CHEMICAL ENGINEERING TRANSACTIONS

VOL. 68, 2018

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216

DOI: 10.3303/CET1868075

SiO_2 Adsorption Aerogel Odor Dissipation Control Technology Based on Active Purification Technology

Zhaohui Liu[a,*], Xin Shu[a], Rui Lin[b], Na Liu[a], Ping Luo[a]

[a]Dept. of Military Facility, Army Logistics University of PLA, Chongqing 401311, China
[b]Northwest Institute of Nuclear Technology, Xi'an 710024, China
18512390923@163.com

As the use of automobiles increases, people spend more time in the car, and the air quality inside the vehicle is receiving more and more attention. Due to the large use of organic chemical materials in automotive decorative materials, it is easy to produce a variety of toxic and harmful volatile compound gases, which would cause the odor inside the car to affect the health of the driver. The unique nano-porous structure of SiO_2 aerogel gives it excellent adsorption properties. Therefore, in this paper, the concentrations of the CO, PM2.5 and TVOC under different road environments and driving conditions are detected and analyzed, based on the active purification technology related to SiO_2 adsorption aerogel, and studies the in-car air odor dissipation control technology. The results show that the concentration of CO in each ventilation mode is higher in the congested road sections, and the road congestion is the main influencing factor of CO concentration in the vehicle; the PM2.5 concentration in the air of the vehicle is greatly affected by the air quality outside the vehicle, and the road condition and form status have no decisive influence on it; the TVOC concentration in the car is relatively stable when the window is closed, but in unobstructed road conditions, the TVOC concentration is lower than that in the congested road conditions and it presents a declining trend; in the air inside the vehicle, for the CO, TVOC and PM2.5 suspended particulate matters, etc., we can use active purification technology related to SiO_2 adsorption aerogel to control and dissipate the odor and air pollutants in the vehicle effectively.

1. Introduction

With the rapid development of technology and the improvement of people's living standards, cars have gradually become the main travel tools for people, and people will spend more time in the car (Verriele et al., 2012; Xi et al., 2018). While paying attention to the performance of all aspects of the car, people are paying more attention to the problem of air quality and odor inside the car. The results of relevant surveys show that, the car decoration materials contain a large amount of organic chemical materials, and the organic chemical materials is prone to produce a variety of toxic and harmful volatile compound gases, therefore, the air quality problems in the car and odor inside the car have become one of the most important factors for customers' considerations in car-purchasing (You et al., 2013). In-car air pollution refers to the phenomenon that, the organic chemical materials inside the car would emit volatile organic compounds (VOC) or the external harmful gases would come into the car, resulting in in-car harmful substances concentration increase or emitting of odor (Kaneko et al., 2009, Mizuno et al., 1996). The air quality inside the car has a great impact on human health, the air pollution and odor inside the car cause the driver to have a "driving syndrome". Long-time driving can also cause bad symptoms such as chest distress and dizziness. Being in this environment for a long time will seriously threaten health, causing imbalance of the body's immune system, damage to the central nervous system, etc. (Sattar et al., 2017, Szczurek & Maciejewska, 2016, Mizuno et al., 1998).

In the *Guidelines for Air Quality Assessment of Passenger Cars* (GB/T 27630-2011), China has limited the concentration of 8 VOCs hazardous substances (formaldehyde, acetaldehyde, acrolein, and benzenes such as benzene, toluene, ethylbenzene, xylene, and styrene) that affect the air quality inside the vehicle due to the SiO_2 adsorption aerogel, so as to reduce the air pollution in the air and improve air quality in the car. However, investigations have found that substances such as acids, esters and amines emitted from the interior of the

Please cite this article as: Liu Z., Shu X., Lin R., Liu N., Luo P., 2018, Sio2 adsorption aerogel odor dissipation control technology based on active purification technology, Chemical Engineering Transactions, 68, 445-450 DOI: 10.3303/CET1868075

vehicle cause unpleasant odors in the air of the car (Stemmler et al., 2005), and such odors are difficult to be controlled effectively (Morvan et al., 2003, Brodzik et al., 2016). Because the air odor inside the car is a reflection of the interaction of multiple volatile substances, the air odor control technology in the car is a major problem in improving the air quality inside the car (Grabow et al., 2012). In order to control the air odor inside the car, this paper discusses the theory of odor emission characteristics, and conducts systematic research on the air odor dissipation control technology based on active purification technology related to SiO_2 adsorption aerogel to improve the air odor inside the car (Deng, 2018).

2. Theory of odor emission characteristics in the car

2.1 Air quality index method

The main research methods for the emission characteristics of the SiO_2 adsorption aerogels in vehicles include comprehensive index method, Air Quality Index method (AQI), Grey Relational Analysis and Health Risk Appraisal (HRA), etc. (Li et al., 2006, Taniguchi et al., 1992). In view of the volatilization characteristics of the materials in the car, combined with the olfactory perception of the odor inside the car, the AQI method is used to grade the air pollution inside the car. When analyzing certain types of pollutants, the total volatile organic matter parameters are used for the correction of AQI. The grading information of AQI in the car is shown in Table 1.

