290 vehicles per hour. There is a certain error between the calculated result and the actual value, but the error is small.

5 Conclusion

Starting from the traffic volume and vehicle emission factors, this paper determines that CO emission from automobile exhaust is the main research object. The calculation model of vehicle exhaust is established. The hourly traffic limit of a road in Yangpu District is estimated quantitatively by an example. The reliability of the model is verified by field investigation. The conclusion is as follows: The mass concentration of a certain road in Yangpu District is 3.62 mg/m^3, which conforms to the environmental quality monitoring standard, and the maximum hourly traffic volume of tail gas emission under the standard is 480 vehicles/hour. The number of hybrid vehicles surveyed was 290 vehicles per hour and less than 480 vehicles per hour. The evaluation model can provide important basis for highway construction project design, traffic control, environmental pollution control, energy saving and emission reduction.

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