Review of control methods of indoor air pollutants

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Abstract

Indoor air environment is an important part of the built environment, including the heat and humidity environment and indoor air quality. As people pay more and more attention to the quality of indoor air, the research on indoor air pollution sources, characteristics, pollution pathways, and control technologies has attracted more and more attention. The article focuses on the types of indoor pollutants and analyzes the control of indoor pollutants in three ways: by reducing the concentration of pollutants in the room through multiple purification methods, and using a more efficient new air system to accelerate the circulation of indoor air to take away indoor pollutants.

Keywords

Indoor air pollutants, control method, purification method, fresh air system.

1. Introduction

Nowadays, with the emphasis on the comfort of human life, the indoor environment of buildings also faces many problems to be solved urgently. With the development of society, modern people's working and living styles have changed greatly. Most people spend about 90% of their time indoors. Good indoor air quality is very important for the comfort and health of the human body. In terms of indoor air quality, due to the interior decoration of buildings, a large number of synthetic materials are used, and the so-called sick buildings appear when the new air volume is reduced blindly for energy conservation. People who stay and work in these buildings for long periods may experience symptoms such as irritability, mucous membrane irritation, headache and lethargy. Therefore, it is urgent to improve the poor air quality and control indoor pollutants.

2. Types of indoor air pollution

The main reason for poor indoor air quality is indoor air pollution, which can be generally divided into three categories: physical pollution, biological pollution and chemical pollution.

Common physical pollutants include particulate matter, fibrous materials and radon (Rn) gas. Particulate matter refers to the solid phase substances in the air -- porous and polymorphic. In addition to ordinary dust, there are more than 130 kinds of harmful substances, including carbon black, asbestos, silicon dioxide, iron, aluminum, cadmium and arsenic. Sometimes particulate matter can also cause chemical pollution by participating in chemical reactions or adsorbing harmful chemical substances. There are ways to deal with physical pollutants in the air; Filter air purification technology, adsorption air purification technology, high voltage electrostatic technology. These technologies have certain advantages and disadvantages, and can solve the problem of controlling physical pollutants in the air.

Indoor air biological pollution is caused by microorganisms. Due to the suitable temperature, humidity and wind speed, indoor microorganisms will accelerate their reproduction and growth, causing more and more serious pollution. Indoor air biological pollution will cause a series of emergent collective disease, fresh air supplement in circulating ventilation or air conditioning system

under the condition of not in time, cause in the same building activity of human body have been affected by biological pollution in the air, this also is much viral flus broke out in a crowded office easily.

Chemical pollution is mainly volatile compounds, such as formaldehyde, benzene series, alkenes and so on. In the study of indoor air, it is found that the main causes of indoor air pollution are outdoor air pollution, indoor personnel pollution and building decoration material pollution. Among these pollutants, the main pollutants caused by volatilization of decoration materials are formaldehyde and benzene series, which are used in the combustion of natural gas in the kitchen and the waste gas generated by waste gas in the toilet to produce CO, CO_2, SO_2, O_3 and NH_3, etc. In 2013, Qiao et al. [1] analyzed the hazardous substances in indoor air pollution, demonstrating that formaldehyde and benzene series pollution is the most severe in indoor air pollution, accounting for the largest proportion and seriously affecting human health. Kitchen and toilet are also one of the important sources of indoor pollutants, which is closely related to human health and poses a serious threat to women's health in particular.

Formaldehyde is a colorless, pungent gas that binds to proteins. In 2010, Lu [2] studied the distribution rules of typical indoor chemical pollutants, which showed that direct contact with the skin to remove formaldehyde could cause dermatitis, pigmentation and necrosis. Regular inhalation of a small amount of formaldehyde can cause chronic poisoning, such as loss of appetite, headache, weakness, sensory disturbance, irregular sweating, palpitations, insomnia, etc. Inhalation of high concentration of formaldehyde, severe respiratory tract irritation and edema, eyes tingling, headache, can also cause bronchial asthma. When formaldehyde concentration in 0.07mg/m3, that can make people smell an odor, 0.3mg/m3 can cause eye irritation, 0.7mg/m3 cause throat thirst uncomfortable.

Formaldehyde comes from many sources, such as plywood, adhesives, coatings and plastic veneers used in interior decoration materials. In 2017, Zhang et al. [3] conducted an experimental study on formaldehyde emission characteristics of fine wood, and studied the significant influence of environmental temperature and humidity on formaldehyde emission characteristics of fine wood. When the temperature increases, the initial dispersible concentration of formaldehyde C_0 and diffusion coefficient D_m increase, while the distribution coefficient K decreases. When the relative humidity increases and the temperature remains unchanged, the initial dispersible concentration of formaldehyde C_0 and diffusion coefficient D_m increase, while the distribution coefficient K remains unchanged.