Table 1: Grade of air quality index method

Grade	IAQI	The concentration of volatile substances(μg/m^3)							
		Benzene	Toluene	Xylene	Xthylben-zene	Styrene	Formald-ehyde	Acrolein	Acetald-ehyde
1	0	0	0	0	0	0	0	0	0
	25	5	45	30	11	6	25	5	26
2	50	9	101	55	22	13	38	10	35
3	75	19	310	128	55	30	51	20	45
4	100	110	1100	1500	1500	260	100	50	50
5	200	220	2200	3000	3000	520	200	100	100
6	500	5500	6500	13500	5000	3600	500	200	450

Notes: IAQI is Individual air quality index

According to AQI, the IAQI of a volatile matter M is calculated according to Equation 1.

$$IAQI_M = \frac{(IAQI_{Hi} - IAQI_{L0})}{(BM_{Hi} - BM_{L0})} \times (C_M - BM_{L0}) + IAQI_{L0} \quad (1)$$

In the above formula, $IAQI_M$ is the individual air quality index of the volatile matter M; C_M is the measured concentration of volatile matter M (μg/m^3); BM_{Hi} and BM_{L0} are the high and low values (μg/m^3) similar to the concentration of substance M in Table 1, respectively; $IAQI_{Hi}$ and $IAQI_{L0}$ are the individual air quality indices corresponding to BM_{Hi} and BM_{L0} of substance M in Table 1, respectively.

2.2 AQI classification of TVOC

Only calculating the IAQI of the eight volatile substances in the car mentioned above cannot fully reflect the air quality inside the car, so the Total Volatile Origanic Compounds (TVOC) in the car should be graded for processing, according to AQI we can calculate to get the grade of TVOC index as shown in Table 2.

Table 2: Grade of TVOC index

Grade	1	2	3	4	5	6
$IAQI_{TVOC}$	25	50	75	100	200	500
Concentration of TVOC (mg/m^3)	1	2	4	8	16	32

Table 3: Grade of olfactory perception in vehicles

Grade	IAQI	Olfactory perception
1	25	Odorless
2	50	Odor, no interference
3	75	Clear odor, no interference
4	100	Odor with interference
5	200	Odor with obvious interference
6	500	Intolerable odor

According to the grading of the above AQI, the larger the IAQI value of the SiO_2 adsorption aerogels in the vehicle, the higher the concentration of the substance, and the lower the grade of the air quality in the vehicle. According to the AQI grade, the olfactory state of the vehicle (namely the smell inside the vehicle) is graded, as shown in Table 3. Using AQI grading of the eight categories of volatile pollutants and TVOC we can give a more comprehensive evaluation of the air quality and odor in the car.

3. In-car pollutant monitoring under different driving conditions

3.1 Pollutants and odors in the car

The SiO_2 adsorption aerogel treatment of volatile pollutants can generally be divided into four categories: (1) inorganic gaseous pollutants: such as carbon dioxide, carbon monoxide, nitrogen oxides, etc.; (2) volatile organic gaseous pollutants: such as benzene, ethylbenzene and other benzene compounds, aldehydes such as formaldehyde and acetaldehyde; (3) Inhalable solid particles: such as PM2.5 and PM10 with a particle size of less than 10 μm; (4) Microbial particles: such as bacteria or molds inside a car or entering a car (Tamainot-Telto et al., 2009, et al., Ongwandee & Kruewan, 2013). The relationship between the CO_2 concentration in the car and the time is shown in Figure 1. The concentration of CO, NOx, organic pollutants, solid particles and microorganisms also increased with time, stronger harmful odor, and longer time staying in the car causes greater harm to the body of the people.

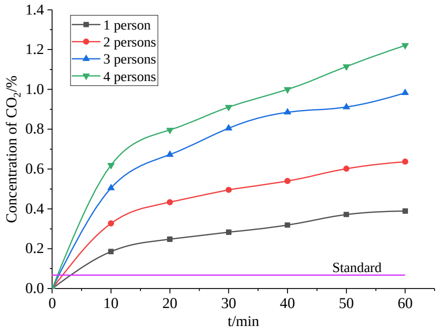


Figure 1: The relationship between CO_2 concentration and time in vehicle

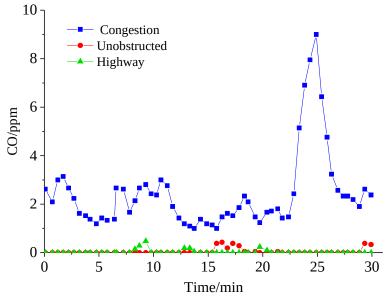
3.2 Driving status pollutant testing program

In this experiment, PM2.5, CO and TVOC were selected as monitoring objects to characterize the air quality and odor inside the vehicle by the active purification technology related to SiO_2 adsorption aerogel. During data collection, the concentration information of the above pollutants was collected using a hand-held rechargeable dust detector and a handheld indoor air quality detector. When sampling, each sampling point was separated by a certain time interval. The total test time set in this experiment was 30min, the time interval between sampling points was 30s, 60 samples were collected continuously, and one evaluation time period was 10min. The sampling concentration is the average concentration in the corresponding time period.

