Filtration performance of new reduced graphene oxide air filter material against bacteria in the atmosphere during the initial stage of heating

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Abstract. With the large-scale outbreak of the COVID-19, people have gradually realized the importance of bioaerosols in the environment, and how to efficiently filter out microbial aerosols in the air, so as to create a safe and healthy air environment is urgent. The non-bacteriostatic F6 non-woven filter material and the synthesized new reduced graphene oxide air filter were tested and analyzed in this paper, and the filtration performance of the material against bacterial aerosols in the atmosphere at the initial stage of heating. The results showed that during the initial stage of heating, the particle size distributions of aerosols in the atmosphere during working days were stageI(>7.0μm)4.34%, stageII(4.7~7.0μm)4.62%, stageIII(3.3~4.7μm)13.30%, stageIV(2.1~3.3μm)21.11%, stageV(1.1~2.1μm)38.70%, stageVI(0.65~1.1μm)17.92%. The particle size distributions of aerosols in the atmosphere on non-working days were stageI(>7.0μm)4.52%, stageII(4.7~7.0μm)13.66%, stageIII(3.3~4.7μm)23.04%, stageIV(2.1~3.3μm)31.82%, stageV(1.1~2.1μm)15.18%, stageVI (0.65~1.1μm)11.78%. The new reduced graphene oxide filter material had a 10% increase in the filtration efficiency of the total bacterial aerosol compared with the ordinary non-woven filter material. Among them, the filtration efficiency of the respirable bacterial aerosol (particle size <4.7μm) was significantly improved by 40%. The results of this study could provide a certain reference for building a safe interior in the post-epidemic era, and also provided reference value for the research and development of functional air filters.

Keywords. Initial heating period，Filter material，Planktonic bacteria，Working day，Non-working day，Efficiency

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1 Introduction

Bioaerosols includes fungi, viruses, bacteria, pollen and organic components of organisms in atmosphere, and the particle size ranges from 0.5 to 100 μm[1]. It will cause great harms to human body if the microbial aerosol entered the human body. Relevant studies had shown that pathogenic bacteria could cause various respiratory infectious diseases, asthma, Sick Building Syndrome (SBS)[2] and so on. Among them, particles of 1-5μm can directly invade the alveoli, 6-10μm are easy to settle in the small bronchi, and 10-30μm will be deposited in the bronchi[3]. With the outbreak of the COVID-19, the main transmission routes are droplet transmission and close contact. Therefore, the hygiene of the indoor environment is urgent.

Air filter is an important way to control the concentration of indoor suspended pollutants. The measured and calculated results of related studies had shown that air filters could effectively reduce the level of indoor air bacterial pollutions[4,5]. At present, the antibacterial agent used for filtration and sterilization has strong bactericidal ability, but it is highly toxic, and may cause great environmental pollution, also the price is relatively high, which is not conducive to produce and use. In recent years, graphene and its derivative materials have become materials with great development prospect for the fields of biomedicine and air purification. There are three mainstream opinions on the sterilization mechanism of graphene: **Nano-Knives**. The edge of the nanomaterial acts like a blade to damage the cell membrane, allowing vital components inside the cell to leak out of the cell, leading to cell death[6].**ROS**. In the process of contacting with bacteria, the surface defects and sharp edge structure of graphene can induce bacteria to produce reactive oxygen species, which will lead to the disorder of their normal physiological metabolism, resulting in bacterial death[7].**Wrapping**. The graphene material wraps the bacteria to isolate it from the surrounding medium, blocks its growth, and has a bacteriostatic effect[8]. However, at present, graphene and its derivative materials are effectively combined with existing materials, and there are relatively few studies on planktonic bacteria in the atmosphere.

Therefore, the new reduced graphene oxide filter material was used to test and analyze in this paper, and the filtration performance of bacterial aerosols in the atmosphere during the initial stage of heating. It provides a certain reference for controlling good indoor air quality.

2 Materials and Methods

2.1 Sampling location and time

The sampling site is located in the student office of a university in Xi'an. The selected office is located on the 7th floor, with a usable area of about 29.6 square meters. There is no visible mold growth indoors, and there is no obvious musty smell that can be smelled. The experimental bench was shown in Fig.1, and collect the samples of microbial aerosols before and after the filter material respectively. The height of the collection point is 1.2m from the ground, and the filtration velocity was 0.8m/s. The sample collection was at 8:00am on November 23rd and 27th, 2021. The sampling period was sunny.

