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Investigation and analysis on indoor air quality of large commercial office building in summer

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Abstract: To study the indoor air qualities (IAQ) of large commercial office buildings in Hunan province of China and the corresponding improvement methods, the IAQ of a large commercial office building in Changsha in July, 2008, is investigated. A questionnaire survey and field tests are used to collect data. According to the data of twelve rooms in this building, objective evaluation and the subjective evaluation of the IAQ are obtained. Almost all of the environmental parameters in these rooms basically meet the standards of the objective evaluation. But the average concentration of carbon dioxide in most rooms cannot reach the value of the cleanliness standards, 1 255 mg/m^3. The average acceptability of the IAQ in these rooms is 71%, which is lower than the value of the ASHRAE 55—1992 standards, 80%. The proper increase in the wind speed and the indoor fresh air supply can greatly improve the objective evaluation and the subjective evaluation of the IAQ.

Key words: large commercial office building; indoor air quality (IAQ); objective evaluation; subjective evaluation

With the coming of the energy crisis in the 1970s, energy saving became a key factor in architectural design[1]. Many self-enclosed buildings were built. It was a great challenge to save energy without sacrificing comfort. The world health organization(WHO) confirmed that poor IAQ could result in sick building syndrome(SBS), a variety of complications and chemical allergies[2]. At present, indoor air pollution becomes more and more serious. The IAQ evaluation is attached great importance both at home and abroad[3-6]. Therefore, a building should be taken as an investigated object for analyzing the IAQ. Herein, considering the living level and economic development in each city of Hunan province, investigations on the IAQ were carried out in July, 2008 in Changsha, China.

1 Method

Twelve rooms in a large commercial office building of Changsha city are selected as the experimental objects. These rooms are on the 1st, 6th, 12th, 15th, 18th and 20th floors of the building. The IAQ of each room is tracked from 10: 00 to 15: 00 every other day. And a questionnaire survey is taken, which contains the building characteristics, the density of people, receptivity, etc.

2 Results

2.1 Basic information of investigation

This large commercial office building with two underground and twenty-nine above-ground floors was built in 1995. The architectural area is 4×10^4 m^2. The construction of this building is a reinforced concrete structure. The exterior wall is a glass curtain wall. A fan coil unit(FCU) system is used for introducing new wind to the room. The floor areas of the rooms range from 22 to 100 m^2 and the average value is 45.20 m^2/room.

Forty office workers join in this investigation. The participants are about 30 years old, and the numbers of men and women are equal. Most of them have lived in this city for over ten years. That is, they have been completely adapted to the climate of this area. Therefore, these selected samples can reflect the actual situation of the office staff.

2.2 Environmental parameters of investigated rooms

Tab. 1 lists the environmental parameters of the investigated rooms. It can be seen that the temperature in an air-conditioning environment in summer is basically lower than 26 ℃. The minimum temperature is only 21.8 ℃. The settings of the air-conditioning temperature in summer are relatively low. The energy-saving potential of a forward-looking energy-efficient construction can be found.

Tab. 1 Outdoor and indoor environmental parameters

Environmental parameter	Outdoor	Indoor				
		Minimum	Maximum	Average	Standard deviation	IAQ standards[7]
Dry-bulb temperature/℃	31.2	21.8	26.7	24.50	1.54	22 to 28
Relative humidity/%	60.2	52.3	69.8	63.50	5.13	40 to 80
Air velocity/(m·s^{-1})	0.83	0.00	0.21	0.09	0.07	≤0.30
Concentration of CO_2/(mg·m^{-3})	820	915	1 664	1 259.24	243.59	≤3 587
Concentration of PM_{10}/(mg·m^{-3})		0.01	0.10	0.05	0.03	≤0.15(average daily value)
Concentration of TVOC/(mg·m^{-3})		0.06	0.30	0.15	0.06	≤0.60(mean value within 8 h)

Note: TVOC means total volatile organic compounds.

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3 Evaluation and Analyses

3.1 Objective evaluation

The comprehensive index method is feasible for evaluating the indoor air quality both at home and abroad. The comprehensive air environmental quality assessment, an in-

dex which combines the highest score index with the average index, is important for a building. The evaluation results are comprehensive, objective and accurate. The comprehensive index can be calculated by

$$I = \sqrt{\left(\max\left|\frac{C_1}{S_1}, \frac{C_2}{S_2}, \cdots, \frac{C_i}{S_i}\right|\right)\left(\frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{S_i}\right)} \quad (1)$$

where C_i and S_i are the concentration and the national standard concentration of the i-th pollutant; C_i/S_i is the dimensionless value (parted index) of the i-th pollutant; n is the type amount of the pollutant; I is the comprehensive air quality index[7].