Benzene series include benzene, toluene, xylene. Benzene is a colorless to light yellow transparent liquid with a strong aromatic odor and is a volatile, flammable and insoluble gas in water. The toxicity of benzene is caused by metabolites. Benzene can be metabolized in liver and bone marrow, and may form metabolites with blood toxicity in hematopoietic tissue itself after entering the body. Long-term exposure to benzene can cause bone marrow and genetic damage, and even lead to anemia and leukemia.

In 2014, Wang et al. [4] monitored the air pollution of benzene series in 32 households newly decorated in Shijiazhuang within two years (<3 months). The study showed that, within a certain range, the release rate of benzene series gradually increased with the increase of temperature. With time, the concentration of the benzene series in indoor air after decoration gradually decreased, and the fastest release rate of benzene series was within three months after the new decoration. The better the indoor ventilation environment is, the longer the air exchange time is, and the more sufficient the air circulation is, the higher the degree of volatilization and dilution of indoor benzene series is, and the lower the concentration of benzene series will be.

Kitchen air pollutants, including the main products of combustion CO, CO_2, SO_2 and lampblack, pose a threat to people's respiratory tract, eyes, nose and throat. Epidemiological investigation data and research results suggest that volatile organic compounds produced by kitchen lampblack have mutagenicity and some mutagenicity. The contaminant inside toilet has NH_3, have strong stimulation,

can produce stimulation to skin respiratory tract and eye, serious when meeting occurrence bronchospasm and emphysema.

In 2017, Li et al. [5] studied the distribution of lampblack particulate pollutants in residential kitchens in northern China, and showed that when doors and Windows are closed in winter and doors are closed in transition season, the pollutant quality fraction of cooking staff in the working area is the largest, and ventilation can minimize the pollutant quality fraction of cooking staff. In 2009, Wang et al. [6] analyzed the air distribution under the mechanical exhaust air of the kitchen and toilet in residential buildings. By taking common residential buildings as the research object, it was concluded that the location and size of the air outlet mainly affected exhaust efficiency. When the tuyere is set under the window, and the section size is 1.8m×0.05m, and the exhaust air volume is 324m3/h, reasonable air distribution can be formed, and the polluted gas containing pollutants can be effectively eliminated. In 2011, Tang et al. [7] conducted an environmental quality evaluation and improvement study on residential kitchen toilets and showed that mechanical ventilation should be adopted for dark toilets in multi-storey buildings, and centrifugal ventilator should be installed to discharge turbidity and moisture from toilets through a vertical exhaust duct. The static outlet pressure of the ventilator is 30~50Pa, and the exhaust air volume is 50~80m3/h. The dark toilets in high-rise buildings must be mechanically ventilated. The static pressure at the inlet of the vertical exhaust duct shall not be less than 80~100Pa, and the exhaust air volume shall be 50~80m3/h. In 2011, Gong et al. [8] conducted numerical simulation of side air supply of pollutants based on indoor air stability, and found in the study on the ventilation mode of pollutants in and out of the air, pollutants could quickly reach the exit under unstable conditions, while they were easy to accumulate indoors and difficult to eliminate outdoors under stable conditions. In the side ventilation model, when the inlet velocity is 1m/s, the CO_2 propagation law is the same as that of NH_3, and the distribution curve is similar in shape, except that the propagation speed is slow and NH_3 arrives at the outlet quickly.

3. Indoor pollutant control technology

3.1 Air filtration technology

The particulate matter in the air is controlled by way of filtering, and the purification process is realized by the way of air purifier, which can be divided into crude efficiency, medium efficiency, high efficiency and super efficiency. In 2011, Song et al. [9] pointed out in the study of indoor air purification technology that most air purifiers adopt HEPA for filtration, which has a strong ability to capture particles and can effectively remove inhalable particles, smoke, bacteria, etc. above 0.3 microns, with a filtration efficiency of 99.97%. However, the disadvantage of filtration technology is that the filter screen needs to be replaced frequently. When the filter screen reaches the filtration saturation, it cannot play an effective role in the purification of indoor air pollutants, and the operation and maintenance cost is relatively high.

