Research progress on indoor formaldehyde pollution and its influencing factors in China, a Review

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Abstract. China's economic development accelerates the process of urbanization, accompanied by formaldehyde pollution in indoor environment. we summarized the recent research on the pollution and impact factor of indoor formaldehyde in China, and elaborated the shortcomings of the existing research and the future research direction from the perspective of source emission, environmental fate and human health effects.

Keywords: Formaldehyde, chinese indoor air, pollution, impactor factor.

1. Introduction
With the acceleration of China's urbanization process and the continuous increase of urban population, the number of people living in the urban indoor environment and the residence time are increasing. According to the research, the average indoor residence time per capita is usually more than 90% [1-5]. Formaldehyde is a typical representative of indoor pollutants. As the world's largest producer of formaldehyde, more than 65% of formaldehyde is used in the production of synthetic resins in building materials [6]. Meanwhile, formaldehyde is a kind of volatile organic compounds, which is listed as a carcinogen by international cancer [7]. There is significant evidence to show that Formaldehyde has a positive and significant impact on the occurrence of nasopharyngeal carcinoma [8-10]. The concentration of formaldehyde in the decorated houses with airtight condition has a long half-life [11, 12], which leads to the formaldehyde content exceeding the standard in the newly decorated houses [13]. The indoor pollution sources of formaldehyde are extensive. Urea formaldehyde resin, melamine resin, phenolic resin used as adhesives in furniture boards [14, 15], paint, cooking fumes in family kitchens and smoking [16] are the most common source [17]. the urea formaldehyde resin in the board or other materials is hydrolyzed and decomposed to release formaldehyde due to the change of environmental conditions.

Excessive formaldehyde will cause a series of problems such as health deterioration, low comfort, low production efficiency and so on. The health effects on indoor people mainly include headache, nausea, mucosal inflammation, irritation of nasopharynx, eyes and throat, asthma, allergy, rhinitis and eczema, fatigued etc. [17, 18]. long-time inhalation of formaldehyde will cause indoor sick
building syndrome, low efficiency in study and work [19-22], and have a comprehensive adverse impact on the physical and mental health of residents [12, 22].

2. Research Background and Proposition Development

2.1. Principle of literature selection
There are two main sources of literature selection for this research review: web of science and CNKI. The main sources of literature selection are published journal research papers, literature reviews and conference papers. The search keywords on web of science are: (1) formaldehyde indoor (2) HCHO indoor, further refine the limited search keywords set as: (1) Chinese (2) China, a total of 45 related literatures were found [1, 6, 23-66]. CNKI set the search words as: indoor formaldehyde, a total of 2157 related literatures were found, because this study focused on the emission and change of formaldehyde concentration in the indoor environment, so the literatures related to the direction of formaldehyde pollution control were not reviewed, and irrelevant literatures were screened out. After literature review, there are only 37 research papers in CNKI [67-103].

2.2. Data selection strategy
The main focuses of these papers’ extraction are: (1) research location and time (2) research test methods and evaluation criteria (3) formaldehyde concentration and range, including mean, upper and lower limits, variance (4) decoration time and environmental control variables

3. Results
At present, the journals published in China such as CNKI only simply test the concentration of formaldehyde, rarely considering the outdoor environment of the test site, without consider the characteristics of test materials, as well as the humidity, temperature and ventilation rate of the test environment, and rarely involve the evaluation of human health effects in these researches. however, for the papers search by web of science, the characteristics of the surrounding environment are taken into account in the study, the monitoring & release regression analysis model is used to study the formaldehyde release model as a common research method, and the correlation between the change of some external environment and formaldehyde concentration is analyzed. However, the scope and conclusion of the study are uncertain under different boundary conditions.

There are many factors that affect the concentration of formaldehyde in indoor environment, which lead to the fluctuation of formaldehyde emission in indoor environment. In addition to the nature of the material itself, it also has a certain relationship with the temperature, humidity and ventilation rate of indoor environment. For example, the research of Tang et al shows that the outdoor source also has an impact on the concentration of formaldehyde in indoor environment [9, 63, 104-106]. Some research show that the concentration of indoor formaldehyde is related to economic development [106, 107], the results showed that the concentration of formaldehyde was also correlated with the income level, education level and career achievement of residents. The existing research shows that the research on indoor formaldehyde emission concentration and change in China is mainly concentrated in some large cities and economically developed areas, while the research scarcely focus on indoor environment in small and medium-sized cities and rural areas.

4. Further Research Directions
Study on the release characteristics of materials. At present, the research on the release mechanism of formaldehyde is mainly limited to the hydrolysis release of formaldehyde containing resin [108-110], the research on the release mechanism of formaldehyde from material properties is less, and the research on the blocking release of material surface packaging is scarce [111]. The release mechanism on the surface and inside of the material was not well explained.

The limit standards of formaldehyde in China mainly include "GB / T18883-2002 indoor air quality standard" and "GB 50325-2010 code for indoor environmental pollution control of civil construction
engineering”, in which the limit values of formaldehyde in residential buildings are 0.10 mg/m³ and 0.08 mg/m³ respectively. The limit of human health exposure prescribed by WHO is 0.10 mg/m³, and the concentration of excess formaldehyde can lead to a significant increase in the incidence rate of nasopharyngeal carcinoma, and WHO is classified formaldehyde as a carcinogen. However, the correlation between formaldehyde and leukemia is not clear [65]. Besides, the toxic effect factor of formaldehyde treatment is not comprehensive. The carcinogenic factor is from the high-dose animal or human to low dose environment. There is uncertainty in the linear extrapolation of radiation [112].

The coupling effect of formaldehyde and other indoor pollutants on human health is mainly based on the calculation model proposed by the U.S. Environmental Protection Agency in 1989. The evaluation of human health effect of indoor multi pollutants is based on the linear accumulation of the evaluation values of human health effect of various pollutants, which lacks the coupling effect of multi pollutants in the presence of main indoor pollutants. Effects on the health of human models [61], so we need to develop a model of human health effect about multi pollutants.

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