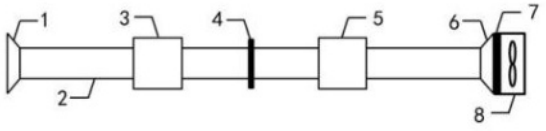


Fig.1. Experiment system
1—Current collector,2—Filter speed measuring hole (side),3—Sampling at the front end of the filter material,4—Filter material to be tested,5—Sampling at the back end of the filter material,6—Expanding tube,7—Soft connection,8—Fan.

2.2 Sampling method and culture method

Six-stage impacts Anderson sampler (type FA-3, China) was used to collect microbial aerosols before and after the filter material in the experiment. The particle sizes are divided into six grades: I (>7.0μm), II (4.7~7.0μm), III (3.3~4.7μm), IV (2.1~3.3μm), V (1.1~2.1μm), VI (0.65~1.1 μm)[9]. Each sampling time is 10min, and the gas flow is 28.3L•min^{-1}. Repeat sampling 3 times to ensure the accuracy of experimental results.

The sampler was sterilized with 75% alcohol before each sampling, and then placed in a petri dish according to the standard GB/T 18204.3-2013. The collected bacteria were cultured in nutrient agar medium (Changde, Beekman) for 48h in a constant temperature incubator at

37°C. When the cultured samples were counted, the positive hole method was used to correct the number of colonies [9].

2.3 Calculation method

According to the sampling flow and sampling time, formula (1) was used to calculate the concentration of microbial aerosols at all levels[9].

$$C_i = \frac{N_i}{t \times F} \times 1000 \quad (1)$$

In the formula, C_i is the bacterial aerosol concentration (CFU•m^{-3}). N_i is the number of colonies at all levels. t is the sampling time (min). F is the gas flow during sampling (28.3L•min^{-1}).Air temperature and relative humidity were monitored with the TSI7545.

Aerosol particles with a particle size of <4.7 μm can enter the lower respiratory tract of people through breathing and are able particles[3]. The proportion of inhalable bacterial aerosols can be calculated according to formula (2) [9].

$$R_b = \frac{C_{b3}+C_{b4}+C_{b5}+C_{b6}}{C_b} \times 100\% \quad (2)$$

Where R_b is the percentage of inhalable bacterial aerosols.

The filtration efficiency of air filter materials for microbial aerosols is calculated by formula (3) [9].

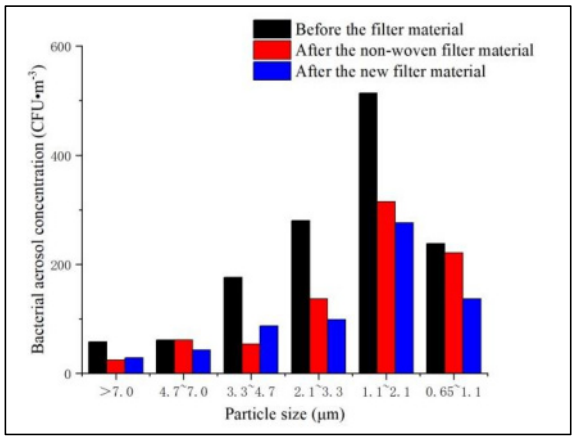
$$\eta = \frac{C_1 - C_2}{C_1} \times 100\% \quad (3)$$

In the formula, C_1 is the microbial aerosol concentration (CFU•m^{-3}) before the air filter material; C_2 is the microbial aerosol concentration (CFU•m^{-3}) after the air filter material.

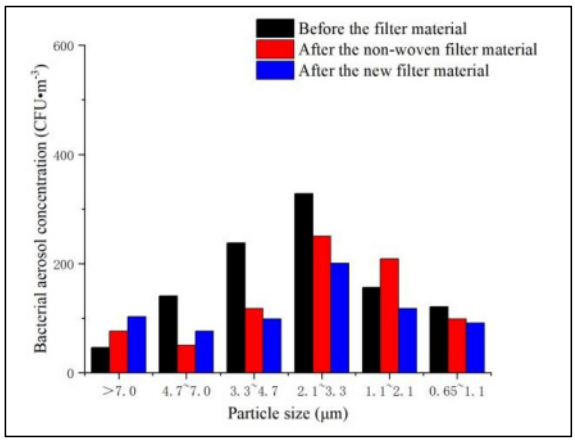
3 Results and Analysis

3.1 Particle sizes comparison of planktonic bacteria before and after the filter material

During working days and non-working days, the number of colonies before and after filtration of non-woven filter media and new filter media is shown in Fig.2.



