

# Chapter 7

## Research on the Present Situation and Factors of Volatile Organic Compounds in Car Cabin

Jiabao Ren, Shujie Xu, Xuefeng Liu, Wei Liu and Enyou Cui

**Abstract** This article analyzed cabin indoor VOCs emission of more than 400 vehicles in attainment rate, average concentration and distribution situation. Result showed that in the past two years, the average concentrations of VOCs in vehicle decreased, but the overall compliance rate was still not high, acetaldehyde becoming limiting factor of overall compliance level. Meanwhile, this paper studies the relationship between sampling time, temperature, seasonal factors and VOCs detection results. The results provide a basis for the revision of the vehicle VOCs testing standards and manufacturing enterprise can use it to predict VOCs detection results.

**Keywords** Vehicle · Vehicle indoor air quality · Volatile organic compounds · VOCs · VIAQ

### 7.1 Preface

In recent years, with the improvement of people's living standards, people are more strict with cabin interior environment, vehicle indoor air quality has become one of the bottlenecks in the development of China's automotive industry. The Ministry of Environmental Protection of the People's Republic of China has promulgated national standard the HJ/T 400 "Determination of Volatile Organic Compounds and Carbonyl Compounds in Cabin of Vehicles" and GB/T 27630 "Guideline for air quality assessment of passenger car", setting vehicle VOCs detection method as well as VOCs concentration limit in vehicle, guiding the direction for domestic automobile enterprises (Table 7.1).

---

J. Ren (✉) · S. Xu · X. Liu · W. Liu  
China Automotive Technology & Research Center, Tianjin, China  
e-mail: renjiabao@catarc.ac.cn

E. Cui  
Ningbo Automotive Component Testing CO., Ltd., Ningbo, China

Domestic experts focusing on vehicle indoor air quality also carried out in-depth study, Professor Ge Yunshan conducted a thorough research on the method of air quality inspection, and compare the volatile substances in the car with that in bus [1, 2]. Liu Xuefeng studied the present situation of VIAQ pollution in China's automobile products, and put forward some constructive suggestions for government [3]. However, domestic research has the problems with small sample size, lacking of effective data mining techniques and so on. In this paper, the VOCs of a large number of domestic and foreign cars was analyzed, and the influence of sampling time, temperature and seasonal factors on the VOCs detection results were analyzed. The results provide a basis for the revision of the vehicle VOCs testing standards and manufacturing enterprise can use it to predict VOCs detection results.

## 7.2 Data

### 7.2.1 Data Sources

China has the largest automotive production and market in the world, and the manufacturers have accumulates certain experience about air quality control in cabin. China Automotive Technology and Research Center has done a lot of research work on VOCs, and collected hundreds of VOCs test data. Suspicious data were deleted to guarantee the reliability (Table 7.2).

**Table 7.1** Limit value of VOCs concentration in the air of cabin in GB/T 27630—2011 (unit: mg/m<sup>3</sup>)

Category	Name	Limit value
Benzene chemicals	Benzene	≤ 0.11
	Toluene	≤ 1.10
	Ethylbenzene	≤ 1.50
	Xylene	≤ 1.50
	Styrene	≤ 0.26
Aldehydes and ketones	Formaldehyde	≤ 0.10
	Acetaldehyde	≤ 0.05
	Propylene aldehyde	≤ 0.05

**Table 7.2** Basic data information

Contents	Details
Test condition	Test date and place
Vehicle information	Vehicle type, production date, interior configuration
VOCs emission situation	The concentration of benzene, toluene, ethylbenzene xylene, styrene, formaldehyde, acetaldehyde, acrolein

### 7.3 Analysis on VOCs Emission of Vehicle in China

Based on the data collected in recent 2 years, this paper made a comprehensive analysis of the air quality in the domestic car from attainment rate, the mean value of eight hazardous substances and overall data distribution. Because attainment rate of propylene aldehyde is 100%, this article does not do the correlation analysis on it.

#### 7.3.1 Attainment Rate

Figure 7.1 showed the attainment rate of vehicle and seven kinds of VOCs, it described that, compared to 2014, the air quality in China’s automotive products had been greatly improved in 2015. Attainment rate of benzene and propylene was 100%, and attainment rate of other substances increased by 2%, acetaldehyde has become the limiting factor to improve the attainment rate. Vehicle attainment rate has improved 3% in 2015, reaching 48%.

