Study on particulate pollution in cities of China and evaluation of protective measurements *

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Abstract: By studying the air quality in the public traffic area of Shanghai, the harm to people's health caused by particulate pollution in Chinese cities has been evaluated. In addition, two devices were developed to test the performance of protective mask against ambient aerosol, and the efficiency of recycle filtering of the air-condition was contrastive tested with the new filtration material. The results show that these protective measures need to be improved because that filtering efficiency of protective mask and air-condition in miniature is too low to filter superfine particles in ambient air.

Keywords: ambient air quality, protective mask, air-condition, testing system, filtering performance

1. Introduction

The coal-burning pollution is typical in cities of China and the main contamination is total suspended particles, which is short for TSP [1,2]. Since 1996, the particle standard PM_{10} was brought into effect in China [3], but at the same time the standard $PM_{2.5}$ has been tried in some developed countries such as United States of America because superfine particles as $PM_{2.5}$ can be easily inhalational into respiratory system.

Based on literature study, two standard test stations were built in Donghua University to test the filtration performance of respirator against ambient aerosol PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ under real condition. Moreover, a contrastive study carries on the results from these stations and from TSI 8130. Furthermore, this study concentrates on the filtration performance of air-condition in miniature for ambient aerosols with size distribution of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ to get the filtration materials with low resistance and high filtering efficiency.

2. Particulate pollution in public areas and it's impact on human health

2.1 Particulate pollution in public areas

At the beginning of July in 2003, the air quality in the public traffic area of Shanghai was studied including the mass concentration of ambient aerosol PM_{10}, $PM_{2.5}$ and $PM_{1.0}$. By TSI 8520 DUSTTRAK Aerosol Monitor, the average data per hour were tested which have been listed in table 1.

Table 1. Mass concentration of ambient aerosol PM_{10}, $PM_{2.5}$ and $PM_{1.0}$

Public traffic area	PM_{10} / (mg • m^{-3})	$PM_{2.5}$ / (mg • m^{-3})	$PM_{1.0}$ /(mg • m^{-3})
The bus stop of Yan'an west road	0.500	0.390	0.367
Middle door of bus	0.524	0.501	0.480
The final stop of bus at the People Plaza	0.300	0.205	0.196
The People Plaza	0.219	0.179	0.159
The shop	0.152	0.119	0.107
Entrance to No.2 underground at the People Plaza	0.188	0.142	0.130
Platform of No.2 underground at the People Plaza	0.204	0.134	0.119
Platform of No.2 underground at Zhongshan park	0.179	0.143	0.119

The size distribution of particle at the bus stop of Yan'an west road and middle door of bus is analyzed with regression method of Rosin-Rammler distributing function [4], which results have been illustrated in Fig.1.

From Fig.1, all of frequency distributing curves incline to the left and the median diameter is between 2 μm and 3μm, which shows that superfine particle is in the majority of the ambient aerosol. As the study, some literatures have made the same conclusion[5,6].

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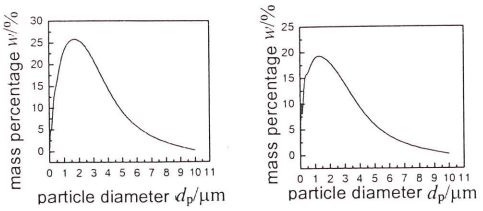


Fig.1. the bus stop of Yan'an west road and middle door of bus

2.2 Impact on human health

A literature indicates that particles which diameter is smaller than 10μm can be breathed into nasal cavity, and fine particles, which range from 2.5μm to 7μm, can penetrate throat, however, the superfine particles which are smaller than 2.5μm can accumulate after reaching to alveolus and infiltrate into blood recycle [7]. With the development of industry, the particulate pollution in cities becomes superfine as a result of more combustion, and these particles have larger surface area so that more poisonous matter may adhere to them and do more harmful to respiratory system.

2.3 protective measurements

Although protective mask has been used in medical and dietetic vocation to filter ambient aerosol for the health of aspiratory system, there have been many problems about the knowledge for it's evaluation and use.

