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Intelligent Oxygen-Enriched and "Sterilized" Underground Gyms: Background, Dilemmas and Pathways

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Abstract

The in-depth integration of healthy China with national fitness and the hope to achieve the long-term goal of "*leading Sports Nation*" by 2035, can't be realized without gyms where people do physical exercise. The international academic community recognizes that the 21st century is the golden time for sustainable and quality development. Taking a national perspective, authors of this paper studied the feasibility of building underground gyms in China through the approach of interdisciplinary research, as well as its dilemmas and pathways, and found out that quality development of underground space can effectively address challenges for large cities in China by increasing the resilience of urban area, and give full engage to underground capacity in striving for the goal of carbon peak and carbon neutrality. Underground gyms can also be incorporated into resident's 15-min fitness circle, satisfying people's needs of doing exercise at any time and in an easily-accessible place. However, China's underground area development has been hindered by unclear property rights, chaotic action and utilization, and relatively backward laws and regulations. Moreover, building underground gyms still has to solve many problems such as poor air quality, severe sweat smell, and excessive bacteria and viruses. It is suggested that the capable authorities shall first clarify laws and regulations over place compound utilization, property rights and fire protection to facilitate the process of building underground gyms; encourage fitness practitioners to explore underground areas as gyms, and transfer their ground business to underground; then produce an intelligent and systematic solution of air quality improvement featuring oxygen-enrichment and "*sterilization*" with integration, a variety of instruments to monitor air quality of indoor gyms in real-time, to realize automatic control and man-

agement, and truly create worry-free and oxygen-enriched underground gyms with no sweat smell and no fear of bacteria and viruses.

Keywords

Underground Space, Gyms, Air Quality, Intelligence, "*Sterilization*"

1. Introduction

Top-level national policies such as the *Outline for Building a Leading Sports Nation* [1] and the *14th Five-Year Plan for Sports Development* [2] have been introduced successively to integrate *Fitness for All* and *Healthy China* to lead Sports Nation and fitness programs by 2035. Sports have become a landmark undertaking of the great rejuvenation of the Chinese nation. However, insufficient and unbalanced domestic sports development remains a prominent problem. According to the *Program of Fitness for All* (2021-2025) [3], building a public service system for the national fitness program with a more balanced distribution of resources, more convenient gym facilities, and more involvement of the people is necessary.

As the urbanization process accelerated in China, the relative shortage of land resources, astonishing PM2.5 records on the continued basis, the smog of high concentrations for an extended period, crowded living spaces, traffic jams, ecological imbalance, environmental deterioration, etc., are all enormous challenges for the living environment [4] [5] [6], impeding the further development of China's sports. Reasonable and efficient underground space development and utilization are expected to solve the problems mentioned above.

The Blue Paper on the Development of Urban Underground Space in China [7] has had six editions since 2014, aiming to raise the public's awareness of underground urban space. Cities in developed countries were the first to explore underground spaces with fruitful results and this has now become a general trend. A perfect example is the Central Artery/Tunnel Project (CA/T Project) in Boston in the United States.

The development and utilization of underground space in Chinese cities started in the 1950s [8]. Compared with foreign countries, even though China has the most significant demand and cover for the development and utilization of underground space, it is still in the initial stage of rapid growth. The complex and efficient development and utilization of underground space have become an inevitable choice in the current urbanization process, and also a recipe to resolve the contradiction that urbanization in China is eroding the red line for arable land.

The goal of "Dual Carbon", or carbon peak and neutrality, mainly addresses two issues: reducing carbon emission and endording harmful carbon emission or carbon absorption. Efficient and scientific development and utilization of underground urban space can generate considerable benefits in both aspects, contributing to reducing carbon emissions.

However, the development and utilization of underground space in China still lag and the construction process of underground gyms is prolonged. On the one hand, there are many practical problems, such as unclear property rights, unreasonable land and space planning, etc. [9] [10] [11]. On the other hand, building underground gyms has to address issues such as poor indoor air quality, strong sweat smell, and excessive bacteria and viruses, challenges that have not been fundamentally responded to [12] [13].

This paper conducts in-depth explorations on these two aspects, putting out the research background, existing difficulties in practice, solutions, and potential pathways. Ultimately, it designs an intelligent system to improve air quality in underground gyms featuring oxygen-enrichment and "*decontamination*" while resorting to technologies to achieve the goal of a *Healthy China* and a leading Sports Nation.

