Research on application of zeolite in air purification of ship cabins

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Abstract. It’s necessary to equip the ship cabins with suitable air purification device which can ensure the ship’s air quality without affecting the physical and mental health of the crew living in the limited space of a ship during ocean voyage. In this paper, zeolite’s characteristics and application in air purification are introduced, and three different types of air purification filters are designed with zeolite particles as main materials, then three development programs of air purification engineering machine for ship cabins are proposed based on modular design concept. The air-purifying machine models proposed in this paper have been trial-produced and tested, which provides new choices for ship cabins’ air-purifying devices.

1. Introduction

At the beginning of 2020, a fierce new coronavirus pneumonia epidemic has continued to spread and swept the world at an alarming rate. It has caused hundreds of thousands of deaths and is showing an increasing trend. Research has found that the main transmission routes of new coronavirus pneumonia are droplet transmission and contact transmission, and that crowded small spaces will increase the risk of infection. If people live in a small and limited space for a long time, the air quality in the space will continue to decline [1], and pollutants will gradually accumulate, which can easily cause bacterial growth and virus transmission. Thus the Japanese “Diamond Princess” cruise ship had hundreds of people infected by the new coronary pneumonia in a short time. Therefore, it is necessary to develop and equip an air purification device suitable for ship cabins. On the one hand, the air purification device can kill bacteria and viruses in the ship cabin, purify the cabin air quality, and ensure the physical and mental health of the crew; on the other hand, it can remove harmful substances in the ship’s cold storage, which will extend the fresh-keeping period of fruits and vegetables in the ship’s cold storage and meet the crew’s supply needs for long-term sea voyages.

2. Zeolite characteristics and air purification technology

As a natural aluminosilicate mineral material, zeolite has huge reserves in China. It has unique microporous structure, ion exchange, adsorption and separation, high catalytic activity, molecular sieve function and acid resistance [2-3]. The pores structure makes it have a large internal surface area. After dehydration, it has a larger internal surface area due to the interconnection and openness of the pores structure, which forms the efficient adsorption performance of zeolite.

At present, the main direction of the development of indoor air purification technology is compound purification technology, which achieves the effect of air cleaning through the comprehensive applica...
tion of various air purification methods. Generally speaking, the main methods of indoor air purification are ventilation, filtration, adsorption, photo catalysis, static electricity and negative ion.

At present, the air purification devices in the working and living compartments of some domestic ships basically adopt the purification scheme with activated carbon as the main filter material. However, the porous structure of activated carbon has a wide pore size distribution, lacks selectivity for adsorbed substances, and has no ion exchange capacity. When it is saturated, or the concentration of harmful gases adsorbed by itself is higher than the environmental concentration, it will be released and must be replaced frequently. The air purification of ship cold storage is mostly achieved by installing an ozone generator or an ethylene removal machine with potassium permanganate as the oxidant, but these two types of equipment have certain limitations in removing harmful gases. Therefore, the development of air purification devices suitable for ship cabins is an issue of urgent concern.

3. Air purification program of ship cabin

Based on the excellent performance of zeolite [7], a new type of air purification material, this paper proposed three preparation schemes of filter material suitable for purification of the main harmful substances in the air of ship cabins, then designed three types of engineering machines for ship cabin air purification, making comprehensive use of both passive adsorption filtering and active air purification technology with modular design scheme. The No. 1 and No. 2 air purification engineering machines are suitable for air purification in the cold storage of ships, and the No. 3 machine is suitable for air purification in the living and working cabins of ships.

3.1. Filter preparation plan

(a) Columnar filter material using zeolite particles

The columnar filter material is designed with zeolite in a columnar array, with low wind resistance and good air passage performance, which can form an air circulation in the cabin, and cyclically purify the cabin air. The air permeability of the filter material is high, and the instantaneous removal rate of harmful gases in the air is limited.

(b) Honeycomb filter material using zeolite particles

The honeycomb filter material is designed with zeolite side-by-side honeycomb, with large wind resistance and general air passing performance. The air stays in the honeycomb filter material for a longer period time than in the columnar filter material, which can improve the instantaneous purification rate of the air by the filter material. Due to the gaps between the zeolite particles, air leakage will occur. In addition, as the wind resistance increases, the power of the original fan for columnar filter is obviously insufficient, and the phenomenon of return air is more likely to occur, which leads to unaccomplishment of the best purification effect.

