Environmental Pollution Assessment System of Indoor Stadium

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Abstract
An indoor stadium has intensive crowd activities. Hence, objects in the stadium such as seats and instruments may become primary sources of methanol, radon, and other substances harmful to human body. The scientific assessment of the quality of the stadium environment quality in a stadium is important to the health of the population. In this paper, the author established a relatively complete indicator system for the environmental pollution assessment of indoor stadiums by using comprehensive assessment methods such as export scoring and analytic hierarchy process. Moreover, the paper subdivided the comprehensive index values of different environmental conditions in combination with the environmental monitoring standard value of indoor stadiums. For example, the feasibility and effectiveness of the assessment system was verified in the badminton stadium of the Olympic Games. Results confirmed that the environmental pollution assessment is Class II, in conformity with the actual conditions. This system can be used as reference for the assessment of the environmental condition of relevant indoor stadiums.
Key words: INDOOR STADIUM, ENVIRONMENTAL POLLUTION, AHP, ASSESSMENT SYSTEM

1. Introduction

In recent years, various types of sports activities with important significance for the promotion of physical exercise have been held in indoor basketball courts, tennis courts, badminton stadiums, and other stadiums. However, the hidden danger of plastic materials and environmental pollution to human health cannot be neglected [1]. At present, plastic materials in most indoor stadiums in China are composed of TDI, which is used as a curing agent. According to the function of TDI in experimental animal and human bodies, TDI inhalation may cause damage to the airway epithelium, interstitial tissue, lung blood vessel, immune system, and other systems of the human body [2, 3]. Plastic sites also contain heavy metals and other substances. For example, lead in plastics can be oxidized and diffused in the air as dust. Is the odor in plastic sites toxic? Do relevant environmental pollution factors of plastic sites cause safety and health problems to the plastic fitness environment? Although plastic provides comfort, people have begun to think of the pollutions in plastic fitness environments.

Brouwere [4] proposed the maximum cumulative ratio method to categorize mixtures according to whether the mixture is toxic and whether toxicity is driven by one substance or multiple substances. Nelson and Page [5] considered these categories in their research describing the use of the Bench-scale Air Purification Testing and Evaluation Chamber (BAP-TEC) to experimentally evaluate and compare the PRE and total energy requirements of novel air purification devices at the bench scale (280-1400 alpm). Furthermore, an AEI device containing fibrous filter media and high intensity sound field in the same control volume is evaluated by using the BAP-TEC. A temporally resolved PRE of a bioaerosol by the AEI is also presented [5]. On the basis of air quality, Song [6] summarized the degree and factors of environmental pollution in the stadium and proposed relevant rectification measures. Tan et al. [7] analyzed the present pollution situation of indoor environmental quality with standard limit, organic pollutants without standard limit, and VOCs and SVOCs. Their study summarized the features of indoor environmental pollution and indicated the necessity of governance and improvement in China. Diao and Lu [8] introduced the theory of euthenics meta-analysis of indoor environmental pollution assessment, established the assessment meta-model, and verified the pollution assessment rating according to the degree of comprehensive association. Zhang and Chen [9] established the comprehensive environmental impact assessment system for school plastic ground track field in combination with qualitative and quantitative indicators, such as site facility, sport culture atmosphere, energy, and pollutant discharge.

In the present paper, the main methods for the comprehensive environmental pollution assessment of plastic sites are arranged and the comprehensive assessment indicator system of the environmental pollution impact in plastic sites is established. The assessment indicator empirically analyzes monitoring data from the badminton stadium of the Beijing Olympic Games to provide reference for similar environmental pollution monitoring and assessment systems.

2. Methods

(1) Logical analysis is a type of scientific method of analysis in which various known conditions of an object are used to reason and judge the results of unknown things according to mutual relations of things [10].

(2) The expert consultation method, which is also called the Delphi method, obtains predictive information by selecting relevant experts according to the issue to be predicted, utilizing the experience and knowledge of particular people in specialized fields, and consulting these experts [11].