(a) working days



(b) non-working days

Fig.2. The particle size distribution of bacterial aerosols before and after the filter material during working days and non-working days

It could be seen from Fig.2. that the particle size concentration and particle size distribution after the filter material were roughly the same. The bacterial aerosol concentration after the new filter material was significantly lower than that of the non-woven filter material. Among them, the bacterial aerosol concentrations in the range of 4.7~7.0μm, 2.1~3.3μm, 1.1~2.2μm and 0.65~1.1μm after the new filter material decreased by 29.86%, 28%, 12% and 38.04%, on working days, respectively. The concentration of aerosols larger than 7.0 μm and 3.3~4.7 μm increased by 14.4% and 61.9%. While the bacterial aerosol concentrations in the range of 3.3~4.7μm, 2.1~3.3μm, 1.1~2.2μm and 0.65~1.1μm after the new filter material decreased by 16.18%, 19.84%, 43.63% and 7.65%, in non-working days, respectively. The concentration of aerosols >7.0μm and 4.7~7.0μm increased by 34.6% and 51.4%. It could be seen that the new filter material had significantly

improved the filtration effect of bacterial aerosol particles. The filtration efficiency of respirable particulate matter (<4.7μm) was significantly improved, which could be increased by 40%. The main reasons were that on the one hand, the the reduced graphene oxide material had a larger specific surface area. The probability of capturing particles below 4.7 μm by the new filter material was increased during the testing. On the other hand, the graphene was added to the new filter material, it led to a decrease in the porosity of the filter material, which was more conducive to capture of the small particle sizes. For large particles, the main filtration mechanism was still dominated by inertial effects, it was not much different from traditional filter materials.

3.2 Comparison of filtration efficiency for microbial aerosols

According to formula (3) and combined with Fig.3, the filtration efficiency of the two filter materials could be calculated.

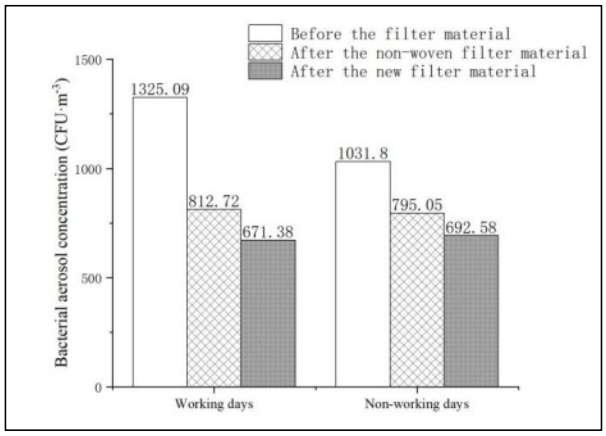


Fig.3. The total concentration of bacterial aerosols before and after the filter material on working days and non-working days,

The filtration efficiencies of ordinary non-woven filter material and new filter material were 38.67% and 49.33%, during working days, respectively While the filtration efficiencies were 22.95% and 32.88%, during non-working days, respectively. Among them, the filtration efficiency of the new filter material has been increased by 10%. The reduced graphene oxide was changed the internal structure of original air filter material, and the filtration performances were also changed at that time.

4 Conclusion

The filtration performances of bacterial aerosols in the atmosphere were tested and studied by using a new type of reduced graphene oxide filter material, and the following conclusions were initially obtained:

(1)The bacterial aerosol concentration after the new filter material was significantly lower than the non-woven filter materials. Among them, the concentration of respirable particulate matter (particle size < 4.7 μm) was reduced by up to 40%.

(2)The new filter material could improve the filtration efficiency of bacterial aerosol concentration by 10%. The attachment of reduced graphene oxide significantly improved the filtration performance of the non-woven filter material.

Considering that the reduced graphene oxide air filter material also has a certain sterilization function, the follow-up will continue to do the sterilization performance test of the air filter material. The sterilization selectivity test of the bioaerosol, and it provide protection for indoor health and health in the post-epidemic situation.

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