A Novel Indoor Air Quality Standards and Design Methods in Environmental Assessment

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Abstract. In recent years, indoor air pollution has become one of the research hotspots. In the environmental assessment project, the indoor air quality standards have been explicitly included in the control items of China's green building environmental evaluation standards, and controlling the indoor environment has become important to achieve green buildings. Analysis of the main factors affecting indoor air quality and discussion of design methods based on typical pollutants for indoor air quality are important links for achieving green environmental assessment.

1. Introduction

Indoor air quality is one of the factors that directly affect the health and comfort of human beings in addition to comfort indicators such as temperature, humidity, and indoor wind speed in an indoor air environment. In recent years, with the improvement of people's living standards [1] and the rapid development of urbanized housing construction, home purchases and decoration of residential houses have become hot spots for consumption by citizens [2]. However, due to the large number of applications of building decoration materials and the incomplete quality control of various building materials, this makes the sources of indoor air formaldehyde and vocal chemical pollution and the factors affecting indoor air quality more and more complicated [3]. In addition, under the background of strict national energy saving requirements for buildings, the degree of airtightness of buildings is increasing, and the corresponding indoor air and the outdoor air ventilation volume is reduced, and there is a serious health risk of chemical pollution of indoor air in the building [4].

On the other hand, due to the frequent appearance of atmospheric haze in the outdoor environment, outdoor fine particles enter the interior through enclosures such as doors and windows and ventilation systems, and indoor PM2.5 pollution poses new health threats to people [5]. Currently, indoor PM2.5. There are relatively few standards for fine particulate matter, and there is also a lack of effective prevention and control schemes for indoor new PM2.5 pollution [6].

In recent years, indoor air pollution has become a research hotspot in environmental assessment. Controlling the indoor environment has become an important link to achieve green buildings. Indoor air quality has been explicitly included in the control item of the new national green building evaluation standard [7]. The main factors of air quality, discuss the current effective indoor air quality evaluation methods.
2. Related Theoretical Review

2.1. Definition of Indoor Air Quality

Over the decades, people's understanding of the concept of indoor air quality has undergone many changes. Initially, indoor air quality was widely regarded as a series of indicators of pollutant concentrations. With the comprehensive development of research and the continuous deepening of people's cognition, people have realized that the definition of purely objective evaluation cannot completely cover indoor air quality, so subjective evaluation was introduced into the definition of indoor air quality [8]. At the International Indoor Air Quality Discussion Conference in 1989, Professor Fanger of the University of Copenhagen proposed that quality reflects the degree to which people's requirements are met. If people are satisfied with the air, it is high quality; otherwise, it is low quality. This definition refers to indoor air quality. It has become a subjective perception of indoor pollution, and it is no longer the control of pollutant indicators in the past. ASHRAE Standard 62-1989 R of the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) combines both subjective and objective evaluation methods. "Acceptable Indoor Air Quality" was first proposed, the definition is that the vast majority of people in the air have not expressed dissatisfaction with indoor air, and that no known pollutants in the air have reached the potential for human health Serious threat concentration. The ASHRAE standard cleverly avoids the absolute concept of indoor environment satisfaction, which is more scientific and perfect than other definitions.

2.2. Related Standards for Indoor Air Quality

Although residential indoor air quality should be limited and evaluated according to subjective and objective factors, indoor environmental control in various countries is still mainly based on quantitative pollution indicators. Based on indoor pollutant research and detection on a large number of buildings, domestic and foreign experts and scholars published a lot of research results for different building types and environments, and many countries have established relatively complete and reference pollutant standards [9]. The indoor air quality standards established by various countries are different in content and purpose and meet their own national conditions: foreign countries are represented by the ashrae standards of the United States and the cibe indoor air quality and ventilation standards of the United Kingdom, and GB/T18883-2002 "Indoor Air Quality Standards" and GB50325-2010 "Code for the Control of Indoor Environmental Pollution in Civil Construction Projects" are the representatives. The specific indicators are shown in Table 1. Although some researchers have pointed out the shortcomings of these two standards [10], they are still current. The most important iaq standard basis. In addition, China has also established many indoor air quality testing standards, including GB/T17785-1999 "Guidelines for the control of new low-rise residential building design and construction", GB/T16146-1995 Concentration Control Standards, etc., these together constitute the existing IAQ control standard system in China.
### Table 1. China's Indoor Air Quality Standards.