2. The Background for the Proposal of Intelligent, Oxygen-Enriched, and "Sterilized" Underground Gyms

2.1. Efficient Development and Utilization of Underground Space Has Become an International Consensus, and the Construction of Underground Gyms Can Make a Massive Contribution to the Goal of *Fitness for All* and Leading Sports Nation

In the 21st century, a golden age for the development and utilization of underground urban space, achieving sustainable and quality development has become an international consensus [14]. *Outline for Building a Leading Sports Nation* encourages cities in all regions to use underground space rationally and incorporates gyms into national land and space planning.

The construction of urban underground gyms is in line with China's primary national conditions regarding urbanization, and exerts a leading effect to drive more social entities to enter urban underground spaces, effectively alleviating stresses on large cities; the development and utilization of underground rooms can make land use more efficient and metropolitan area more resilient, as well as expand three-dimensional urban space format, and more importantly, give full play to underground spaces in realizing the goal of "*Dual Carbon*" as well as reserving energy and reducing emissions.

Besides, it can make full use of empty spaces in urban underground rail transit, underground commercial complexes, underground supermarkets, and underground parking in residential areas to shape a 15-minute circle for an underground fitness venue so that governing bodies can allow people to be fully engaged in sports and exercises at any moment and in the most convenient places.

2.2. Cities in Developed Countries Made an Early Start in the Development of Urban Underground Gyms and Now Have a Pretty Mature Business Model in Terms of Commercial Walkways (PATH) in Rail Transit and Underground Gyms on Campus

In 2020, around 19.0% of American people hit the gym, which is followed by the

UK (15.6%), Germany (14.0%), and France (9.2%) [15]. In 1863, the world's first subway was commissioned in London, England, setting an example for the development and utilization of underground urban space.

Accumulated experience over many years has equipped foreign countries with a complete set of laws and regulations, advanced design concepts, mature construction technology and science-based management expertise in exploring underground urban space.

And in foreign cities, it is mainly dominated by rail transit. In terms of sports and fitness, Toronto's commercial trail PATH is a typical case [9]; underground sports and fitness venues are mainly gyms on campus, such as the Danish Cortex Park and the Swiss Arbon, two campus complexes, and Osaka Municipal Central Gymnasium in Japan, etc. [16] [17] [18]. Their underground exploration is partly down to the early start of urbanization in developed countries, shortage of land on campus and local policy restrictions.

2.3. With the Deep Integration of *Health for All* and *Fitness for All* in China, the People's Need for Better Air Quality in Gyms Has to Be Satisfied by Scientific Analysis and Application of Technologies

Scientific studies show [19] [20] [21] [22] that the lack of physical exercise is the fourth health risk factor leading to unnatural death. It accounts for 6% of death causes, ranking only after hypertension (13%), smoking (9%) and hyperglycemia (6%). Since October 2014, *Fitness for All* has become a national strategy [23]-[28]. Since the 18th National Congress of the Communist Party of China, President Xi Jinping has repeatedly emphasized the importance of developing China's sports on different occasions [29]. Exercise is medicine [30] [31] for it can effectively improve the physical and mental health. The Chinese people have become the primary driving force for China's sports development.

With accelerated industrialization and urbanization, China is aging faster and its people are constantly changing their ways of living and working. The disease spectrum is also in constant growth. Cardiovascular and cerebrovascular diseases, cancer, chronic respiratory diseases, diabetes and other chronic non-communicable diseases account for 88% of the total deaths [32] [33] [34] and take at least 70% of the national expenditure for disease treatment [35] [36].

In 2017, President Xi Jinping put forward the *Healthy China* strategy at the 19th National Congress of the Communist Party of China, requiring comprehensive and full-cycle health services for the Chinese people. He affirmed that the regular health of all is essential to building a complete prosperous society [37] [38].

Research statistics show that [39] for an average longevity of 80 years, the gas inhaled is 300,000 m^3; since working, studying and living indoors takes more than 80% of people's time in modern society [40] [41], air quality seriously affects human health.

Since 2013, smog has frequently been recorded in China [42] [43] [44]. Gas

and solid pollutants in polluted air, such as CO, CO_2, O_3, NO_x, and PM2.5, can enter pulmonary alveoli and endanger human health [45]. China's national *Fitness for All* and *Healthy China* strategies are severely challenged. As *Healthy for All* and *Fitness for All* are more than ever closely intertwined, people's demand for better air quality in living and fitness environments deserves scientific research [46].