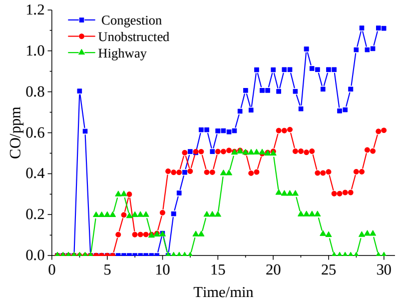
In order to comprehensively explore the situation of different dynamic driving, this experiment selected three sections of different environments: (1) Congestion status A: a congested section in an urban area, the average speed does not exceed 20km/h; (2) Unobstructed state B: a suburban section in a city, the average speed can be basically stabilized at about 40km/h; (3) Highway state C: a second-ring road section of an urban area, the average speed is basically maintained at about 80km/h. Each environmental section was sampled 4 times. The corresponding numbers of each section are A1-A4, B1-B4, and C1-C4. The number 1 represents the car windows are not opened and the air conditioner is not turned on, the number 2 represents the car windows are slightly opened and the air conditioner is turned off, the number 3 represents the car windows are closed and the air conditioner is turned on by the external circulation mode, the number 4 represents the car windows are closed and the air conditioner is turned on by the internal circulation mode. Finally, according to the collected data, the concentration of pollutants which adsorbed by SiO_2 aerogel in the vehicle under different environmental sections and different driving conditions is analyzed and compared.

3.3 Test results and analysis

The test found that in the four driving conditions in the highway environment, the CO is basically not detected in the car, the concentration of PM2.5 is also less than the standard value, and TVOC is not detected in most of the time. According to the experimental results, the influencing factors of the four pollutants were analyzed.

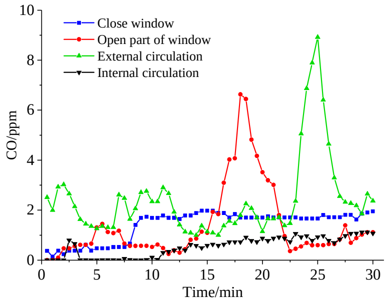


(a) CO concentration of different road conditions in the case of air conditioner external circulation

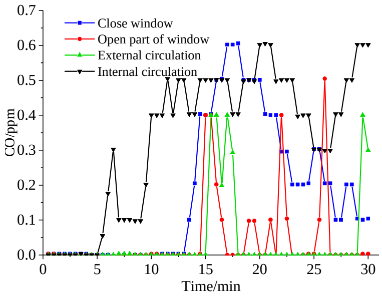


(b) CO concentration of different roads in case of air conditioner internal circulation

Figure 2: Change trend of CO in same ventilation mode and different road conditions

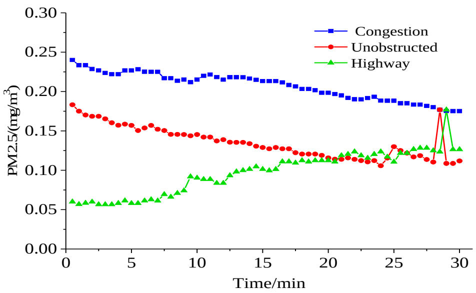


(a) CO concentration of different ventilation modes in congested road conditions

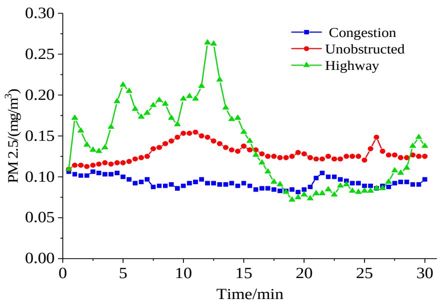


(b) CO concentration of different ventilation modes in unobstructed road conditions

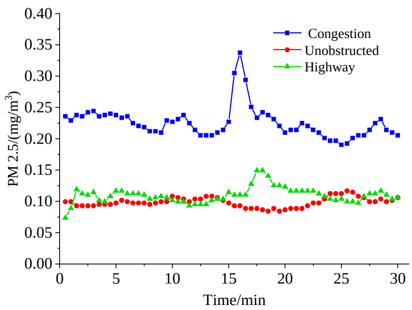
Figure 3: The changing trend of CO under different ventilation modes on the same road