(3) AHP refers to a system of approaches in which a complicated multi-objective decision issue is taken as a system and the objective is decomposed into multiple objectives or rules, i.e., several layers of multiple indicators (or rules, and restraints). The qualitative index fuzzy quantization method is used to establish single hierarchical arrangement (weight) and total arrangement as objective (multi-objective) and multi-scheme optimization decision, respectively [12].

(4) Fuzzy comprehensive evaluation is a comprehensive assessment method based on fuzzy mathematics [13].

3. Establishment of indoor stadium environmental pollution assessment indicator system

Environmental pollution assessment refers to the establishment of relevant environmental pollution assessment indicator systems and comprehensive assessment judgment functions by applying scientific methods to screen appropriate assessment parameters on the basis of the environmental pollution conditions of various indoor stadiums (e.g., indoor basketball court, tennis court, and badminton stadium) and the manifestation of various factors influencing environmental quality. The environmental conditions of indoor stadiums are reflected through the size of the function value.

3.1. Establishment of assessment indicator system

Many factors influence the effectiveness of comprehensive environmental assessment on plastic ground track fields. The objects involved in comprehensive assessment involve complicated systems, such as society, economy, science and technology, education, environment, and management. However, some indicators are not always better in practical comprehensive assessment activities. The key factor is the function of the assessment indicator. In this paper, AHP is utilized to preliminarily screen the relevant comprehensive assessment indicators of indoor stadium environmental pollution effects, and indicator systems are divided into three hierarchies, namely, objective, rule, and indicator.

On the basis of the discharge standard of pollutants in China [14], the main properties of indoor environmental pollutants are shown in Table 1.

The primary sources of pollution in indoor stadiums are building materials and plastic sites. Relevant assessment indicators are judged according to the pollutant discharge of unit areas and the cleanliness of indoor environments. The environmental level of indoor stadiums is comprehensively embodied through qualitative and quantitative methods. The relevant indicator systems are shown in Table 2.

After the establishment of indoor stadiums, hardly any surface wastewater exists. Therefore, wastewater pollution will not be considered. In the comprehensive assessment indicator system in the above table, the objective hierarchy is the environmental pollution assessment system of indoor stadiums. The rule hierarchy is a subordinate to the Class I indicator of the total system hierarchy. These hierarchies are independent from each other and can reflect the general indicators for the degree of indoor stadium environmental pollution. The indicator hierarchy belongs to Class II indicators. This hierarchy is subordinate to the rule hierarchy (Class I indicator) and provides comprehensive reflection to the specific and easily assessed indicators of various environmental factors on plastic site. According to the nature of indicator, the whole indicator system includes qualitative and quantitative indicators; the former is represented with character and the latter by specific data.

Table 1. Properties of primary indoor environmental pollutants

Pollutant	Source	Harm
Methanol	Artificial board (e.g. plywood), adhesive, foamed plastic, paint, et al.	Carcinogenic and teratogenic substance, release period: usually 3-15 years
Ammonia	Concrete admixture (antifreezing agent), biological secreta, and decorative material	Stimulate eyes, respiratory tract, and skin, and cause bronchospasm and emphysema
Benzene	Paint, coating, adhesive, and rubber solvent	Cause anesthesia, simulate respiratory tract, damage hematopoietic function, and strong cancerogenic substance
TVOC	Building material and biological secreta	Local tissue inflammation, and neurotoxicity reflection
Radon	Building material	Increase the illness rate of lung cancer
CO_2	Biological activity	Increase discomfort
Microorganism	Liquid aerosol, and biological activity	Natural dissemination disease
Solid waste	Building material, and biological activity	Affect environmental cleanness and normal activity
Wastewater	Construction, and biological activity	Affect environmental cleanness and normal activity

Table 2. Environmental pollution assessment indicator system of indoor stadium

Objective hierarchy	Rule hierarchy	Indicator hierarchy	Attribute
Indoor stadium environmental pollution assessment indicators	Environmental cleanness	Environmental health of indoor stadium	Qualitative
		Environmental comfort of indoor stadium	Qualitative
	Waste gas pollution	Methanol discharge of unit space	Quantitative
		Ammonia discharge of unit space	Quantitative
		Benzene discharge of unit space	Quantitative
		TVOC discharge of unit space	Quantitative
		Radon discharge of unit space	Quantitative
		CO_2 discharge of unit space	Quantitative
	Solid waste pollution	Solid waste discharge of unit space	Quantitative
		Microbial population of unit space	Quantitative

3.2. Determination of assessment index weight

For the existing assessment indicator system, it is necessary to set different weight in combination with the degree of environmental pollution of various indicators, for the convenience of future assessment calculation. Weight of 10 indicators is determined with expert scoring method, AHP and eigenvalue method.