| Parameter category        | Parameter | GB/T18883-2002 | GB50325-2010 |
|---------------------------|-----------|----------------|--------------|
|                           |           |                | Type II Civil | Type I Civil |
|                           |           |                | Construction  | Construction |
|                           |           |                | Engineering   | Engineering   |
|                           | Sulfur dioxide/(mg.m$^{-3}$) | 0.50 (hourly average) |              |
|                           | Nitrogen dioxide/(mg.m$^{-3}$) | 0.24 (hourly average) |              |
|                           | Carbon monoxide/(mg.m$^{-3}$) | 10 (hourly mean) |              |
|                           | Carbon dioxide/% | 0.10 (daily average) | 0.20 | 0.20 |
|                           | Ammonia / (mg.m$^{-3}$) | 0.20 (hourly mean) | 0.20 | 0.20 |
|                           | Ozone/(mg.m$^{-3}$) | 0.16 (hourly average) |              |
| Chemical                  | Formic acid/(mg.m$^{-3}$) | 0.10 (hourly average) | 0.08 | 0.10 |
|                           | Benzene / (mg.m$^{-3}$) | 0.11 (hourly average) | 0.09 | 0.09 |
|                           | Toluene/(mg.m$^{-3}$) | 0.20 (hourly mean) |              |
|                           | Xylene/(mg.m$^{-3}$) | 0.20 (hourly mean) |              |
|                           | Benzo [a] pyrene/(ng.m$^{-3}$) | 1.0 (daily average) |              |
|                           | Respirable particulate matter/(mg.m$^{-3}$) | 0.15 (daily average) |              |
|                           | Total volatile organic compounds/(mg.m$^{-3}$) | 0.60 (8-hour average) | 0.5 | 0.6 |
| Biological                | Total number of colonies/(cfu.m$^{-3}$) | 2500 (depending on the instrument) |              |
| Radioactivity             | Radon 222Rn/(Bq.m$^{-3}$) | 400 (annual average) | 200 | 400 |

Countries around the world have developed IAQ related standards, as shown in Table 2. And each standard has different building types and different detection methods due to the applicable building types and major pollutants of concern in the corresponding standards/guidelines. National and regional differences.
Table 2. IAQ Standards and Contents at Home and Abroad.

| Country/region | standard name | main content |
|----------------|---------------|--------------|
| Canada         | Technical Guidelines for Air Quality in Office Buildings | Provides 11 physical and chemical index limits for CO, CO₂, PM, Rn, NO₂, SO₂, O₃, T, RH, formaldehyde, and air velocity value |
|                | Building health regulations | Develop CO, CO₂, NO, O₃, RH, T, air velocity and other standards |
| Japan          | Office building hygiene regulations | Specify the area that employees need to open windows, and other indicators such as CO and RH are the same as the building health regulations |
| Singapore      | Guidelines for Good Indoor Air Quality in Office Buildings | Specified standard values of CO, CO₂, O₃, TVOC, RH, formaldehyde, temperature, total microorganisms, and air velocity |
| United States  | Acceptable aq ventilation standards | Specify the concentration standards of 12 pollutants such as formaldehyde, acetaldehyde, CO, asbestos, lead, chlordane, nitrogen oxides, and HVAC standards |
|                | Guidelines for Indoor Air Quality Management in Offices and Public Places | Defines physical, chemical, and biological indicator limits including temperature/humidity, formaldehyde, PM, total bacteria, etc. |
| Hong Kong      | Recommended standards for indoor air pollutants | Includes 7 pollutants including indoor formaldehyde, total bacteria, CO₂, respirable particulate matter, nitrogen oxides, SO₂ & and benzo (a) pyrene health standard |
|                | Indoor air quality sanitation specifications | Provides 15 physical, chemical, and biological control indicators for indoor air, as well as requirements for ventilation and purification |
|                | Code for indoor environmental pollution control of civil construction projects | According to the use function and people's staying time, the civil buildings are divided into two categories and control requirements are respectively set. The radioactive radon, formaldehyde, ammonia, benzene, and tvoc are five indoor indoor pollutants that are generally concerned by people. |
| China          | Indoor air quality standards | The standard is applicable to residential and office buildings, and provides 19 types of control indicators of chemical, physical, biological and radioactive, and also adds the requirement that "indoor air should be non-toxic, harmless, and no abnormal smell" |

It can be seen from Table 2 that the US IAQ standard includes asbestos and chlordane, but not in other countries. The main reason is that many houses in the United States use a large amount of wood. Chlordane is often used to control termites that can damage the wood construction materials of houses and become indoor. One of the major pollutants, most countries do not have this problem. Compared with other countries' iaq standards/guidelines, China's GB 18883-2002 "Indoor Air Quality Standards" stipulates the most air indicators, including chemical, physical, biological and radiological, etc. 19 limit values indicators. At present in China's construction engineering design [11], in addition to the four physical indicators of temperature, humidity, air velocity, and fresh air volume in the standard have clear design control methods [12], other indoor pollution indicators control There is no relevant design control specification. A feasible indoor pollution control mode is to screen one or several characteristic pollutants according to the main source and status of indoor air pollution, and dilute the
typical characteristic pollutant concentrations in the room through ventilation, while achieving dilution. The concentration of other pollutants is below the limit.