3.2 High voltage electrostatic technology

The use of high voltage direct current electric field corona discharge, through the generation of free ions, adsorbed on the dust particles in the air, dust particles with charge, under the action of the electric field deposition on the dust collector plate, in this process to reduce the concentration of dust particles in the air. In 2013, Peng et al. [10] studied the purification and transformation of central air conditioning system with electrostatic dust removal technology, and showed that the removal efficiency of single-stage electrostatic dust removal reached 92.78% for particles with a diameter of more than 2 microns, and 94.5% for particles with a diameter of more than 5 microns. In 2017, Wang et al. [11] researched on high voltage electrostatic air purifier suggests that high voltage electrostatic purifier is one of the major disadvantages of particulate matter of CADR value relative to the HEPA filter purifier is too low, and in the use of high voltage electrostatic technology would produce O_3, become a new kind of indoor air pollutants may heart cerebrovascular and so on have a harm to human body, the need for removal purification.

3.3 Fresh air system purification

Fresh air system adopts indoor ventilation to take away pollutants in indoor air, replenish fresh air and dilute the concentration of pollutants in indoor air. Meanwhile, it can also take away residual heat and humidity in indoor air. It works together with central air conditioning to improve indoor comfort and benefit human health.

The fresh air system is mainly composed of the blower, exhaust fan, air duct and tuyere, which ensures that fresh air is continuously supplied to the room without windows, to achieve the purpose of ventilation. The common fresh air system has one-way flow exhaust type two-way flow feed exhaust type and heat recovery type.

Single-flow exhaust type mainly USES exhaust fans to discharge indoor air to outdoor air, generating negative pressure indoors. Under the action of pressure difference, outdoor air is filtered through the air inlet and then enters into the room. In the one-way air exhaust type fresh air system, the indoor air is simply pumped and discharged, and the outdoor air is filtered and inhaled by negative room pressure. The power is insufficient, and the fresh air is not effectively treated. In the process of air supply and exhaust, the air velocity of the air supply and exhaust outlet is too large, and the air distribution is not uniform, which will make the human body in this environment uncomfortable.

Two-way air supply and exhaust system are used to force air supply and exhaust, which has a good ventilation effect. The air supply and exhaust can be carried out synchronously. The air supply and exhaust volume is equally controlled, and no negative pressure will be generated. The fresh air is treated by filtration, purification and even electric heating, but the exhaust air cannot be recycled.

Full heat, sensible heat recovery type two-way flow supply and exhaust system, heat exchange system are based on the two-way flow, added a heat recovery function of the supply and exhaust system. The principle is the same as the two-way flow, except that the air supply and exhaust are only completed by one main engine, and a heat exchange core with energy exchange function is added inside the main engine. The difference between the full heat and sensible heat lies in the filter core, the full heat exchange new fan heat exchange core belongs to the paper foil thermal conductivity material, the sensible heat exchange core belongs to the aluminum foil material; Total heat exchange involves water molecules, sensible heat exchange involves gas molecules.

Menzies R et al. [12] have conducted a questionnaire survey on two office buildings. When the new air volume is $34m^3$/ (h/ person) and $85m^3$ / (h/ person), the symptomatic people account for 7.12%~14.9% and 11%~14.9%, proving that the increase of new air volume can only increase the comfort of the human body within a certain range, and unreasonable air distribution will affect the comfort of the human body. Lin et al. [13] compared the distribution characteristics of toluene, benzene and formaldehyde in four typical Hong Kong buildings under mixed ventilation and displacement ventilation, and pointed out that displacement ventilation can improve indoor air quality. In 2010, Fu et al. [14] studied displacement ventilation and said that the indoor air distribution generated by displacement ventilation is a typical "piston flow". Fresh air is gradually pushed upward from the lower space, and the pollutant concentration at different heights on the ground varies greatly at the same time. Displacement ventilation provides better comfort for the human body under the premise of high air quality. In 2014, Yue et al. [15] conducted ventilation optimization study on indoor pollutant diffusion, which showed that compared with the opposite side returned wind ventilation mode, the same side returned wind mode had a better effect on formaldehyde emission due to the large airflow transport operation. In 2016, Li et al. [16] studied the effects of different ventilation modes on indoor air quality, showing that the air supply mode can affect the distribution of indoor pollutants, and the drainage efficiency of displacement ventilation mode is better than that of upper feed and upper return ventilation and collision jet ventilation. In 2016, Kuang et al. [17] conducted numerical simulation study on residential fresh air system, showing that the air velocity in the main indoor activity areas was less than 0.2m/s, and the wind speed in the tuyere was more than 0.5m/s when the air volume was too large, which affected human comfort, and the indoor dirty air was trapped when the air volume was too low. In 2017, Zhang et al. [18] studied the monomer fresh

air purification system and showed that the gas velocity, direction and inlet and outlet distance of air inlet and outlet play a key role in the airflow flow of the whole space. The farther the inlet and outlet distance is, the larger the airflow vortex will be, and the more areas with larger airflow velocity will be, and the higher the purification efficiency of pollutants will be.

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