3. Dilemmas in Building Intelligent, Oxygen-Enriched, and "Sterilized" Underground Gyms

3.1. Insufficient Top-Level Design for Underground Space, Chaotic Development and Utilization, and Relatively Retrograde Laws and Regulations

The development and utilization of underground urban space in China started in the 1950s [9] following the basic idea of independent development centering on rail transit or a specific building without an organic network structure. It suffers from many problems, such as unclear reserves and utilization, insufficient systematic top-level design, chaotic functional settings, and spatial layout, relatively retrograde laws and regulations, and lack of management systems and mechanisms.

Researchers are still focusing on property rights and legislation, the primary issues impeding the development of underground gyms. Lu Shiliang (2017) [47] analyzed the advantages, disadvantages and feasibility of recessed sports buildings for underground spaces for fitness venues and proposed design principles and strategies in terms of lighting, ventilation, disaster prevention and evacuation; Su Naite (2018) [48] mainly focused on design difficulties in fire protection for underground sports spaces, proposed fire protection design strategies as concerns fire separation, safe evacuation, and fire protection facilities, and conducted simulation experiments and safety demonstrations without any mention of the issue of air quality.

Functions of sports areas in China are mainly realized on campus, mostly represented by the gym of the High School Affiliated with Peking University, and that of Yuanling Campus for Shenzhen Hongling Middle School. In conclusion, Chinese researchers have done little research on the fundamental improvement of air quality in underground spaces.

3.2. Few Studies on the Construction of Underground Gyms in China

In the latest version of *the Blue Paper on the Development of Urban Underground Space in China* in 2020, Academician Qian Qihu of the Chinese Academy of Engineering pointed out that the development of underground space in China was dominated mainly by urban rail transit, comprehensive pipeline corridors, and underground parking lots whose extensive growth remained insufficient. Only ten projects approved to be established by the National Social

Science Fund of China over many years are on underground urban space but mainly concentrated in law, management and economics.

The research directions are mostly property rights, legislation, and dealings of undercover metropolitan areas, with few examining into the construction of underground gyms, let alone topics on indoor air quality in fitness venues. In summary, China has neither fundamental solutions nor research foundations for the issue of indoor air quality in underground gyms.

3.3. Moving Underground Is the Future of Fitness Venues Yet Facing Key Issues Such as Poor Indoor Air Quality, Strong Sweat Smell, and Excessive Bacteria and Viruses

3.3.1. Poor Indoor Air Quality in Fitness Facilities

In the past three years, the penetration rate of Chinese body-builders has been around 5.0% [49] [50], only 1/4 of that in the United States and primarily concentrated in first-tier and second-tier cities as big cities often have a large population of high density, high disposable income per capita and well-developed gym industry. Air quality in main fitness venues such as municipal Olympic sports centers, university stadiums, and gymnasiums often diminishes people's optimism [51]. Poor indoor air quality has been listed as one of the five significant environmental risks to public health [52] [53] [54]. Domestic researches such as Ning Yong [55], Zhang *et al.* [13], and Xu *et al.* [56] conducted researches on indoor air quality in China to confirm this assertion.

Zhang *et al.* [13] investigated and analyzed air pollution in10 commercial indoor gyms above ground in a specific city, and identified many challenges such as numerous exercisers, inadequate ventilation equipment, and severe air quality degradation. Xu *et al.* [56] analyzed the air quality of underground spaces in typical integrated commercial buildings in Shanghai, and found that PM2.5 and the total number of bacteria surpassed the standard. Foreign scholars, Choe, Y. [57], Susanto, A. D. [58], and Gail Williams *et al.* [59] also paid attention to the poor indoor air quality of fitness venues.

Multiple pollution sources in a relatively closed building structure [56], together with a high flow of exercisers and high exercise intensity inside, lead to the deterioration of indoor air quality and pose threats to the safety and health of exercisers. Common challenges in terms of air quality in gyms often refer to poor air quality, strong sweat smell, excessive bacteria counts, CO and CO_2 concentrations, and poor ventilation [13] [14]. However, these issues have not received enough attention. A complete set of solutions has not yet been produced.

3.3.2. Strong Sweat Smell inside Fitness Facilities

Human sweat is originally neutral and tasteless. However, when it is decomposed by some specific bacteria on the skin's surface, it will produce an unpleasant and sour smell. Contrary to the intuition that more sweat means a more pungent smell, these two are not directly related to each other. Human sweat is

mainly composed of water and sodium chloride, which is tasteless. However, the human skin surface contains protein and amino acid components which might be decomposed by some particular bacteria when immersed in sweat, producing a sour smell as a result. Some parts of the human body, such as armpits, feet and perineum, are prone to bacteria accumulation and more sweat glands, which are the primary source of sweat smell.

