Study on emission characteristics and health effects of volatile organic compounds in child seats

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Abstract. This paper takes two mainstream child seats on the market as the research object, based on the test standard of volatile organic compounds (VOCs) and the objective odor test standard of components and parts assembly, and under 25°C standard condition, the emission concentration of VOCs and the odor objective level of the two seats were detected to understand the VOCs emission and odor performance of the child seats. Gas chromatography-mass spectrometry (GC-MS) was used to analyze the whole spectrum, and the odor threshold database was used to screen out the key odor components contributing to the odor in the car. According to the WHO-IARC to analyze the carcinogenicity of key odor contributing substances. The results show that the odor performance of the two types of child seats is in average level, and the objective odor intensity were 3.3 and 3.7. The emission of Formaldehyde, Acetaldehyde and Benzene of the two seats were significantly lower than the average value of the seat industry, while dimethylbenzene and Styrene were higher than the industry average. In addition, Benzothiazole, 2,6-Ditert-butyl-4-methyl phenol, Isooctanoic Acid, Cyclohexyl Isothiocyanate, etc. The above-mentioned high-risk odorants are harmful to health, which should be paid more attention by manufacturers.

1. Introduction
Affected by the COVID-19, the consumers' attention to the health of vehicles has been increasing. The Volatile Organic Compounds (VOCs) are the main pollutants in the vehicles, which mainly come from seats, carpets, roofs and other interior parts, as well as child seat and other parts that are in direct contact with human's body. Most of these substances are carcinogens, which do great harm to human liver, kidney, brain and nervous system, and seriously affect human health [1], in addition, some substances also have certain irritation, which will lead to car odor pollution. At present, China's vehicle odor level is between level 3-3.5 (level 1-6, level 1 is the best), and the odor performance of children's seats in this test is lower than the industry average level, so the situation is not optimistic.

China is a big country in the production and export of child seats, and its production and export volume are in the forefront of the world. In recent years, with the increasing awareness of the importance of using child seats and the improvement of relevant laws, the consumption of children's seats in China will gradually increase. Therefore, in order to pay attention to the development of children's physical and mental health and promote enterprises to strengthen management and control, it is necessary to carry out in-depth research on the health performance of child seats.
2. Experiment process
This test focuses on the emission characteristics of volatile organic compounds (VOCs) of child seats, mainly including odor performance, eight substances of VOCs and VOCs full spectrum substances [2]. As shown in Table 1.

| Test index          | Index items                                      | Focus points                                      |
|---------------------|--------------------------------------------------|--------------------------------------------------|
| Odor performance    | Subjective odor intensity, Objective odor intensity | Olfactory sensory stimulation level               |
| Eight substances of VOCs | Benzene, Toluene, Ethylbenzene, Dimethylbenzene, Styrene, Formaldehyde, Acetaldehyde and Acrolein | Emission performance of eight substances of VOCs controlled by vehicle regulation GB/T 27630 |
| Full spectrum substances of VOCs | Other VOCs substances that can be detected by GC-MS | Impact on odor and health                         |

The samples of this test are two best-selling child seats purchased from regular market channels, one for domestic and one for foreign brands, as shown in Table 2.

3. Results and discussion
3.1. Analysis of odor performance
When there is unpleasant odor in the vehicle, it will stimulate people's olfactory organs, and even cause psychological and physiological harm to the human body [3]. The current odor evaluation methods in automobile industry are mainly based on subjective evaluation of human beings, which have some problems such as great subjective influence, poor statistics and occupational health hazards, and can not meet the requirements of odor evaluation. The odor performance results of the two child seats in this test are shown in Table 3.
Table 3. A table with the comparison of odor performance results of child seats with industry average.

| Brand     | Subjective odor intensity | Objective odor intensity | Industry average |
|-----------|---------------------------|--------------------------|------------------|
| Goodbaby  | 3.5                       | 3.3                      | 3.0-3.5          |
| COSATTO   | 4.0                       | 3.7                      |                  |

It can be seen from Table 3 that the odor performance of the two child seats is average, compared with the average level of the industry, Goodbaby Brand is at the average level of the industry, while COSTATTO Brand performs poorly, exceeding the odor range of the industry, and the odor performance still needs to be improved. The deviation of subjective and objective odor intensity grade of the two products is less than 0.3, which indicates that the objective odor evaluation has good accuracy. At the same time, the objective odor evaluation method can accurately determine the odor level of samples, which has a great prospect for later application.

3.2. Analysis of eight VOCs

At present, China has established the national control standards for eight VOCs substances in vehicle, and various automobile enterprises have also established the control limits for VOCs in interior parts and materials. In the early stage, China Automotive Technology and Research Center Co., Ltd.(CATARC) accumulated VOCs data of 40 types of driver's fabric seats. Under the same detection conditions, the comparison data between the two types of child seats in this study and the industry average is shown in Table 4.