#### 7.3.2 The Mean Value

The average value of VOCs concentration reflects the automobile enterprise VOC management and control level. In order to compare various harmful substances directly, we design the dimensionless mean value coefficient  $k$ .

$$k = \frac{\text{Average value of the concentration of certain volatile substance}}{\text{The material limits prescribed in national standard}}$$

Figure 7.2 showed the  $k$  value of 2014 and 2015, the figure described that enterprise had a different control capabilities of different hazardous substances.

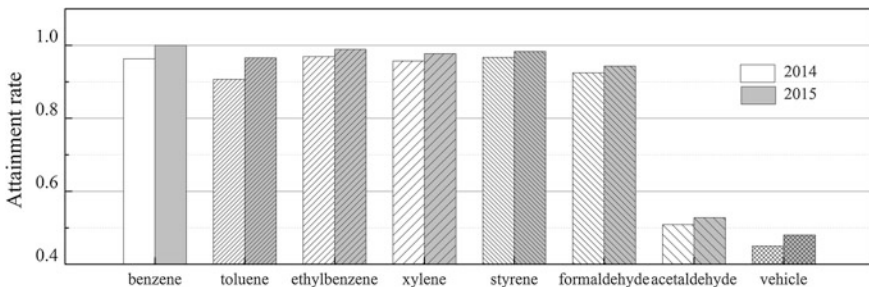


Fig. 7.1 Attainment rate of VOCs and vehicles

In 2014, acetaldehyde, benzene, toluene were more likely to exceed the standard, however, the concentration of benzene had reduced by 70% in 2015, and the order of the substances changed, meanwhile, xylene and toluene reduced a lot.

### 7.3.3 Data Distribution in 2015

In order to study the overall situation of VOCs emitting in China, we define the ratio coefficient  $h$ .

$$h = \frac{\text{Concentration of volatile harmful substances}}{\text{The material limits prescribed in national standard}}$$

Figure 7.3 showed part of the collected VOCs data with box chart. In the picture, the vertical coordinate represent  $h$  and the horizontal coordinates represent