According to Eq. (1), the results of the objective evaluation can be obtained, as shown in Tab. 2. It can be seen that the comprehensive air quality index is between 0.110 and 0.256, which is lower than the value of the cleanliness standards, 0.490[8]. It is generally believed that the indoor environment is clean when the composite index is under 0.5. The proper increase in fresh air supply can improve the objective evaluation of the IAQ.

Tab. 2 Objective evaluation on IAQ

Floor	I	CO_2		PM_{10}		TVOC	
		$C_1/(mg\cdot m^{-3})$	C_1/S_1	$C_2/(mg\cdot m^{-3})$	C_2/S_2	$C_3/(mg\cdot m^{-3})$	C_3/S_3
1st	0.256	1 529.45	0.424	0.085	0.567	0.220	0.367
6th	0.156	1 405.07	0.390	0.065	0.433	0.155	0.258
12th	0.106	906.67	0.252	0.055	0.367	0.150	0.250
15th	0.110	1 310.43	0.364	0.045	0.300	0.145	0.242
18th	0.128	1 416.78	0.393	0.06	0.400	0.100	0.167
20th	0.185	1 602.40	0.445	0.075	0.500	0.200	0.333

Note: I is the composite air quality index.

3.2 Subjective evaluation

The IAQ should be analyzed by subjective evaluation and objective evaluation. As shown in Tab. 3, in a certain wind speed range, the average acceptability of the IAQ increases with the increase in the average air velocity. According to the ASHRAE—1991 standards, the indoor wind speed in the office building should be within the scope of 0.13 to 0.23 m/s.

Tab. 3 Subjective evaluation on IAQ

Floor	Staff density/(person·m^{-2})	Average luminance/Lx	Average noise/dB	Average air velocity/(m·s^{-1})	Average acceptability/%
1st	0.17	365.5	46.0	0.08	68
6th	0.03	571.5	52.0	0.09	75
12th	0.19	406.5	52.0	0.12	72
15th	0.10	429.0	53.0	0.12	80
18th	0.06	423.0	53.5	0.11	83
20th	0.12	423.5	52.5	0.05	49

3.3 Analysis of IAQ

Based on the results of the IAQ in these rooms, the comprehensive air quality index on the 12th floor is at a maximum, and a clean environment exists in this building. However, the average concentration of carbon dioxide in most rooms cannot meet the requirements of the standards of cleanliness. The average acceptability of the IAQ on the 15th floor is at a maximum. It can be found that there are three main effects on the acceptability of the IAQ, dry-bulb temperature, air velocity and humidity. Most of people participating in the investigation feel utter lassitude because of the low air velocity. Therefore, the results of the objective evaluation and the subjective evaluation are quite different.

4 Conclusion

The IAQ of a building in summer basically meets the requirements of the national standards. The average concentration of airborne particulate matters and carbon dioxide in the large commercial office building are 0.05 mg/m^3 and 1 259.24 mg/m^3, which reach the values of the national standards. The comprehensive air quality index is between 0.110 and 0.256, and the indoor environment is clean. Thus, the results of the objective evaluation are satisfactory. However, the results of the subjective evaluation are unsatisfactory. The acceptability of the IAQ is low because of the low indoor wind speed. A reasonable organization of indoor air can greatly improve the subjective evaluation of the IAQ. The average acceptability of the IAQ is only 71%, which is lower than the value of the ASHRAE 62—1989 standards, 80%. The investigation results show that the proper increase in the wind speed can increase the acceptability of the IAQ when the humidity remains unchanged. It is an important characteristic that the IAQ is evaluated mainly by the sense of people.

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某大型商业办公建筑夏季室内空气品质的调查与分析

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摘要:为了研究中国湖南省大型商业办公建筑室内空气品质环境现状及其改善对策,选取湖南省长沙市某大型商业办公建筑为研究对象,对此建筑在2008年7月的室内空气品质状况进行了调研. 采用问卷调查和现场测试的方法收集数据,并基于这些数据对12个房间的室内空气品质进行客观和主观评价. 结果表明,这些房间室内空气品质的主要参数基本满足客观评价的标准,但大部分房间的 CO_2 平均浓度未能达到清洁标准规定值1 255 mg/m^3. 这些房间室内空气品质的平均接受率为71%,低于ASHRAE 55—1992标准规定值(80%). 适当地提高空气流速、增加新风量可以很好地改善室内空气品质的主、客观评价.

关键词:大型商业办公建筑;室内空气品质;客观评价;主观评价
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