3.3.3. Indoor Bacteria and Viruses in Fitness Places Exceed the Standard

According to Dr. Bryan Combs from the UAB School of Nursing, the most significant advantage of gyms is that bacteria, viruses and fungi can exist in many places year-round [56]. This humorous description is confirmed as the handles and cushions of treadmills, elliptical machines, spinning bikes, strength training machines, etc., in gyms are probably the dirtiest places a person might ever touch in a day.

In summer, bacteria are prone to breed in humid places. In the cold winter, warm gyms become a hotbed for bacteria reproduction. Microbiological scientists at the University of Texas in the United States have shown that body-builders sweat profusely after intense training, and sweat stains accumulate in fitness training facilities. Without thorough cleaning and disinfection, harmful bacteria will survive for several days [60].

The most common one on these devices is Gram-positive coccid, which can easily infect human skin and cause pneumonia and leukemia. Gram-negative coccids may infect the skin too. Gram-positive bacilli and bacillus may infect the ears, eyes, and respiratory system. These bacteria can also cross-infect and form flesh-eating bacteria, which "eat away" flesh and fascia of the human body. Without being killed immediately, they will quickly cause toxic shock in the human body, sending the death rate extremely high.

Generally speaking, the size of the virus is measured by nanometers, while that of bacteria is measured by micrometers. What bacteria are to viruses is what people to houses. In this way, tiny viruses attach themselves to bacteria. When smog occurs frequently, viruses, bacteria, and toxic and harmful substances are bound to PM2.5 particles [61] [62], entering the human body through the respiratory tract and increasing the incidence of respiratory diseases. Fine particles with a diameter larger than PM10 are often blocked by nose hairs and the respiratory tract without reaching the lungs. However, PM2.5 particles with a smaller diameter can quickly and deeply enter the respiratory tract and accumulate in the alveoli, potentially damaging human health.

4. Theoretical Basis for the Construction of "Sterilized" Underground Space for Sports

4.1. Analysis of the Working Principle of Sweat Smell

Human skin has three glands: eccrine sweat glands, apocrine sweat glands, and sebaceous glands by which odorless and colorless sweat has been secreted, and 99% of its composition is water, the remaining 1% is salt, lactic acid, uric acid,

and other substances. Therefore, body sweat under normal conditions is of no smell.

According to scientific studies, bacteria on the skin surface react chemically with glycoproteins in sweat to release mercaptan, a sour-smelling chemical, thus producing an unpleasant sweat smell. A scientific team at the University of York in the United Kingdom found that among more than 20 kinds of bacteria, three types of Staphylococcus bacteria in armpits are the top suspects, and it eventually proved that these three candidates are the culprit of human sweat smell.

4.2. The Working Principle of Sterilization, Dust Reduction, and Sweat Smell Elimination by Negative Ion

Negative air ions were discovered by German scientists Elster and Geitel in 1889. Aschkinass *et al.* 1902 also affirmed the biological significance of negative air ions. After they are adsorbed to bacteria (viruses), the structure of bacteria (viruses) will change or transfer energy, resulting in the death of bacteria (viruses) (killing staphylococci). Then, there is no sweat smell in the air due to the absence of bacteria that decompose sweat smell. Negative ions can also be combined with delicate particulate matter (PM) in the mood to precipitate PM2.5, reducing dust as a result.

4.3. The Working Principle of Sterilization by Ozonizer and Ultraviolet Lamp

Ozonizers and ultraviolet lamps are mainly applied to kill bacteria and viruses at night when no one is inside the room.

Ozone is a strong oxidant, and its sterilization process is biochemical oxidation following these steps:

1) oxidize and decompose enzymes which are needed to digest glucose inside bacteria, and thus inactivate bacteria when there is no nutrient supply;

2) directly react with bacteria and viruses to destroy their organelles, DNA, RNA, as well as the metabolism of bacteria, and put the bacteria to death;

3) penetrate the cell membrane and invade a bacterial cell, act on lipoprotein of the outer membrane of bacteria and lipopolysaccharide inside, thus resulting in absorbency distortion and dissolution of bacteria.