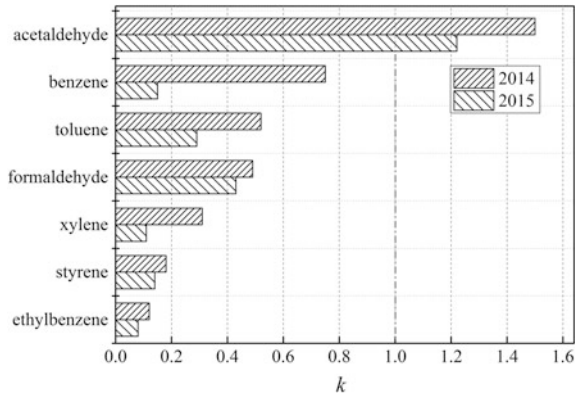


Fig. 7.2  $k$  of 2014 and 2015

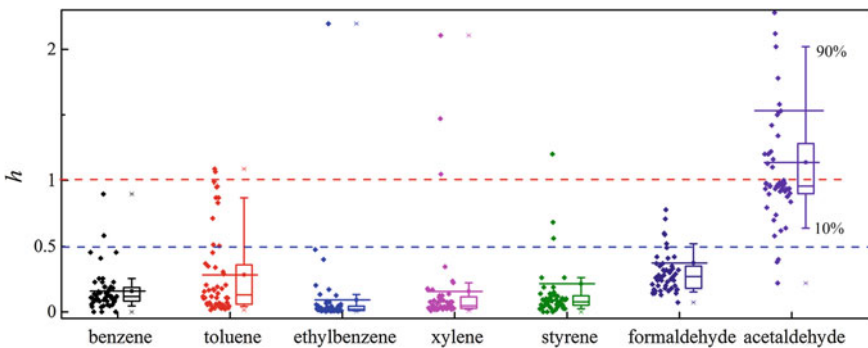


Fig. 7.3 VOCs distribution in 2015

**Table 7.3** Statistical analysis of VOC data in 2015

Substance	National standard limit (mg/m <sup>3</sup> )	Mean value (mg/m <sup>3</sup> )	Median (mg/m <sup>3</sup> )	<i>k</i>	Coefficient of variation
Benzene	0.11	0.02	0.013	0.15	0.78
Toluene	1.1	0.32	0.14	0.29	1.19
Ethylbenzene	1.5	0.12	0.026	0.08	3.75
Xylene	1.5	0.16	0.06	0.11	2.59
Styrene	0.26	0.04	0.014	0.14	3.08
Formaldehyde	0.1	0.05	0.04	0.42	1
Acetaldehyde	0.05	0.06	0.05	1.22	0.62

concentration of seven kinds of harmful substances. It was shown that, the VOCs concentration in different vehicle varied dramatically, data of formaldehyde and acetaldehyde was more dispersed than others. Besides, the data in 2015 were statistically analyzed, the results were as follows (Table 7.3).

According to statistical analysis above, mean value shows that acetaldehyde was more difficult to control, coefficient of variation showed that discrete degree of ethylbenzene, styrene and xylene was larger than others, reflecting enterprises had different management and control capabilities about the three substances.

## 7.4 Study on Influencing of Sample Time, Testing Temperature and Seasonal Factors

Air quality in car is affected by many factors. In this paper, based on the investigating data, combined with data from test, the influence of sample time, test temperature and season were studied. In the process, formaldehyde was used to represent aldehydes, and toluene was used to represent benzene.

### 7.4.1 Effect of Sample Time on VOCs Test

Vehicle would gradually release VOCs in daily use. Part of the VOCs were left in the producing process, such as volatile solvents in adhesives, others were decomposed from interior parts, such as decomposing from instrument panel under sun light. In this paper, the VOCs concentration changes of a normal used car was recorded.

Figure 7.4 showed the change of formaldehyde and toluene in the cabin in 0–300 days leaving assembly line, assuming that the initial emission concentration is 1, the following conclusions are drawn:

As can be seen in Fig. 7.4, the concentration of formaldehyde and toluene reduced gradually in cabin. 50 day is a key point in the picture, after 50 days

leaving assembly line, the concentrations of each reach just half of that on the assembly line.

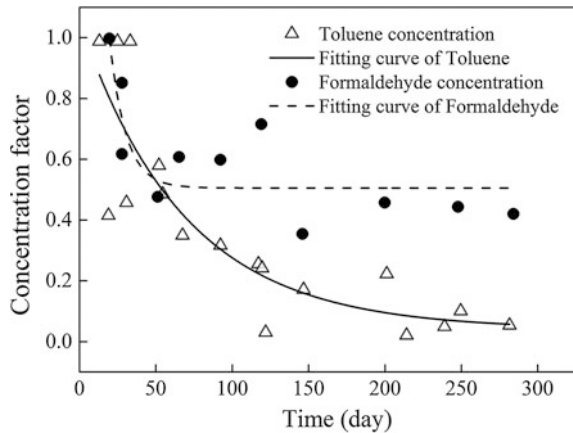
The decay rate of formaldehyde is less than toluene. The figure showed that after the concentration of the formaldehyde reduced to half of that in factory, change with time is no longer obvious, but toluene concentration still decreased with the time.

It was concluded that after the product leaving assembly line, formaldehyde concentration was more easier be influences by the surrounding environmental than toluene. So, formaldehyde was more difficult to control than toluene for enterprises.

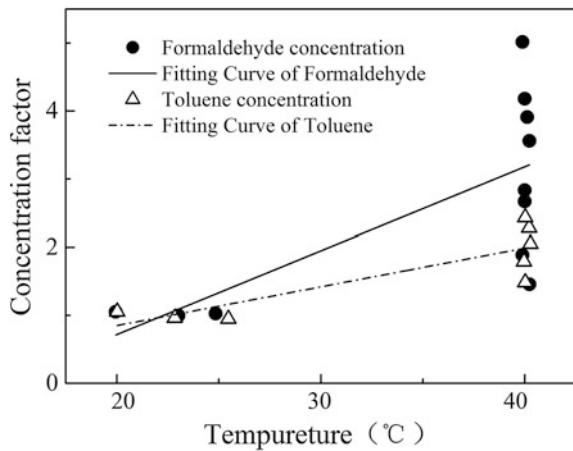
### 7.4.2 Effect of Temperature on VOCs Test

The VOCs in vehicle cabin is small molecules, and the effect of temperature on the movement of small molecules is obvious. Figure 7.5 shows the distribution of the

**Fig. 7.4** The concentration of formaldehyde and toluene changed with time



**Fig. 7.5** The concentration of formaldehyde and toluene changed with temperature



concentration of formaldehyde and toluene with the detection of temperature changes.

