A Study of the Ventilation Performance for Automobile Indoor Air Pollution Reduction

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ABSTRACT

In this study, we evaluated the ventilation performance of an automobile interior with the aim of minimizing the influence of harmful materials emitted from new cars. We measured the ventilation performance of a selected domestically manufactured passenger car by the concentration decay method using tracer gas. For a total of four cases of test conditions, we compared the ventilation volume and concentration of pollution materials. Under various settings for the internal circulation and external circulation of the air circulation unit, the automobile is started in the open air. This is because the volume of pollution materials emitted by indoor materials of an automobile is comparatively greater than the increase of ventilation frequency. In addition, it is believed that the serious pollution of indoor air of an automobile due to the discharge of indoor materials is significantly influenced by the ventilation of the car according to the operation of the fan.

1. INTRODUCTION

Recently, the indoor air quality of the environment of vehicles has become a major concern. Currently, social concerns related to sick house syndrome are also prevalent within the context of the automobile environment, where the similar sick car syndrome occurs. Motor vehicles emit a variety of air pollutants that are known to be associated with adverse health effects [Michael chertok 2004]. Contaminants appear in formaldehyde (HCHO), and Volatile Organic Compounds (VOCs) that are emitted from interior materials that are applied to new cars.

In major advanced countries, manufacturers have adopted their own measurement and management of Indoor Air Quality In 2007, the Ministry of Construction and Transportation in Korea suggested a "Recommended standard for Indoor Air Quality of new cars". In particular, the driver of a new automobile should follow the management guidelines for ventilation during the initial period of 90 days after delivery. In addition, they should ensure that the influence of harmful materials that affect the passenger is minimized. The purpose of this study is to evaluate ventilation performance of automobiles in order to minimize the influence of harmful materials emitted by new cars.

2. STATUS OF INDOOR AIR QUALITY IN A CAR

2.1 Status of Korea

In Korea, concerned administration departments established 'The basic plan of indoor air quality control' in December 2004, and in March 2005, selected detailed research projects of the indoor air quality control of new cars.

In order to meet the recommendation standards (draft) for a new car of several pollutants including formaldehyde, benzene, toluene, xylene, ethyl-benzene, and styrene, the initial concentrations after assembly, the time variations of the concentrations, and the ventilation feasibility were analyzed. In addition, a risk assessment was conducted for 36 new cars. The measurement concentration and recommendation standards are presented in table 1.

Table 1: New Car Indoor Concentration Guideline

Substance	Measured Concentration ($\mu g/m^3$)	Guideline ($\mu g/m^3$)
HCHO	22~145	250
Benzene	1~22	30
Toluene	30~832	1,000
Xylene	10~919	870
Ethyl Benzene	3~594	1,600
Styrene	1~71	300

2.2 Status of main countries

In 2007, ISO/CD 16000-2 was proposed as an appendix to ISO/TC146/SC6, and in October 2007, in “Car Interior", ISO/WD 16000-26 was proposed as an addition to 6WG of ISO/TC146/SC (Indoor air-Part 26: Road vehicle test stand-Specification and method for the determination of volatile organic compounds in car interiors.

As a voluntary measure to reduce VOC levels in automobiles, the Japan Automobile Manufacturers Association (JAMA) has made an effort to meet the indoor concentration criteria for 13 substances, as established by the Ministry of Health, Labor and Welfare in 2005.

In Germany, the German Quality Management System for the automobile industry (VDA) suggests the use of the VOC emission evaluation method for automobile interior materials, and the TÜV Rheinland group is operating the “Allergy Free" certification system for automobile interior materials.

In 2007, the State Environmental Protection Administration of China addressed the measurement methods used for air pollutants in cabins of different types of vehicles (M1, M2 and M3). As described above, some countries have created their own standards for measurement methods and for recommendation standards of total volatile organic compounds (TVOC) in automobile indoor air.

It is expected that worldwide environment restrictions will be endorsed through establishing international testing standards and guidelines such as ISO/WD 16000-26.

Furthermore, considering the standardization trends of the measurement techniques of volatile organic compounds in cars, further research on the ventilation effects within the car is also required.

3. METHODS

3.1 Overview of ventilation

There are two methods that have been used to remove indoor pollution materials known to cause problems such as new house syndrome and new car syndrome. The first method prevents outdoor pollution materials from flowing indoors, while the second method rapidly removes pollution materials that persist indoors.

In the former method, the origination source is either removed or modified to become non-harmful by changing its properties. In the latter method, pollution materials are either removed directly using an air cleaner or are diluted or discharged outdoors by ventilation.

