Developing Indoor Air Quality Related Standards in China

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Abstract

Legislative history of indoor air quality (IAQ) in China may be simply divided into three stages: starting stage (late 1970s-1993), developing stage (1994-2000), and normative management stage (2001-present). Up to date, China has established two sets of IAQ relevant standards: one set directly dealing with indoor air concentration limits, and the other dealing with limits of harmful substances contained in materials that will be used for constructing or furnishing the interior of buildings. This paper reviews the background, objectives, and approaches of various IAQ related standards in each of the three IAQ legislative (management) stages.

Keywords: standards and regulations; IAQ; indoor decorative materials; limits of harmful substances; developing stages

1. Introduction

The number of airtight buildings with air-conditioning as well as interior decorations has increased markedly in China since 1990 due to the rapid economic growth. However, decorative materials used in residential and commercial buildings can be major sources of a series of toxic compounds that degrade indoor air quality. In order to control indoor air pollution in civil buildings (residence and office buildings), China has issued not only standards for IAQ, but also limits of harmful substances contained in interior decorative materials (LHSCIDM) ¹⁻⁹.

The development of IAQ related standards in China may be divided into three stages: starting stage, developing stage, and normative management stage. Because a recent paper has reviewed standards of IAQ in China¹, this paper focuses primarily on LHSCIDM.

2. Starting Stage (1970s-1993)

Research of IAQ started in China in the late 1970s, leading to the publication of some comprehensive studies in the 1980s ¹⁰, and consequently, some legislative efforts concerning IAQ in workplaces and other types of indoor environments.

“Hygienic Standard for Industrial Enterprises Designing (TJ36-1979)” ¹¹ was issued in 1979. It regulated concentration limits of 111 toxicants and 9 dust standards related to different production processes in workplaces and residential areas. It is still in effect currently. However, the term “indoor environment” used in this paper does not include factories and workplaces.

In 1988, the Ministry of Health issued hygienic standards for 12 types of public places. Some examples of the public places covered by these standards are: hotels; bathhouses; barber-shops and beauty salons; natatoriums; gymnasiums; libraries; museums, art and exhibition galleries; emporium and department stores; bookstores; hospital waiting rooms and restaurants. Revised versions of these standards were issued in 1996. However, there were no stipulations for any concentration limits for the indoor environment of civil buildings until 1995 ¹.

In this stage, LHSCIDM were only mentioned in some standards for products. For example: GB/T4897-92 included emission limitation of free formaldehyde in wood-based panels; JC518-93 included limits of radionuclides, and HG2454-93 included limits of free toluene diisocyanate (TDI) in paints. As a special concern, radioactivity had its independent standard earlier and was revised later on (GB/T 16146-1995).

Starting stage for regulating IAQ was more than 10 years in length. Within this stage, China began economic reform and opening to the world. Urban residents usually did not own their apartments or other types of houses. Indoor decorating and remodeling activities were not prevalent. Indoor air pollution caused by decorative materials was not obvious to attract wide attentions at that time. Therefore, the research on IAQ was kept in the areas of cooking activities, environmental tobacco smoke (ETS), cooking and/or heating using coal stoves with or without chimneys, etc.

3. Developing Stage (1994-2000)

From 1994 to 2000, high-speed economic growth has improved the living standards of many people in urban
areas in China. A large fraction of urban residents started to own apartments or townhouses. As a result, home refurbishment/decoration/remodeling for new constructed or existing apartments has become very popular and brought health concerns.

To accommodate the public call for improving IAQ, researchers began to conduct studies on IAQ, such as those designed to characterize indoor air pollution\(^{(12-17)}\). In this stage, a few IAQ related standards were issued, which played significant and positive roles in controlling the problem.