Table 4. A table with the comparison of the results of eight substances of VOCs in child seats with the industry average. (Unit: g/m³)

| Brand     | Benzene | Toluene | Ethylbenzene | Dimethylbenzene | Styrene | Formaldehyde | Acetaldehyde | Acrolein |
|-----------|---------|---------|--------------|-----------------|---------|--------------|--------------|----------|
| COSATTO   | N.D.    | 31.0    | 34.0         | 276.0           | 58.0    | 27.0         | 13.0         | N.D.     |
| Goodbaby  | N.D.    | 202.0   | 83.0         | 234.0           | 452.0   | 20.0         | 15.0         | N.D.     |
| Industry average | 7.1 | 114.7   | 40.1         | 213.8           | 38.7    | 195.5        | 139.4        | N.D.     |

It can be seen from Table 4 that the emission of Formaldehyde, Acetaldehyde and Benzene of the two child seats are significantly lower than the industry average, while Dimethylbenzene and Styrene are higher than the industry average. The Toluene, Ethylbenzene and Styrene of Goodbaby Brand were significantly higher than the industry average and COSTATTO Brand, especially the Styrene concentration was as high as 452 g/m³, more than 10 times higher than the industry average. In addition, Styrene is a suspected carcinogen (published by WHO-IARC), which can stimulate the nervous system and respiratory tract. Long term exposure may cause lung diseases, and enterprises need to focus on control [4].

3.3. Analysis of VOCs full spectrum substance

VOCs full spectrum analysis refers to the process of analyzing all the VOCs substance in the sample. CATARC has built a threshold database containing more than 2500 kinds of vehicle odor substances, the database was used to calculate the threshold dilution multiple of VOCs (threshold dilution multiple = detection concentration / olfactory threshold), and it is considered that VOCs with threshold dilution multiple greater than 1 have odor contribution, which will cause interference to human body. The specific analysis results are shown in Table 5.
Table 5. A table with the VOCs full spectrum analysis in child seats.

| No. | Chinese Name               | CAS Number | Threshold Dilution Multiple | COSATTO Brand | Goodbaby Brand |
|-----|---------------------------|------------|-----------------------------|---------------|----------------|
| 1   | Benzothiazole             | 95-16-9    | 247.4                       |               | /              |
| 2   | 2,6-Ditert-butyl-4-methyl Phenol | 128-37-0 | 229.5                       | 185.3         |               |
| 3   | 2,4-Ditertbutyl Phenol    | 96-76-4    | 47.8                        | 13.8          | 7.5            |
| 4   | Isooctanoic Acid          | 149-57-5   | 36.4                        | 40.1          | 7.5            |
| 5   | Longifolene               | 475-20-7   | 28.6                        | 7.5           |                |
| 6   | Cyclohexyl Isothiocyanate | 1122-82-3  | 22.1                        | 63.1          |                |
| 7   | Propanoic Acid            | 79-09-4    | 8.8                         | /             |                |
| 8   | 2-Phenyl-2-propanol       | 617-94-7   | 4.0                         | /             |                |
| 9   | 2-Methylnaphthalene       | 91-57-6    | 3.6                         | /             |                |
| 10  | Phenol                    | 108-95-2   | 2.3                         | /             |                |
| 11  | Hexadecane                | 544-76-3   | 1.9                         | /             |                |
| 12  | Nonyl Aldehyde            | 124-19-6   | /                           | 30.3          |                |
| 13  | Octyl Aldehyde            | 124-13-0   | /                           | 27.8          |                |
| 14  | Hexanal                   | 66-25-1    | /                           | 19.4          |                |
| 15  | Decyl Aldehyde            | 112-31-2   | /                           | 5.1           |                |
| 16  | Styrene                   | 100-42-5   | /                           | 4.4           |                |

It can be seen from Table 5 that some VOCs in child seats have strong odor, such as Benzothiazole, 2,6-Ditert-butyl-4-methyl phenol, Isooctanoic Acid, Cyclohexyl Isothiocyanate, etc. Benzothiazole has a quinoline like odor and is a highly toxic substance [5], 2,6-Ditert-butyl-4-methyl phenol has a certain odor and belongs to toxic substance, Isooctanoic Acid has bad smell and belongs to toxic substance, Cyclohexyl Isothiocyanate has pungent odor. The above-mentioned high-risk odor and health hazards should be paid great attention by manufacturers, and the product performance should be improved by strengthening technical research.

4. Results and discussion
The content of VOCs in the two child seats analyzed in this paper is relatively high. VOCs have a huge impact on human health, it can damage the liver, kidney, brain and nervous system, and cause memory loss and affect children's intellectual development and other serious consequences [6]. Therefore, it is urgent to formulate relevant standards for child seats.

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