The advantage of using ventilation is that it enables certain object pollution materials to be discharged outdoors even in cases where certain types of indoor pollution materials are not able to be detected. In particular, this method is considered to be the most effective method for improving Indoor Air Quality of newly manufactured automobiles by removing pollution materials that have complicated characteristics such as HCHO, VOCs, cigarette smoke, and bad smells.

3.2 Measuring methods of ventilation volume

Various tracer gas methods are used to measure ventilation volume. These methods vary according to the particular method used for injecting the tracer gas and the sampling method. Such methods include the concentration decay method, the constant injection method, and the constant concentration method, etc. SF_6, which is used in this study as the tracer gas, is nontoxic, harmless to the human body, and is chemically inert, making it safe, odorless and tasteless. In addition, it is inflammable, non-explosive and easy to detect as it does not exist in the outdoor air. The different types of tracer gas methods used are shown in Table 2.

Table 2: Type of Tracer Gas

Tracer Gas	MAK* Value ㎎/㎥(ppm)*
CO_2	9100(5000)
N_2O	180(100)
Sulphur hexafluoride (SF_6)	6100(1000)

* MAK values are published by the "Senatorial commission for the examination of hazardous working materials" of the German Science Foundation. The list of MAK values is annually checked and enlarged.

In this study, we measured the ventilation performance of a selected domestically manufactured passenger car by using the concentration decay method with a tracer gas. In addition, in order to achieve an even mixture for the tracer gas, N_2 90% and SF_6 10% were used.

3.3 Test conditions

A total of four different test conditions were applied and the ventilation volume and concentration of pollution materials were compared according to the internal circulation and external circulation settings of the air circulation unit when the automobile is started in the open air. In addition, ventilation volume and concentration of pollution materials were compared according to the internal circulation and external circulation settings of the air circulation fan after operating the ventilation fan. Test conditions are shown in Table 3.

Table 3: Automobile Air Circulation Test Condition

<table>
<tr><th>case</th><th>Engine</th><th>Fan</th><th>Air Circulation mode</th></tr>
<tr><td>1</td><td rowspan="4">on</td><td>off</td><td>internal</td></tr>
<tr><td>2</td><td>off</td><td>external</td></tr>
<tr><td>3</td><td>low(1)</td><td>internal</td></tr>
<tr><td>4</td><td>low(1)</td><td>external</td></tr>
</table>

We measured the concentration of the tracer gas by connecting a Teflon pipe to a gas monitor (INNOVA Multi-gas Monitor 1302) in order to collect the indoor air while the passenger car is stationary. The position for measuring the indoor pollution materials and ventilation volume of the automobile is located in the center of the automobile, as shown in Figure 1.

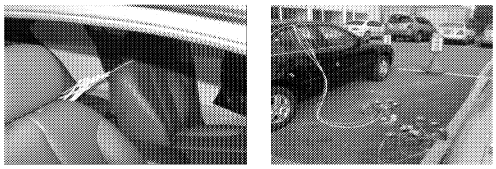

Figure 1: Method used to measure automobile ventilation

3.4 Results and Discussion

In test 1, the automobile was started in the open air, the ventilation unit was set at an internal circulation state and the fan was not operated. Results of the measurement show that the ventilation frequency was 1.1 ㎥/h. SF6 gas concentrations, as shown as Fig.2, showed an overall decreasing tendency with time.