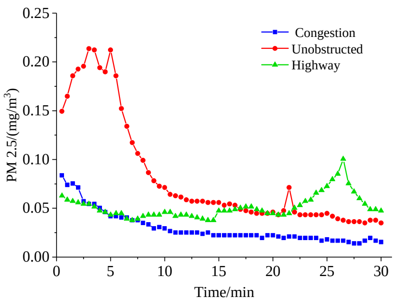
(a) PM 2.5 concentration of different road conditions in the case of closed windows



(b) PM 2.5 concentration of different road conditions in the case of slightly-opened windows



(c) PM 2.5 concentration of different road conditions in the case of external circulation air conditioner mode



(d) PM 2.5 concentration of different road conditions in the case of internal circulation air conditioner mode

Figure 4: Trends of PM2.5 in different road conditions in the same ventilation mode

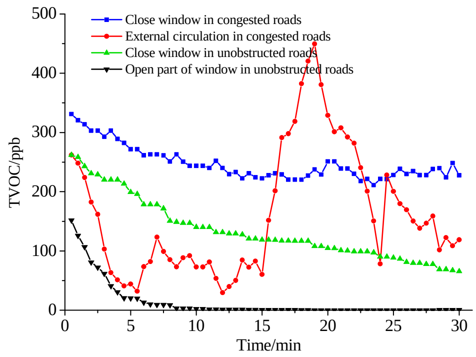


Figure 5: Change trend of TVOC concentration

The trend of CO changes in different road conditions in the same ventilation mode is shown in Figures 2 (a) and (b). The concentration trends in different ventilation modes in the same road conditions are shown in Figures 3 (a) and (b). It can be seen that the concentration of CO in both ventilation modes is always higher in the urban congested sections, and the average CO concentration under the air conditioner external circulation state of the unobstructed section is about zero. In air conditioner internal circulation mode in the high-speed state, the CO concentration decreases, while in the other two road conditions, the CO concentration only changes slightly. The main influencing factor of CO concentration in the car is road congestion.
The change trend of PM2.5 in different road conditions in the same ventilation mode is shown in Figure 4 (a)~(d). The results show that the PM2.5 concentration in the air of the car is greatly affected by the air quality outside the car, and the road condition and ventilation mode have no decisive influence on the PM2.5 content in the car. The change trend of TVOC concentration in the vehicle under different road conditions and driving conditions is shown in Figure 5. It can be seen that the TVOC concentration in the car is relatively stable when the window is closed, but under unobstructed road condition the TVOC concentration is lower than that of the congested road sections and it presents a declining trend.

4. Pollutant purification

Both CO and TVOC in the air of the vehicle caused by organic chemical materials are gaseous chemical pollutants, both of which can be photocatalyzed by photocatalyst, or physically adsorbed by adsorption materials such as SiO_2 aerogel, thereby removing the smell of the vehicle and achieving the purpose of air purification. For PM2.5 suspended particles in the car, solid materials can be used for negative ion filtration, electrostatic filtration or mechanical filtration, SiO_2 aerogel filtration, etc. to dissipate the odor and pollutants in the car. The active purification technology related to SiO_2 adsorption aerogel can effectively improve the air quality inside the vehicle and improve the comfort of the driver and the passenger in the vehicle.

5. Conclusion

This paper discusses the theory of odor emission characteristics, detects and analyzes the CO, PM2.5 and TVOC concentrations of organic chemical materials volatile substances in vehicles under different road environments and driving conditions, and studies the air odor dissipation control technology based on active purification technology related to SiO_2 adsorption aerogel. The conclusions are as follows:
(1) In each ventilation mode, the concentration of CO is always higher in the urban congested sections, and the average concentration of CO in the external circulation air conditioning state in unobstructed road sections is about 0. The main influencing factor of the CO concentration in the vehicle is road congestion; The PM2.5 concentration in the air of the car is greatly affected by the air quality outside the car; the TVOC concentration in the car is relatively stable when the windows are closed, but under unobstructed road conditions the TVOC concentration is lower than that of the congested road sections and it presents a declining trend.
(2) In the four driving conditions in the highway environment, the CO is basically not detected in the vehicle, and the concentration of PM2.5 is also less than the standard value, and TVOC is not detected in most of the time.
(3) CO and TVOC in the air volatilized by organic chemical materials can be photocatalyzed by photocatalyst, or physically adsorbed by adsorption materials such as SiO_2 adsorption aerogel; for PM2.5 suspended particles, the solid materials can be used for negative ion filtration, electrostatic filtration or mechanical filtration, SiO_2 aerogel filtration, etc. to dissipate the odors and pollutants in the car.

Acknowledgements

PLA logistics research project (BY115C007).

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