(1) Structure the judgment matrix A

$$A = \begin{bmatrix} a_1 & a_2 & \cdots & a_{1m} \\ a_2 & a_2 & \cdots & a_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ a_{m1} & a_{m2} & \cdots & a_m \end{bmatrix} \quad (1)$$

The value of judgment matrix element reflects people's cognition of relative significance (or advantage & disadvantage, preference, intensity, et al.) of various factors. Generally, the scale method of 1-9 and their reciprocals is used.

(2) Judge the solution w of the characteristic root question $AW = \lambda_{\max} W$ of matrix A and its corresponding vector; vector component of eigenvector is the weight to an indicator corresponding to a certain objective.

$$\lambda_{\max} = \frac{1}{m} \sum_{i=1}^{m} \frac{\sum_{j=1}^{m} a_{ij} w_j}{w_i} \quad (2)$$

(3) Test consistency of the judgment matrix A. Consistency indicator CI of the judgment ma-

trix

$$CI = (\lambda_{\max} - m) / (m - 1) \quad (3)$$

B. Average random consistency index RI of the judgment matrix; for 1-10-order judgment matrix, RI values are shown in table 3:

Table 3. RI values

Order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

C. Random consistency ratio CR

$$CR = CI / RI \quad (4)$$

When $CR < 0.1$, it is deemed that the judgment matrix has satisfactory consistency and effective weight. Or, the judgment matrix needs to be adjusted, so as to make it to have satisfactory consistency.

According to relevant steps of eigenvalue, and set the determination of weight as the situation of group judgment, so as to obtain the weight of various indicators about indoor stadium environmental pollution:

$$w_{ij} = (0.057, 0.045, 0.198, 0.159, 0.131, 0.118, 0.105, 0.095, 0.034, 0.058)$$

3.3. Determination of assessment model

In the quantitative and qualitative assessment indicator system in this paper, common and representative indicators that can reflect energy conservation, consumption reduction, pollution reduction, and benefit increase are selected for comprehensive assessment on indoor stadium environmental pollution situation. Therefore, it is necessary to further combine relevant features of assessed objects, and establish an assessment judgment model to comprehensively reflect the environmental pollution situation embodied by various indicators. On this basis, the following assessment model is established in combination with AHP and relevant features of indoor stadium:

$$I = \sqrt{(\max\left|\frac{C_1}{S_1}, \frac{C_2}{S_2}, \ldots, \frac{C_i}{S_i}\right|) \cdot (\frac{1}{n}\sum \frac{w_i C_i}{S_i})} \quad (5)$$

Wherein: Ci stands for mean value of measured pollutant concentration. Si means standard value of indoor pollutant concentration. Considering the difference between the highest scores and mean scores, it can give relatively objective reflection to the pollution conditions of indoor stadium. In practical application, relevant comprehensive indicators can be obtained by combing relevant data collected from the assessment indicator system, and putting into this model after weight.