### 3.1 Labeling Limits of Harmful Substances in Products

In May 1994, China Certification of Environmental Labeling Committee was formally established\(^{(19)}\). At the beginning of establishing the committee, “Water-based Coatings” (HJBZ4-1999) - one of the seven products that firstly gained environmental labeling certification, was the product related to indoor air pollutants in construction industry. Later on, some standards for building and decorating materials were issued, such as: “Adhesives” (HJBZ28-1998), “Phosphogypsum Products” (HJBZ29-1998), “Non-Asbestos Construction Products” (HJBZ25-1998), “Man-made Wood-based Board” (HJBZ37-1999), “Plastic Pipes for Construction” (HJBZ39-1999), etc. While China Environmental Labeling was not compulsive, the environmental standard contents for indoor decorative materials and the emission limits of pollutants were first included. It indicates that China began to establish independent LHSCIDM. In recent years, the committee has been revising all the standards continuously. This committee firstly proposed the measurement method for volatile organic compounds (VOCs) in the standard - “Water-based Paints”. It is clear that the products with environmental labeling should be excellent in product quality and healthy characters. Issuing certification of environmental labeling for building/decorating materials industry has promoted the improvement of IAQ.

### 3.2 Local LHSCIDM

#### 3.2.1 Shanghai Local Standard - Healthy Indoor Building Coatings

On July 10\(^{th}\), 1998, the China State Quality Supervision-Inspection-Quarantine Administration (SQSIQA) Shanghai branch promulgated the local standard - healthy indoor building coatings (DB31/T 15-1998)\(^{(19)}\), which was the first local standard related to LHSCIDM. This standard mainly consulted “The Establishment of The Ecological Assessing Regulations for the Indoor Colored Coatings and Varnish (96/13/EC)” which was issued by European Community and the “Technical Requirements for Products with Environmental Labeling - Water-based Paints (HJBZ4-1999)”. The technical requirements include: (1) routine indices: the routine characteristics of products must comply with technical indices of indoor coatings (first grade products) of synthetic latex resin (GB/T9756); (2) health related indices: the health related indices of products must comply with the regulation in the technical requirements of HJBZ4-1999, and the requirements listed in Table 1.

| No. | Item                              | Technological Index |
|-----|-----------------------------------|---------------------|
| 1   | Content of Total Volatile Organic Compounds (TVOC) | ≤ 30 g/L           |
| 2   | Retaining Air Concentration of VOCs | ≤ 3.0 mg/mL         |
| 3   | Toxicity Index of Paints (TIP)    | ≤ 10                |
| 4   | Heavy Mental Contents             | ≤ 90 mg/kg          |
| 5   | Brightness (°)                    | ≤ 15                |
| 6   | Permeability                      | ≥ 200 g/m²          |
| 7   | Dermal reaction                   | Non-irritancy       |

Note: Retaining concentration of VOCs in air: healthy paints should meet not only the indices in this table but also those in TJ36-1979.

#### 3.2.2 Beijing Assessment Regulation for the Safety, Healthy and Quality of Indoor Building Paints

“Beijing Assessment Regulation for the Safety, Healthy and Quality of Indoor Building Paints”\(^{(20)}\) was promulgated by SQSIQA Beijing Branch. This regulation addressed safety assessment and method as well as judgment principals for the content of the harmful substances in the indoor building paints (see Table 2). For example, this regulation requires that the contents of VOCs, benzene, toluene, xylene, TDI and emission of free formaldehyde, etc, should be measured using environmental chamber method. Compared to the Shanghai Standard (DB31/T15 -1998), the Beijing Assessment Regulation added measurement methods of harmful substances including substituted benzenes in paints.

| No. | Item                                        | Technological Index |
|-----|---------------------------------------------|---------------------|
| 1   | VOC                                         | ≤ 300 g/L           |
| 2   | Benzene (%)                                 | Cannot be detected  |
| 3   | Toluene/Xylene                              | ≤ 2.0 mg/m²         |
| 4   | Lead                                        | ≤ 0.01%             |
| 5   | Chromium                                    | ≤ 0.005%            |
| 6   | Mercury                                     | ≤ 0.1 %             |
| 7   | Cadmium                                     | ≤ 0.05%             |
| 8   | Free Released Formaldehyde                  | ≤ 0.5 mg/m³         |
| 9   | Toluene Diisocyanate (TDI)                  | ≤ 0.1 mg/m³         |

#### 3.3 Recommendatory Hygienic Standard for 7 Types of Indoor Air Pollutants

At the beginning of establishing Chinese IAQ standards, the Ministry of Health promulgated the Recommendatory Hygienic Standard for Indoor Formaldehyde (GB/T 16127-1995) in 1995, and then issued recommendatory standards for other 6 types of pollutants in the following five years, including indoor bacteria total (GB/T 16127-1995), carbon dioxide (GB/
Wood-based panels of A Grade can be directly used in furniture manufacturing and indoor decorating, while panels of B Grade cannot but if the emission of formaldehyde falls into the limit of A Grade after proper disposal then can be used. Panels of C Grade are not acceptable for furniture manufacture and indoor decoration.