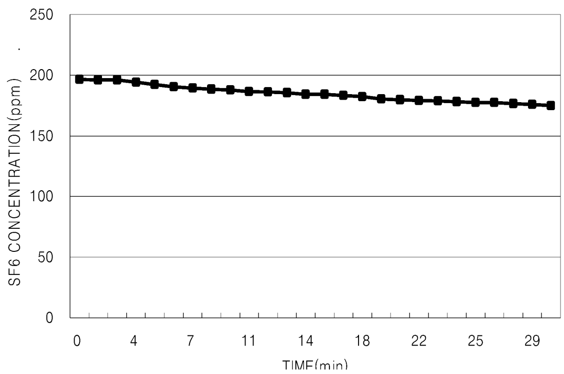

Figure 2: Concentration distribution of SF6 gas in test 1

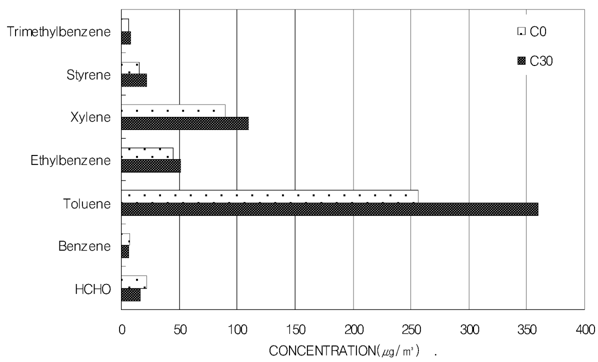

Figure 3: Concentration distribution of pollution materials in test 1

After 30 minutes (C_{30}), the concentration distribution of pollution materials discharged by indoor materials showed an increasing tendency, with the exception of formaldehyde (HCHO). The toluene ranged from 256.1μg/m^3 to 360.2μg/m^3, increasing by about 40%, as shown in Figure 3.

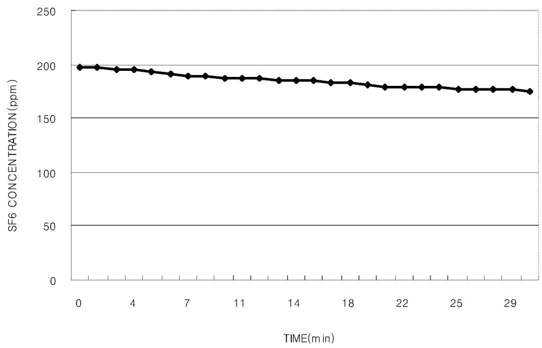

Figure 4: Concentration distribution of SF6 gas in test 2

For the test where the air circulation unit was operated in an external circulation state and the fan was not operated, the ventilation frequency was 1.1 m^3/h. SF6 gas concentrations, as shown in Figure 4, show an increasing tendency with time.

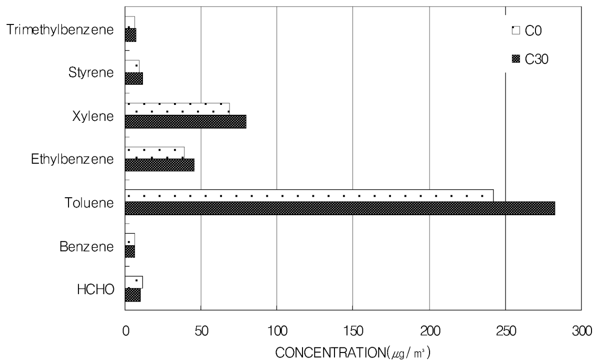

Figure 5: Concentration distribution of pollution materials in test 2

After 30 minutes (C_{30}), the concentration distribution of pollution materials discharged by indoor materials showed an increasing tendency. The toluene ranged from 242.5μg/m^3 to 282.7μg/m^3, increasing by about 16%, as shown in Figure 5.

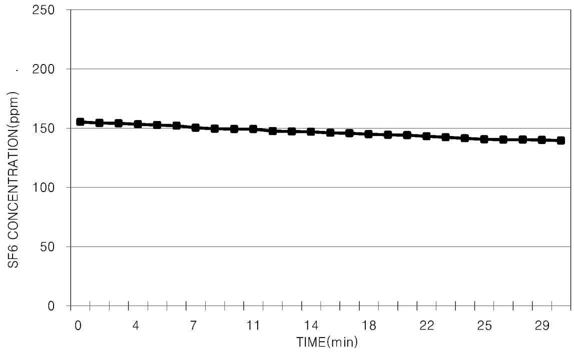

Figure 6: Concentration distribution of SF6 gas in test 3

In test 3, the automobile was started in the open air, the ventilation unit was operated in the internal circulation state and the fan was operated at low speed (1st step).The ventilation frequency was 1.4m^3/h.

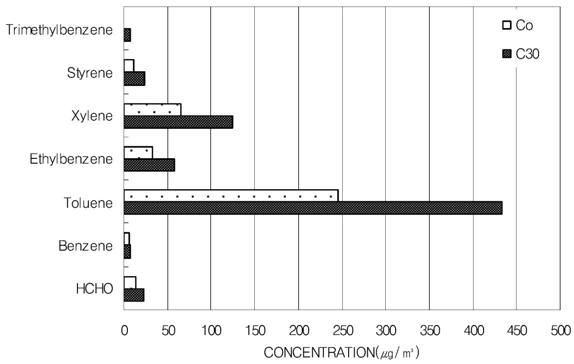

Figure 7: Concentration distribution of pollution materials in test 3

After 30 minutes (C_{30}), the pollution materials discharged by indoor materials of the automobile mostly increased. In this case, the toluene ranged from 245.4μg/m^3 to 432.8μg/m^3, increasing by about 76%, as shown in Figure 7.