4. Empirical analysis of the badminton stadium of Olympic Games

To verify the feasibility and effectiveness of this assessment indicator system, relevant monitoring data are combined to provide a comprehensive judgment on the environmental pollution situation of indoor stadiums. The badminton stadium of the Beijing Olympic Games is used an example of a typical indoor stadium. The environmental quality of this example stadium should meet certain national standards. To ensure that the detection basis can meet relevant requirements for indoor buildings to reflect the features of stadiums, standards for this indoor stadium environmental pollution assessment should include the following: (1) Indoor Air Quality Standard (GB/T 18883-2002,; issued by the SEPA in November 2002, and implemented in 2003); (2) Code for Indoor Environmental Pollution Control of Civil Building Engineering (GB 50325-2001; issued by the MOHURD); (3) National Standards for National Standard Limit of Ten Indoor Decorative Materials (GB 18580 – 18588, GB 6566-2001; issued by the AQSIQ); (4) Evaluation Standard for Green Building (GB/T 50378-2006; issued by the Ministry of Construction, and implemented in 2006); (5) Testing Method for Purifying Effect of Indoor Air Purification Products (QB/T 2761-2006; issued by the Indoor Environmental Monitoring Committee of China National Interior Decoration Association, and implemented in December 2006); and (6) Hygienic Standard for Gymnasium (GB9668-1996; issued by the AQSIQ and the SAC, and implemented in 1996). Standard values of various quantitative indicators about indoor stadium environmental pollution can be obtained with reference to the assessment indicator system and various standards, as shown in Table 4.

Table 4. Standard values of quantitative indicators of indoor stadium environmental pollution

Pollutant	Standard Value
Free formaldehyde (mg/m^3)	0.12
Ammonia (mg/m^3)	0.50
Benzene (mg/m^3)	0.09
TVOC (mg/m^3)	0.60
Radon (Bq/m^3)	400
CO_2 (mg/m^3)	0.15
Solid waste (kg/m^2)	0.05
Microorganism (cfu/m^3)	4000

As shown in the above table, the example stadium has certain environmental pollution when the values of various indoor stadium indicators exceed standard values. On the contrary, the stadium belongs to clean environment if the values of various indicators are less than the standard values. According to the expert scoring method, under the circumstance of standard values, the value is 1 for two qualitative indicators in the indicator system. If it is good, the value is 0.8. If it is moderate, the value is 0.7. If it is qualified, the value is 0.6. If it is unqualified, the value is 0. To distinguish the different degrees of pollution, different indicators are further subdivided, as shown in Table 5.

Table 5. Degree of pollution of indoor stadium

Pollution degree	Judgment basis	Pollution characteristics
Clean	Less than standard value	Suitable for exercise
Not polluted	Conform to standard value	Normal exercise
Slightly polluted	One indicator exceeding standard value	Unsuitable for sensitive groups
Moderately polluted	2-3 indicators exceeding standard value	Unsuitable for normal people
Seriously polluted	3-4 indicators exceeding standard value	Unsuitable for exercise

Comprehensive indicators under different environmental pollution conditions can be obtained by calculating the assessment model in combination with subdivided basis and environmental pollution standard values, as shown in Table 6.

Table 6. Comprehensive pollution indicators of indoor stadium

Pollution degree	Comprehensive indicator	Assessment ranting
Clean	≤0.49	I
Not polluted	0.5-0.99	II
Slightly polluted	1.0-1.49	III
Moderately polluted	1.5-1.99	IV
Seriously polluted	≥2.0	V

The environmental quality level of the stadium is reflected through the data in the table. The environmental conditions of the stadium can be objectively obtained with reference to this table and comprehensive indicator values using the comprehensive assessment indicator system.

Then, a comprehensive assessment must be combined with environmental pollution indicator system of indoor stadiums and actual conditions of the stadium. The badminton stadium of Beijing Olympics Games was completed in 2007. This badminton stadium covers an area of approximately 66,000 m2 (including 22,269.28m2 indoor area) with capacity of 7500 audiences. The stadium is used for competition events of badminton and rhythmic gymnastics. After the event, the stadium is mainly used as the training base for badminton teams of the Badminton World Federation and General Administration of Sport. Certain parts are open to the public. Comprehensive assessment indicators are calculated in this paper in combination with relevant data monitored by environmental protection and other departments in the construction and operation period of Olympic venues to further verify the reliability of the indicator system. Table 7 shows the monitoring data.