Adding the material with high filtering efficiency in air-condition is the best measure to filter superfine particles of ambient air, but Netlon and wire mesh are the main equipments in using for purifying air and their meshes are not enough fine to hold up superfine particles such as aerosol $PM_{2.5}$ and $PM_{1.0}$.

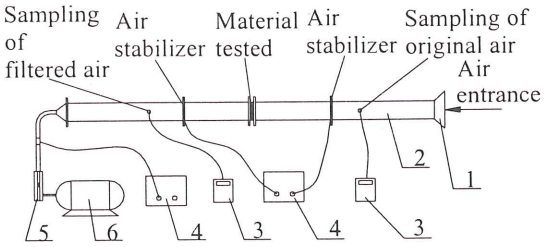
3. Testing systems and environmental parameter

3.1 Testing systems

Two devices were developed to test the performance of protective mask against ambient aerosol, which are DHU- I flat model mask performance testing system and DHU- II Real condition mask performance testing system. On the side, TSI 8520 DustTrak Aerosol Monitor and TSI 8585 CompuFlow are used to study the performance of filtration materials in air-condition.

3.1.1 DHU-I flat model mask performance testing system

Fig.2 shows DHU- I flat model mask performance testing system, in which the ambient air enters the tube from current collector and through material tested and Floater flowmeter, and at last be vented back to the ambient by pump.



1: Current collector; 2: Tube(φ50mm); 3: TSI 8520 DustTrak Aerosol Monitor; 4: SwemaAir300 (SWA07) digital manometer; 5: Floater flowmeter; 6: Pump

Fig.2. DHU-I flat model mask performance testing system

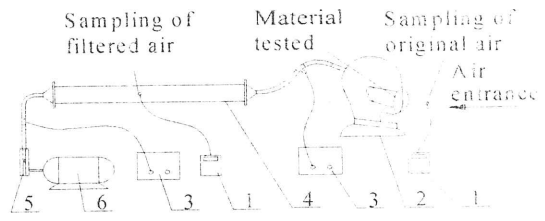
TSI 8520 DustTrak Aerosol Monitor is used to test the mass concentration of ambient aerosol PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ in original air and filtered air, and SwemaAir300(SWA07) digital manometer is adopted to get the pressure drop of airflow through the mask material. So that the filtering efficiency of samples against ambient aerosol is related to mass concentrations by

$$\eta = \frac{\rho_1 - \rho_2}{\rho_1} \times 100\% \quad (1)$$

where ρ_1 is the mass concentration of ambient aerosol in original air and ρ_2 is the mass concentration of ambient aerosol in filtered air.

3.1.2 DHU- II Real condition mask performance testing system

Fig.3 shows DHU-II Real condition mask performance testing system, in which the ambient air enters the tube through material for test and nostril of Dummy headform, and at last be vented back to the ambient by pump.



1: TSI 8520 DustTrak Aerosol Monitor; 2: Dummy headform; 3: SwemaAir300(SWA07)digital manometer; 4: Tube(φ50mm); 5: Floater flowmeter; 6: Pump

Fig.3. DHU- II Real condition mask performance testing system

The measurement of getting results of DHU- II Real condition mask performance testing system is same as that of DHU- I flat model mask performance testing system.

3.2 size distribution of ambient aerosol for testing

The mass concentration of ambient aerosol for testing is showed in Table 2 and the result analyzed with regression method of Rosin-Rammler distributing function is listed in Table 3.

Table 2 Parameters of ambient aerosol

Particle diameter d/μm	Concentration ρ / (mg·m^{-3})
$PM_{1.0}$	0.2649
$PM_{2.5}$	0.3121
PM_{10}	0.3149

Table 3 Particle diameter distribution

Particle diameter d/μm	Weight percentage w_B/%
0~0.05	15.26
0.05~0.20	30.25
0.20~0.50	30.62
0.50~1.00	17.44
1.00~2.50	6.28
2.50~5.00	0.14
5.00~10.0	0.01

From Tables 2 and 3, it can be concluded that the most of particles for testing is smaller than 2.5μm, so that there is a great value of the study on filtering performance of protective mask and the filter equipment of air-condition against ambient aerosol because of the harm of the superfine particles.