(c) Honeycomb filter material combined with both zeolite particles and activated carbon

This type of filter material uses activated carbon to partially fill the gaps between the zeolite particles to prevent air leakage and improve the adsorption effect. The instantaneous removal ability of the filter material is also greatly enhanced. The harmful gases released after the activated carbon is saturated can be adsorbed by the zeolite particles and solidified in the cavities, thus secondary pollution from activated carbon is avoided. The air gap in this type of filter material is extremely small, and the wind resistance is greatly increased. Therefore, it is necessary to be equipped with more powerful fans.

3.2. Development of air purification engineering machine program

According to the air composition characteristics of the ship cabin, the size of the space and the air purification efficiency requirements, we have designed three types of engineering machines for the air purification of the ship cabin. Among them, the No. 1 and No. 2 air purification engineering machines are suitable for air purification in ship cold storage, and the No. 3 machine is suitable for air purification in the living and working cabins of ships. They all adopt modular design and are mainly composed of cabinets, zeolite filter, sterilization module, ventilation devices, microcomputer controller and power modules.
(a) Technical scheme of ship air purification No. 1 engineering machine
The external dimension of No. 1 machine does not exceed 525mm×380mm×290mm, including 2 fans. Mainly composed of 3 modules, the front and rear are columnar array filter modules, and the middle is the sterilization module. The advantages are good air fluidity, low wind pressure, energy saving; the disadvantage is low air purification efficiency, but the air purification effect in a confined space per unit time is good. This model is suitable for ships with a space within 100m³ or cold storage with a single type of storage of fruits and vegetables.

Figure 1. Module structure diagram of the first unit of the ship cabin air purification device.

(b) Technical scheme of the ship's air purification No. 2 engineering machine
The outline size of the second unit shall not exceed 700mm×380mm×290mm, including 4 fans, and mainly composed of 4 modules: the first is a columnar array filter module, the second is a sterilization module, the third and the fourth are honeycomb filter modules. The columnar filter and the honeycomb filter can be combined in both directions to improve purification efficiency of harmful gases, reduce the workload of the fan, and increase air mobility. This scheme is suitable for cold storages with a space over 100m³ on ships, high removal rate requirements, mixed types of vegetables and fruits (one of which is easy to have a catalytic reaction with other types, for example, where bananas are mixed with other types of fruits and vegetables).

Figure 2. Module structure diagram of the second unit of the ship cabin air purification device.

(c) Technical Scheme of Ship Air Purification No. 3 Engineering Machine
No. 3 engineering machine, which is suitable for the living and working cabins of ships, is composed of 3 modules, the front and rear are columnar array modules, and the middle is the sterilization module. The sterilization module uses a 254nm wavelength ultraviolet lamp tube and a special negative ion
generator (different from the ordinary negative ion generator that produces ozone when wet). Its advantage is that it does not produce ozone, can make the air fresher, and greatly improve the crew's work and living environment.

Figure 3. Module structure diagram of the third unit of the ship cabin air purification device.

The above-designed three types of air purification devices suitable for ship cabins have been preliminarily completed and tested. They have anti-salt spray and anti-fungal capabilities, and can work under ship attitude conditions (15° heel, 22.5° roll, Trim 5°, tilt 7.5°) work reliably, the purification rate of harmful gases (ethylene, acetaldehyde, ethanol, hydrogen sulfide, formaldehyde, sulfur dioxide, etc.) exceeds 90% / (100m³•1h). After a certain period of use, it can be reused after activation, which saves maintenance costs, significantly prolongs the preservation period of fruits and vegetables in ship cabins, and improves the working and living environment of the crew.

4. Conclusion
In this paper, by studying the excellent performance of air purification material zeolite, three kinds of air purification device filter materials based on zeolite are proposed. Taking the composite air purification technology as the starting point and based on the modular design concept, three air purification device models suitable for ship cabins have been designed. The prototypes of the three models have been preliminarily completed and tested. The No. 1 and No. 2 air purification device models designed in the article can remove harmful gases in the ship’s cold storage, thereby prolonging the preservation period of fruits and vegetables. The No. 3 model has greatly improved the air quality of the ship’s cabin and can ensure the physical and mental health of the crew better. This paper provides a new solution for air purification in the cabin of ocean-going ships.

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