Table 7. Monitored environmental indicator values of the badminton stadium of Beijing Olympic Games

Pollutant	Standard value	Monitored value	Difference
Free formaldehyde (mg/m^3)	0.12	0.10	↓
Ammonia (mg/m^3)	0.50	0.52	↓
Benzene (mg/m^3)	0.09	0.04	↓
TVOC (mg/m^3)	0.60	0.48	↓
Radon (Bq/m^3)	400	362	↓
CO_2 (mg/m^3)	0.15	0.11	↓
Solid waste (kg/m^2)	0.05	0.02	↓
Microorganism (mg/m^3)	4000	4250	↑

Source of data: environmental monitoring data of Olympic venues

Table 7 shows that various monitoring indicators of the badminton stadium reach the requirements of standard values. Only the indicator of microorganism slightly exceeds the standard value, which may be correlated with numerous audiences in the stadium. According to preliminary judgment, normal exercise standards can be reached. For the sake of objectivity, however, the values must be put into the assessment system for verification. In addition to the above quantitative indicators, expert judgment indicates that the badminton stadium has clean environment. On this basis, the comprehensive indicator values of environmental conditions of this stadium can be obtained in combination with index weight, standard value, and assessment model:

$$I = \sqrt{(\max\left|\frac{C_1}{S_1}, \frac{C_2}{S_2}, ..., \frac{C_i}{S_i}\right|) \cdot (\frac{1}{n}\sum\frac{w_i C_i}{S_i})}$$

$$= \sqrt{(\max\left|\frac{0.8}{1}, \frac{0.8}{1}, \frac{0.1}{0.12} .., \frac{4200}{4000}\right|) \cdot (\frac{1}{10}\sum\frac{w_i C_i}{S_i})} = 0.56$$

As measured and calculated, the comprehensive indicator value is 0.56 for environmental conditions of the badminton stadium in the monitoring period. Table 5 shows that the environment of this stadium is not polluted and the stadium is assessed as Class II. According to this result, this stadium can undertake normal sports events without damage to human health. Actually, all Olympic venues are constructed in strict accordance with environmental pollution control standards to guarantee the normal development of sports events and health and assure the safety of people to the maximum extent. This calculated result indirectly proves good environmental quality of Olympic venues, especially for the badminton stadium. In practical situation, this stadium also successfully finished relevant tasks in and after the events. In daily operations, no environmental pollution is reported. On one hand, this stadium has high-quality environmental protection materials and environmental health systems. Various types of pollution from building materials and human activities are reduced to the maximum extent. On the other hand, this stadium is also correlated with ingenious architectural design. This stadium also adopted the design mode of air supply below the auditorium to guarantee the optimal level of athletes. It guarantees comfort of people in the stadium, increases ventilation, and evacuates some residual gas pollutants.

5. Conclusions

The scientific and objective judgment of the environmental pollution of indoor stadiums is helpful to guarantee the physical health of personnel in the stadium. At the same time, this analysis can also be taken as the reference basis for acceptance of the stadium. By using comprehensive assessment methods as expert scoring and AHP, the author established an indicator system exclusive for environmental pollution assessment. This system can comprehensively assess environmental conditions of the stadium. At the same time, the author also calculated the comprehensive indicator values of different environmental conditions and subdivided the degree of environmental pollution according to the environmental monitoring standard values of indoor stadiums. According to the research result of the badminton stadium, the environmental quality is Class II in the monitoring period. This result is consistent with practical conditions. Thus, this assessment system is reliable and can be used as reference for environmental assessment on similar stadiums in the future.

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Dynamic Simulation of Compressible Fluid Network

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Abstract
Oil and gas transmission is a very complex industrial process. To improve system security and reduce costs, pipeline network simulation has been developed. The classical approach is to establish mathematical models and solving method, however, solving is complicated and slow. In this paper, we proposed a new method which can be used in simulation for analyzing compressible fluid network dynamically. The proposed method is simple and easy to implement, which can compute the pressure and flow of pipeline network in real time, and let the system reach steady state quickly. The simulation example verifies the accuracy of the algorithm. The experimental results indicate that our method is efficient, and the simulation data can truly reflect the changing process of the real pipeline network system.
Key words: COMPUTER SIMULATION, COMPRESSIBLE FLUID, PIPELINE NETWORK, FLUID COMPUTATION