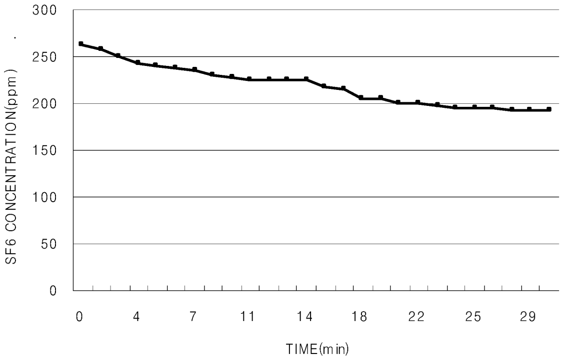

Figure 8: Concentration distribution of SF6 gas in test 4

In test 4, the automobile was started in the open air, the ventilation unit was set at external circulation, and the fan was operated at low speed (1st step). The ventilation frequency was 4.0㎥/h.

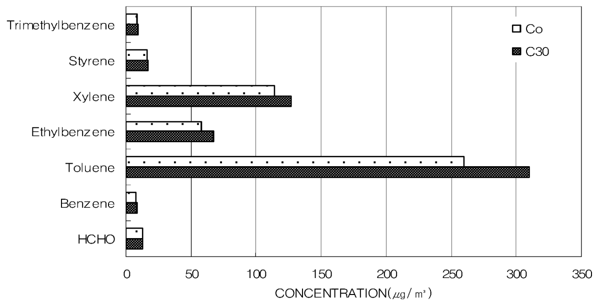

Figure 9: Concentration distribution of pollution materials in test 4

After 30 minutes(C_{30}), the pollution materials discharged by the indoor materials of the automobile increased and the toluene, ranged from 259.4㎍/㎥ to 309.9㎍/㎥, increasing by about 19%, as shown in Figure 9.

4. DISCUSSION

From the above results it can be seen that, for case 1 and case 3, while there was minimal change of increase according to ventilation frequency (from 1.1 to 1.4), the toluene of pollution materials in these cases increased to 76.4% after 30 minutes, which is an increase of 40.6% compared to the initial concentration. The increase of ventilation frequency in case 2 and case 4 significantly increased from 1.1 to 4.0,and the toluene of pollution materials increased by 16.6% for case 2 and 19.5% for case 4. C_0

Table 4. Concentration of pollution materials according to ventilation performance of automobile

Case	Engine	Fan	Circulation	ACH (㎥/h)	Time (min)	Concentration (㎍/㎥) HCHO	Benzene	Toluene	Ethyl Benzene	Xylene	Styrene
1	On	Off	Internal	1.1	C_0	21.74	7.04	256.09	45.01	90.10	15.98
					C_{30}	16.90	6.47	360.15	51.48	110.11	21.89
2		Off	External	1.1	C_0	11.49	6.66	242.51	38.74	68.45	9.12
					C_{30}	10.19	6.29	282.67	45.75	79.82	11.86
3		Low	Internal	1.4	C_0	13.76	6.57	245.38	32.53	66.12	10.91
					C_{30}	22.89	7.72	432.84	58.43	124.08	23.76
4		Low	External	4.0	C_0	12.84	7.67	259.39	57.87	114.17	16.01
					C_{30}	12.51	8.57	309.99	66.93	127.13	17.25
outdoor	-	-	-	-	-	7.02	1.01	40.32	12.24	51.39	7.04

It can therefore be deduced that the volume of pollution materials discharged by indoor materials of an automobile is comparatively greater than the increase of ventilation frequency. In addition, it is determined that the serious pollution of indoor air of the automobile due to pollution materials discharged by indoor materials is considerably influenced by the operation of the fan ventilating the car. It is suggested that when the automobile is stationary, when open air flows into the ventilation unit, pollution materials arising from the exhaust pipe can reenter the automobile.

5. CONCLUSION

Recently, social interest in the Indoor Air Environment of newly built apartment houses has extended to the Indoor Air Quality of automobiles. Accordingly, we examined the initial concentration and indoor concentration of an automobile after30 minutes under 4 different test condition cases according to ventilation conditions of the automobile when it is in operation and stationary.
Test results indicate that the discharged volume of pollution materials is greater than the increase of ventilation frequency. In addition, the discharge of pollution materials caused by the operation of the fan is considered to be a major factor influencing serious pollution of indoor air. We conclude that a further study is required on the air circulation apparatus installed in automobiles.

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