HNICM applies to all kinds of water-based and solvent coating materials that are intended for indoor use. The norm forbids the use of high-toxicity materials, for instance, phthalic esters, glycol ether and its esters. Any material resulting in malformation, carcinogen, and mutation is not allowed to use for making indoor coatings. The following items are regulated in this norm: TVOC, toluene, xylene, benzene, free formaldehyde, heavy metals (total lead, soluble lead, cadmium, chromium, and mercury), and free TDI.

4.2 Code for Indoor Environmental Pollution Control of Civil Building Engineering (GB 50325-2001)

GB 50325-2001 was enacted and promulgated by the Ministry of Construction and the SQSIQA. It is the first code for controlling indoor environmental pollution for civil buildings and came into effect on January 1, 2002. This code applies to the control of indoor air pollution in newly constructed, enlarged, or renovated civil building engineering, but not in industrial building engineering, storage building engineering, structures or the rooms with special sanitary requirements. Indoor environmental pollution mentioned in this code is the pollution caused by building or decorative materials before they are sold/delivered to users.

The indoor air pollution limits imposed by GB 50325-2001 are listed in reference [1]. The regulated pollutants are radon, released formaldehyde, benzene, ammonia, and TVOC. There are two groups of Civil Building Engineering, which are classified according to human exposure duration. Group I includes residential apartment and house, hospital, senile building, kindergarten, and schoolroom. Group II includes office building, shop, hotel, entertainment, bookstore, library, gallery, gymnasium, waiting room of public transportation station, restaurant, and barber shop.

GB 50325-2001 also stipulated the limits of harmful substances in building materials and decorative materials including: (1) inorganic nonmetal building materials and decorative materials such as sand, rock, brick, cement, commodity, concrete, prepared structures, and new-style wall bricks; (2) wood-based panels and decorated wood-based panels; (3) paints such as water-based and solvent-based paints; (4) adhesives including water-based and solvent-based; and (5) water-soluble treatment agents such as fire retardants, waterproof agents and antiseptics.

This code puts forward higher requirements for the designing firms and builders.

4.3 Compulsory National LHSCIDM

The SQSIQA set the compulsory national standards
for limits of harmful substances in ten types of indoor decorative materials in 2001 \(^{22-31}\), which came into effect on January 1, 2002. In these 10 standards, the concentration limits for pollutants include the emission limits and the content limits of building/decoration materials. Detailed measurement methods for all the regulated harmful substances are required to be included in these standards. These standards provide mighty technical and legal support for ultimately improving IAQ and safeguarding people’s health.

These standards were mainly derived from former China national standards, European standards and/or International Standard Organization (ISO) standards. For instance, the concentration limits of formaldehyde in wood-based panel and finishing products are uniform with those of European related standards; the concentration limits of VOC and formaldehyde in carpets, carpet cushions and A Grade environmental carpet adhesives are the same as the norm issued by American Carpet Research Institution (CRI). There are also some concentration limits of harmful substances that are not regulated in foreign countries. However, because they were detected at high levels in decorative materials in China, the standards drafting workgroup has stipulated concentration limits for them based on available experimental data.

4.4 Standards for Indoor Air Quality

The SQSIQA, State Environmental Protection Administration (SEPA), and the Ministry of Health worked together to develop the first recommendatory IAQ standard in China - Standards for Indoor Air Quality (SIAQ GB/T 18883-2002) \(^{32}\), which applies to residence and office buildings, and came into effect on March 1, 2003. SIAQ is supposed to replace the Hygienic Norm of IAQ (HNI AQ) proposed by the Ministry of Health.

Compared with HNIAQ, SIAQ takes HVAC index into account. The HVAC index has great effects on indoor air quality and human health. “The amount of fresh air” is regulated at 30m\(^3\)/h-person. As indices, two compounds - toluene and xylene are added. Except that the concentration limit for carbon dioxide is set as 8-hour averages and that the concentration limits for benzo(a)pyrene and PM10 are set as 24-hour averages, the limits for all other pollutants are set as 1-hour averages. The feeling index of “no odor in indoor air” appears in this standard.