3. Sources of Indoor Air Pollution

3.1. Sources of Indoor Pollutants

Indoor air pollutants can be divided into physical pollution, chemical pollution, and biological pollution by nature, including solid particles, microorganisms, and harmful gases. According to their sources, they can be divided into the following eight categories, as shown in Table 3.

Table 3. Sources of Indoor Air Pollution.

| No. | Sources of Indoor Air Pollution |
|-----|--------------------------------|
| 1   | CO₂, SO₂, NOₓ, formaldehyde, inhalable particulate matter, etc. from fuel combustion, cigarette incense, etc. Furniture and building materials, artificial board, synthetic resin, paint, daily necessities, and other decoration materials will release volatile organic compounds during use, including formaldehyde, btx (benzene, toluene and xylene), ketones and esters, etc. The body's own exhaled exhaust gas, sweat, CO₂, dimethylamine, benzene, methanol, SO₂, ammonia, acetone, etc., while coughing and sneezing will also discharge bacteria and viruses. Household appliances, such as computers, printers, copiers, etc., will generate ozone, organic matter and particulate matter during use. |
| 2   | Volatile organic compounds are produced in household chemicals such as air fresheners, pesticides, detergents and cosmetics, as well as kitchen fumes and incense. Household air conditioners and central air conditioners, if not properly maintained, dust deposited on the filter screen during use is likely to breed bacteria, viruses, etc. Biological pollution from indoor appliances, such as dust mites breeding on carpets, pillows, and quilts; radon pollution. |
| 3   | Outdoor polluted air enters the room through doors, windows, gaps, etc., mainly including automobile exhaust in the atmosphere, industrial exhaust gas, haze fine particles, pollen pollution, etc. |

Table 3 summarizes the 8 types of pollution sources and main pollution harmful component indicators that can cause indoor air pollution. For the design of architectural IAQ projects, continuous emission from pollutants should be considered as the main control object. For cigarettes in category 1; printers in category 4 And copiers; Category 5 household chemicals, kitchen fume, incense and other intermittent indoor pollution sources will not be considered for the time being. For Category 3, the human body emits pollutants that can be ignored due to their small emissions and low harmfulness. The combustion of fuels such as cooking in Class 1 is mainly due to the burning of natural gas and coal-based gas in urban residences in China, and indoor soot pollution caused by coal types is not considered. Microbial pollution is caused to Type 6 and 7 air conditioning systems and furniture. Under the ventilation conditions, it may cause disease transmission. The more effective method is the prevention, control and killing purification technology of microorganisms [13], which shows that it is not appropriate to solve the problem by ventilation design. According to the above, the residential IAQ engineering design indicators should be from Category 2 Typical pollutants are selected for decoration and construction materials, paint, and type 8 outdoor particulate pollution. This article uses formaldehyde and pm2.5 fine particles as examples to introduce these two types of typical pollutants.

3.2. Typical Indoor Pollutants

3.2.1. Formaldehyde. The main sources of formaldehyde in residential environments are: artificial boards such as plywood, particleboard, fiberboard used as interior decoration; furniture made of
artificial boards; various wall materials such as paint, coatings, wallpaper; chemical fiber carpets, foam plastics, and other buildings Decoration materials. At present, the applicable standards for formaldehyde in residential air are GB/T 18883-2002 "Indoor Air Quality Standards" (<0.1mg/m³) and GB 50325-2010 "Code for Indoor Environmental Pollution Control of Civil Building Engineering" (<0.08 mg/m³).

The over-standard indoor formaldehyde concentration in China is relatively serious. The environmental concentrations of similar apartments in different cities have little difference, that is, the regional differences are not obvious. There is a certain difference in formaldehyde concentrations in different functional rooms of the same residence [14]. The general situation is: The concentration is higher, and the concentration in the bedroom is usually higher than that in the kitchen and living room. In addition, the length of time for the completion of the decoration is the factor that has the greatest effect on the indoor formaldehyde concentration. The formaldehyde release cycle in general wood-based panels and adhesives is 3-15 years, as figure 1, and long-term exposure in the indoor environment where polluting formaldehyde and voc pollution exists, even if the concentration of pollutants is not high, the harm to the human body cannot be taken lightly due to the cumulative effect, especially to the vulnerable groups such as children, the elderly, and pregnant women.