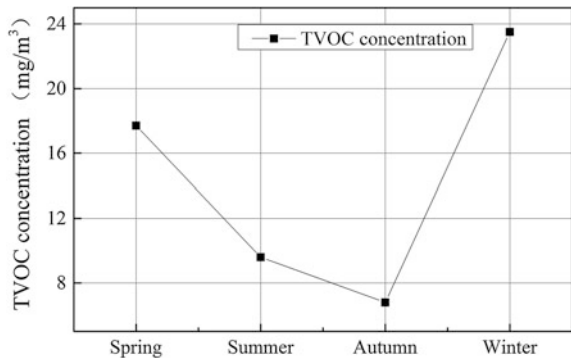
The concentration of formaldehyde and toluene increased with temperature rise. Formaldehyde concentration increased at a faster rate than toluene. As can be seen from the figure, when the temperature rose from 20 to 40 °C, the formaldehyde concentration increased by about 2 times and the concentration of toluene increased by about 1 times.

### 7.4.3 VOCs Test in Different Seasons

Many experts pointed out that the VOCs concentration detected in different season different a lot. So, the relationship between VOCs emission and the test season was studied.

In the figure above, the coordinates represent the four seasons in one year, and the vertical coordinate represents the average value of certain VOCs concentration detected in this season.

**Fig. 7.6** TVOC concentration detected in different seasons



**Fig. 7.7** Toluene concentration detected in different seasons

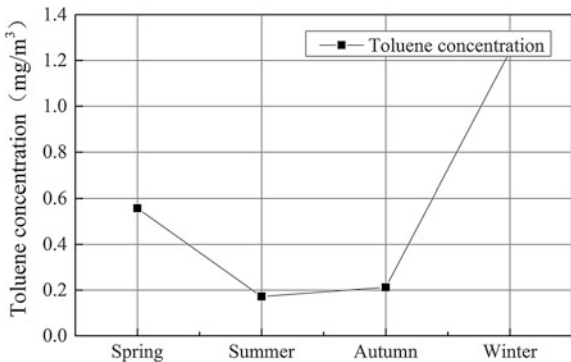


Figure 7.6 showed that TVOC data was sensitive to seasonal factors, of which the average of winter ( $23.5 \text{ mg/m}^3$ ) was 3.45 times of that of autumn ( $6.8 \text{ mg/m}^3$ ). Figure 7.7 showed the data of toluene, the average of winter ( $1.2 \text{ mg/m}^3$ ) was 6 times of that of summer ( $0.19 \text{ mg/m}^3$ ).

Due to different vehicle models were used for statistics, the number of data in different seasons was also different, so it was not scientific to derive a mathematical formula with the data. However, these data proved that season had certain influence on VOCs test. The relationship between the VOCs emission and the season remains to be further studied.

## 7.5 Conclusions

This article analyzed air quality of nearly 400 vehicles through attainment rate, mean value of VOCs concentration and data distribution in 2015. Through the work, it was more convenient for enterprises to quickly locate their level and made reasonable planning of the car VOCs control work.

By analyzing the influence of sampling time, temperature and seasonal factors on VOCs testing, it made a reference to revise existing VOCs testing standards.

At the same time, it also provided a basis for the vehicle enterprises to predict vehicle VOCs concentration after leaving the factory.

## References

1. Ge Y (2006) In-car air pollution and its testing technology. *Automot Eng* 28(5):495–503
2. Ge Y (2009) Measurement of in-vehicle concentration of volatile organic compounds. *Automot Eng* 31(3):271–277
3. Liu X (2015) Situation and management policy about China's car VOC. *Environ Sustain Dev* 5:26–29