5. Comparison of Limits of Harmful Substances in Indoor Decorative Materials

Summary of some limits of harmful substances in indoor decorative materials is shown in Table 4, 5 and 6. HJBZ28 regulates that contents of heavy metals including mercury, lead, cadmium and chromium, should be less than 500 mg/kg, GB50325-2001 does not regulate any limits for heavy metals.

In GB50325 and GB18583, water- and solvent-based adhesives are regulated separately and have different limits. In GB18583, the total content of toluene and xylene must be less than 10g/kg, while in HJBZ28, the limit for benzene and substituted benzene is less than 2g/kg. There is no limit for total of toluene and xylene in GB50325-2001. Beside solvent-based adhesives, there are limit values for free formaldehyde in the three standards, but the limit of 2g/kg in HJBZ28 is lowest. The toluene diisocyanate (TDI) ( 10g/kg) is regulated in GB50325 and GB18583.

Due to the page limit of the article, we only take water-based interior architectural coatings for example to make the comparisons. Since heavy metals in materials belong to contact pollutants, heavy metals are forbidden to add, limit for heavy metals in HJBZ4-1999 is less than 500mg/kg (counted by lead). Limits on soluble lead, cadmium, chromium and mercury are set in GB18582 (water-based). Heavy metals have no direct relation to the 5 indoor air pollutants controlled in GB50325, in which there are no limits set for heavy metals. TVOC and free formaldehyde are regulated in these standards.

Formaldehyde in man-made panels is regulated in HJBZ37-1999, GB18580-2001 and GB50325. The emission limits of formaldehyde are not quite different in the three standards. The simulated chamber (1 m x 1m x 1m) method is one measurement method, and other two methods described in GB50325-2001 are the perforation method and the desiccator methods.

6. Discussion

The benefit will be significant for consumers. Finally, it means that indoor air pollution can be controlled from the beginning of building design, during building construction, during decoration activities, and through other daily-life activities (e.g., increasing ventilation and staying away during high-emission periods). These standards are important in improving IAQ, enhancing people’s environment consciousness, keeping rights and interests of consumers and safeguarding human health.
### Table 5. Limits of Harmful Substance Regulated in Environmental Labeling Products

| Standard Name of Product | Scope | Technical Requirements and Limitation |
|--------------------------|-------|---------------------------------------|
| Adhesives (HJBBZ8-1998)  | Building Adhesives | Adding no formaldehyde, halogenated hydrocarbon or substituted benzene, and the compounds of mercury, lead, cadmium, chromium; the content of benzene and substituted benzene, halogenated hydrocarbon and formaldehyde in raw materials should be less than 2000 mg/kg; the content of mercury, lead, cadmium and chromium must less than 500 mg/kg. |
| Water-Based Coatings (HJBBZ4-1999) | Water-Based Paints | VOC ≤ 250 g/L, heavy metals less than 500 mg/kg (calculated by lead), formaldehyde and its polymer ≤ 500 mg/kg, adding no compounds contain heavy metal and formaldehyde and its polymer in the production process. |
| Man-made Wood-based Panels (HJBB37-1999) | All Kinds of Man-made Panels | (1) Emission limitation of formaldehyde in man-made panels < 0.20 mg/m²; (2) Emission limitation of formaldehyde in wood-based panels < 0.12 mg/m². |