![Figure 1. Formaldehyde Concentration Change Chart.](image)

3.2.2. Particulate matter. The impact of indoor particulate matter on human health depends on its chemical characteristics, biological characteristics, particle size, and other characteristics. It is classified according to the size of the particle diameter, of which less than 100 pm is called total suspended particulate matter (TSP), less than 10 pm Respirable particulate matter (PM10) and fine particulate matter (PM2.5) are less than 2.5 pm. The sources of particulate matter in the house can also be divided into two categories: the penetration of outdoor particulate matter and the indoor source. The indoor source is mainly indoor. The combustion process of food, heating, human activities such as cleaning and smoking, and the volatilization of the surface of building materials. China's indoor air quality standards only limit the concentration of PM10 inhalable particulates (24 h average concentration <0.15 mg/m³). Since 2007, China's PM2.5 (i.e. fine particulate matter) environmental pollution has become increasingly serious, and the harm of PM2.5 to human health has gradually been widely concerned. In this context, China revised a new GB 3095 in 2012— The 2012 “Ambient Air Quality Standard” officially lists PM2.5 as an indicator of ambient air quality control, requiring a daily average concentration limit of 75 pg/m³. For the concentration limit of indoor PM2.5 related specifications, refer to this standard.

4. Design Factors for Target Pollutant Control

China currently proposes some countermeasures and measures to improve indoor air quality, and establishes a comprehensive indoor air quality assessment method [15] that meets China's national conditions. For indoor pollutant control, it mainly includes 3 control methods, namely pollution source control, ventilation dilution, Air purification: From the perspective of engineering design, in order to
achieve indoor target pollutant concentration control, pollution source control and ventilation dilution of pollutants should be the first choice, and try to choose the way to reduce indoor pollution from the source and avoid pollution before treatment.

4.1. Formaldehyde

Regarding a calculation method of ventilation volume based on the emission rate of pollutants from building materials, it is proposed that the method of B3.1.2 in ISO 16814 can be used to calculate the concentration of pollutants under steady-state conditions [7,13]:

\[
q_v = \frac{(\sum G_h \cdot S)}{(C_{h,i} - C_{h,o})} \times \frac{1}{\varepsilon_v}
\]

(1)

In formula (1):
- \(q_v\) — design fresh air volume, m\(^3\)/h;
- \(G_h\) — formaldehyde emission rate of certain building material pollutants, mg/(h \cdot m\(^2\));
- \(S\) — the exposed area of the building corresponding to the room;
- \(C_{h,i}\) — limit concentration of indoor formaldehyde, mg/m\(^3\);
- \(C_{h,o}\) — Background concentration of outdoor formaldehyde, mg/m\(^3\);
- \(\varepsilon_v\) is ventilation efficiency.

In formula (1), the intensity of indoor pollution sources is determined according to the emission rates \(G_h\) of different building materials and the use area \(S\). Among them, the emission rates of various building materials pollutants need to be obtained through laboratory testing. It can be seen that it can be selected at the design stage. Green building materials with a low \(G_h\) emission rate have the effect of controlling indoor pollution sources. For buildings using other building materials, paints and other VOC-type pollution sources, they can also be calculated by the above method, and the maximum design fresh air volume can be selected through calculation.

4.2. PM2.5

For the design and calculation of residential pm2.5, taking the general fresh air system filtration and indoor air purifier as examples, it can be calculated by formula (2) steady state.

\[
[Q_f (1-\eta_f) + Q_L P] C_o + Q_f C_i - (kV + CADR) C_i \times 0 = 0
\]

(2)

In the formula: \(C_i\) — limit value of room pollutant concentration, pg/m\(^3\);
- \(Q_f\) — Fresh air volume, m\(^3\)/h; \(V\) : room volume, m\(^3\);
- \(\eta_f\) — fresh air filtration efficiency;
- \(Q_L\) — Air leakage (including natural ventilation), m\(^3\)/h;
- \(C_o\) — calculated outdoor particulate matter concentration, pg/m\(^3\);
- \(P\) — penetration coefficient;
- \(k\) — natural sedimentation rate of particles, h\(^{-1}\);
- CADR — clean air volume of air purifier, m\(^3\)/h;

By formula (2), it is possible to realize the calculation of indoor new air filter efficiency and CADR selection of air purifiers [16], and also to evaluate the indoor PM2.5 concentration level under the conditions of new air filter efficiency and CADR. It should be noted that In the indoor PM2.5 design, the calculated concentration of outdoor particulate matter \(C_o\) should be determined based on environmental meteorological data in the design area. The natural sedimentation rate \(k\) of the particulate matter can be ignored. In addition, the calculated values of the room air leakage \(Q_L\) and the penetration coefficient \(P\) are required. Parameters should be derived from a large number of measured data [17].
5. Conclusion
This paper discusses the standard of indoor air quality control in environmental assessment, and discusses the design and calculation method with formaldehyde and PM2.5 as indoor characteristic pollutant indexes. This method can realize the environmental protection of indoor building materials, coatings and coatings from the source, and also can realize the selection of residential fresh air filtration and purification system.

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