4. Sample collected and experimental test

4.1 protective mask

4.1.1 sample collected and contrastive test

The samples have been classified as gauze mask and non-woven mask and complex mask, which labeled as Table 4.

Table 4 label of mask samples

Label	Mask	Label	Mask
A	20-layer gauze mask	J	DHU 150 non-woven mask
B	16-layer gauze mask	K	DHU 250 non-woven mask
C	Two 16-layer gauze mask	L,M, N,O	Complex mask with active carbon
D	Three 16-layer gauze mask	P	Complex cotton mask
E,F, G,I	Plat model non-woven mask	Q,R	Complex mask treated with reagent
H	Disposal model non-woven mask		

The velocity of airflow is 7.66 m·min^{-1}[8]. The results show as Fig.4 and Fig.5.

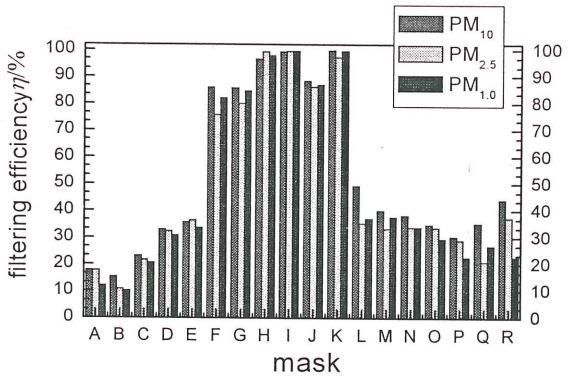


Fig.4. Filtering efficiency of masks

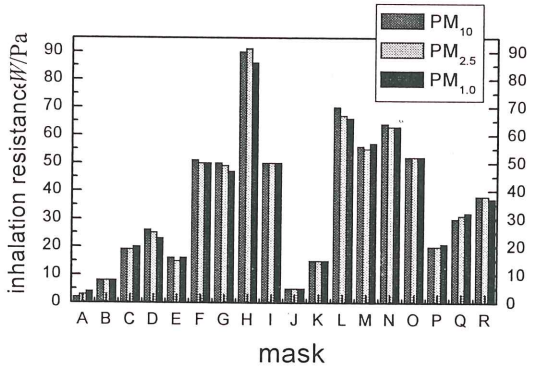


Fig.5. Inhalation resistance of masks

Taking the real condition of using mask into account, DHU- II Real condition mask performance testing system is designed to simulate respiration. The study uses this system to contrast with TSI 8130 as show in Fig.6.

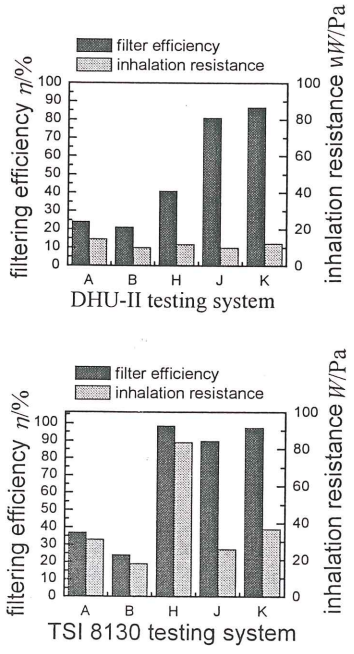


Fig.6. the contrast between DHU- II testing system and TSI

8130 testing system

4.1.2 Results analysis

From Fig.5 and Fig.6, the filtering efficiency of 16-layer gauze mask is always lower than 25 %. Another measurement made with three overlapping masks (D) show that the filtering efficiency is still lower than 40%. Considering this kind of mask is most popular used in Chinese hospital, this measurement results give a reasonable explanation that why there are so high infection rate in Chinese hospital in early stage of SARS. However, the inhalation resistance is quite low, about 1-14Pa in most cases.

Mask made of Non-woven material: its filtering efficiency is between 70.0% and 99.3%. However, the inhalation resistance is very high (4-157Pa). Such a higher resistance could cause clogging and the carbon dioxide content of the inhalation air could be higher than 1% in breathing zone. Therefore, this kind of mask is also needed improved. And that Fig.6 can prove this view.