### Table 6. Limits of Harmful Substances in Indoor Decorative Materials

| Standard Name of Product | Scope | Technical Requirements and Limitation |
|--------------------------|-------|---------------------------------------|
| Wood-based Panel and Finishing Products (GB18580-2001) | All Kinds of Wood-based Panel and Finishing Products | Limit of released formaldehyde ≤ 0.12 mg/m² (Environmental Chamber Methods, E1). |
| Solvent Coatings for Woodenware (GB18581-2001) | Nitro-laqueur | VOC ≤ 750 g/L, total of toluene and xylene ≤ 45%, Benzene ≤ 0.5% |
| | Polyurethane Paint | VOC ≤ 600 g/L or 700 g/L*, total of toluene and xylene ≤ 45%, free TDI ≤ 0.7%, Benzene ≤ 0.5% |
| | Alcohol Acid Lacquer | VOC ≤ 550 g/L, total of toluene and xylene ≤ 10%, benzene ≤ 0.5% |
| Interior Architectural Coatings (GB18582-2001) | Substances of Interior Architectural Coatings | VOC ≤ 200 g/L, free formaldehyde ≤ 0.1 g/kg, soluble lead ≤ 90 mg/kg, soluble cadmium ≤ 75 mg/kg, soluble chromium ≤ 60 mg/kg, soluble mercury ≤ 60 mg/kg. |
| Adhesives (GB18583-2001) | Water-based Rubber Adhesive** | TVOC ≤ 50 g/L, free formaldehyde ≤ 1g/kg, benzene ≤ 0.2 g/kg, total of toluene and xylene ≤ 10 g/kg. |
| | Solvent-based Polyurethane Adhesive*** | Benzene ≤ 5 g/kg, total of toluene and xylene ≤ 200 g/kg, TVOC ≤ 750 g/L, TDI ≤ 10 g/kg. |
| Wood-Based Furniture (GB18584-2001) | Wood-based Furniture | Limit of released formaldehyde ≤ 1.5mg/L, soluble lead ≤ 90mg/kg, soluble cadmium ≤ 75mg/kg, soluble chromium ≤ 60mg/kg, soluble mercury ≤ 60mg/kg. |
| Wallpapers (GB18585-2001) | Wallpapers | Formaldehyde ≤ 120mg/kg, vinyl chloride monomer ≤ 1.0mg/kg, barium ≤ 1000mg/kg, cadmium ≤ 25mg/kg, lead ≤ 90mg/kg, chromium ≤ 60mg/kg, mercury ≤ 20mg/kg, arsenic ≤ 8mg/kg, antimony ≤ 20mg/kg, selenium ≤ 165mg/kg. |
| Polyvinyl Chloride Roller Floor Coverings (GB18586-2001) | Foaming Floor Coverings | Limited vinyl chloride monomer ≤ 5mg/kg, soluble lead ≤ 20mg/m², soluble cadmium ≤ 20mg/m², volatile matter (fiberglass-based coverings) ≤ 75g/m², volatile matters (other materials-based) ≤ 35g/m². |
| | Non-foaming Floor Coverings | Volatile matter (fiberglass-based coverings) ≤ 40g/m², volatile matters (other materials-based) ≤ 10g/m², other items are the same as those of foaming floor coverings. |
| Harmful Substances Emitted from Carpets, Carpet Cushions and Adhesives****(GB18587-2001) | Carpets | VOCs, formaldehyde, styrene, 4-phenylcyclo ethane. |
| | Carpet Cushions | VOCs, formaldehyde, 4-phenylcyclo ethane, butyrate hydroxyanisole. |
| | Carpet Adhesives | VOCs, formaldehyde, 2-ethyl hexanol. |
| Ammonia Emitted from the Concrete Admixtures (GB18588-2001) | Concrete Admixtures | Ammonia released ≤ 0.5% concrete admixtures (mass ratio). |
| Radionucleoids in Building Materials (GB6566-2001) | Building Materials, Main Materials for Building, Decorative materials | Radionucleoids (referring to GB6566-2001 for the limits of radionucleoids in different materials). |

* When luster (φ = 60°) ≥ 80, VOC ≤ 600 g/L, and when luster (φ = 60°) < 80, VOC ≤ 700 g/L; ** Other water-based rubber adhesives only stipulates limit for free formaldehyde ≤ 1 g/kg; *** Other two detection methods of formaldehyde are perforation method and desiccator method; **** The limitation unit of harmful substances is mg/m²·h in this standard and cannot compare with others, so the limits are not listed here.
effectively. Meanwhile, as people's requirements for the indoor environment quality are increasing, advancement in IAQ researches will help improve the legislations.

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List of Abbreviations

GB/T GB means national standard, T means recommendatory.
HNFWP The Hygienic Norm of Formaldehyde in Wood-Based Panels
HNICM Hygienic Norm of Indoor Coating Materials
IAQ indoor air quality
LHSCIDM Limits of harmful substance contained in interior decorative materials
SIAQ Standards for Indoor Air Quality
SQSQA China State Quality Supervision-Inspection-Quarantine Administration
TDI Toluene disocyanate
VOCs Volatile organic compounds