The new type of mask (J and K): with the help of new filter material, these masks have satisfied performance in both inhalation resistance and filtering efficiency. The inhalation resistance is similar to the 16-layer gauze mask. However, the filtering efficiency to ambient aerosols was higher than 96% in Fig.4. Especially, the mean efficiency of PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ was 99.3%, 97.1% and 99.4% respectively. Although the filtering efficiency reduces by DHU-II Real condition mask performance testing system, the result is better than that of others, which is 80% and 96%.

Complex mask with active carbon: the inhalation resistance is moderate (17-122Pa) and its filtering efficiency is between 24.7% and 51.2%. However, measurement data indicates that active carbon can only deal with airborne with bigger size—almost 50% of $PM_{1.0}$ will penetrate the respirator. It is almost no possible to reduce exposures of the wearer to particulate hazards.

4.2 Filter material of air-condition

4.2.1 sample collected and contrastive test

Wire mesh and sample J are contrastively studied and the former is labeled as S. A air-condition in miniature from market is used for the test, which has the maximum recycling airflow volume of $780 m^3 \cdot h^{-1}$.

The test is carried out under three different airflow volume (Min, Med and Max) with the power of air-condition. The results are showed in Figs.7 and 8.

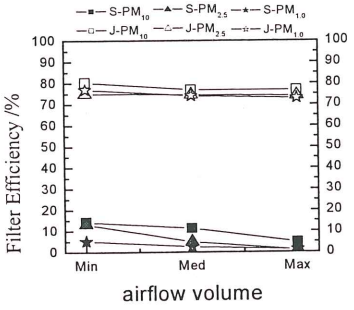


Fig.7 change of filtering efficiency with airflow volume

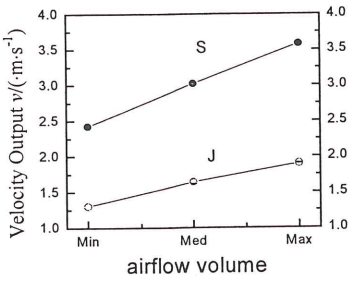


Fig.8 Change of velocity output with airflow volume

4.2.2 Results analysis

Although airflow velocity output stabilizes from $2.42 m \cdot s^{-1}$ to $3.58 m \cdot s^{-1}$ with wire mesh, filtering efficiency is lower than 14.3%, so much as 1.1 % at airflow volume of Max. Because of wire mesh's low filtering performance, superfine particles and dust may penetrate easily into the interior of air-condition, which can lower effect of heat exchange, and pathogen can nourish in air-condition, which may do harm to people.

However, filtering efficiency with sample *J* is between 73.0% and 80.3% at airflow velocity output ($1.3 m \cdot s^{-1}$~$1.9 m \cdot s^{-1}$), especially reaching to 73.0% against ambient aerosol $PM_{1.0}$. Therefore, the authors strongly recommend to apply this type of filter material in the future.

5. Conclusions

1) The gauze mask has a filtering performance of low inhalation resistance and low filtering efficiency, so superfine particles can easily penetrate it. Considering this kind of mask being most popularly

used in Chinese hospital, the measurement results give a reasonable explanation that why there are so high infection rate in Chinese hospital in early stage of SARS. The author recommend prohibiting the use of gauze mask for medical staff.

2) The filtering performance of non-woven mask is superior to gauze mask, but some non-woven mask have too high inhalation resistance to breathe swimmingly. As a result, particles can leak into respiratory system while using this mask.

3) The new non-woven mask with low inhalation resistance and high filtering efficiency is the best substitute for old model ones.

4) Complex mask with active carbon may purify ambient air with any dangerous gas, but it is not well at filtering superfine particles.

5) Netlon or wire mesh are filter equipments of air-condition in miniature, which hole is 1mm or coarser. With these filter equipments, particles with larger diameter than 10μm may be hold up and superfine particles as $PM_{2.5}$ or $PM_{1.0}$ can easily penetrate them. Therefore, new filter material with high filtering efficiency and low resistance is needed urgently. From the study, non-woven filter material with new technology should be applied in air-condition in miniature.

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