Ultraviolet sterilization has a strong bactericidal effect thanks to short-wave ultraviolet (UVC) irradiation whose wavelength range is 200 - 300 nm. When ultraviolet UVC irradiates bacterial DNA, its DNA structure loses cell activity. Ultraviolet disinfection is an environmentally friendly and reliable disinfection method. However, authors have noted that ozone irritates the mucous membrane of the human respiratory tract. And the disinfection can only be carried out when no one is on site. It shall take at least 30 minutes for people to enter the room after disinfection. In the ultraviolet disinfection process, the ultraviolet light source is especially harmful to the skin, especially the eyes, so consider leaving the room during disinfection.

4.4. The Working Principle of Fresh Air System (HEPA)

HEPA refers to a high-efficiency particulate air filter mainly using fiber adsorption to "stick" PM2.5 dust. The fiber diameter is about the same as dusts, but HEPA fibers are arranged in multiple layers where fine particles inevitably collide with some fibers when passing through. As a result, particles are absorbed. So for particles in the air once touching some fibers of the HEPA filter, this is the "interception" process. In addition, particles in fresh air flowing through the filter are also captured by existing particles. A load limit caps the ability of the HEPA filter to carry particulate matter. Its interception efficiency gradually decreases as time passes by and as the concentration of particles in the air increases. As a consumable material, it has to be replaced regularly to ensure high interception efficiency.

4.5. Principle of Oxygen Enrichment by an Oxygen Generator

The physical adsorption and desorption technology of molecular filters mainly produces oxygen. The interior of an oxygen generator is filled with molecular filters, which can absorb nitrogen in the air when pressurized, leaving the remaining part that is not interested in oxygen. Therefore, responsible can collect high-purity oxygen. Molecular filters re-emit adsorbed nitrogen to the ambient atmosphere when depressurize, and re-adsorb nitrogen from the atmosphere while producing high-purity oxygen for the next pressurization, a periodic dynamic cycle with no consumption of molecular filters.

4.6. Design Principle of the Intelligent System to Sterilize Indoor Air and Improve Air Quality

The intelligent system to sterilize indoor air and improve air quality mainly includes hardware and software systems. The first mainly contains ambient air intervention instruments (negative ion generator, oxygen generator, air conditioner, fresh air system, ozonizer, ultraviolet lamp, etc.), online sensors (negative ion sensor, formaldehyde sensor, CO sensor, O_2 sensor, benzene sensor, VOC sensor, etc.) and the central controller; the latter can automatically start and shut down the air mentioned above intervention instruments according to the real-time monitoring data of online sensors.

First, agents can be intelligently controlled when parameter values are set following the *Indoor Air Quality Standards*. When environmental parameter values (formaldehyde value, benzene value, CO value, VOC value, etc.) are captured by any sensor knot and detected to be higher or lower than the user-set value (negative ions, O_2 value), the central controller will automatically start the corresponding instrument. When ambient air quality parameters collected by all sensor knots are within the normal range, the central controller automatically stops corresponding air intervention instruments. So this is the fully automatic control process for the facility even when unattended.

5. Intelligent Pathway to Build Oxygen-Enriched and Sterilized Underground Gyms

5.1. Pathway for the Construction of Underground Gyms

1) First, the competent authorities need to clarify laws and regulations related to the multiple utilization of land and space, property rights, fire protection, etc. in the construction of gyms and formulate preferential policies.

China has policies to optimize the support for gyms rather than financial subvention policies. However, under the current national strategy of *Fitness for All*, the development prospects of fitness venues have no boundaries. It is a long journey for China to develop its underground space as fitness venues for there are a lot of improvements to be made in terms of the government's policy support, the incorporation of underground gyms into national land and space planning, the clarification of property rights and transactions, as well as fire protection and safety issues. Meanwhile, government departments are expected to introduce favorable policies in support of underground spaces used as fitness venues to lessen the worries of fitness practitioners and consumers. In this way, the development of underground gyms will not be disordered, contributing to realizing the goal as fast as possible so that the nation can exercise at any time and in the most convenient places.

2) Encourage fitness practitioners to develop and utilize underground space, and shift their business from above the ground to underground

Insufficient ground space, traffic congestion, and parking difficulties can be addressed by effective and green development and exploitation of underground rooms, boasting an irreplaceable role in raising land utilization efficiency and urban resilience. On the one hand, government body departments can use the land and space planning program to be fully leveraged to expand three-dimensional urban space forms. Conversely, cities would become more resilient in support of the "Dual Carbon" target since underground spaces have natural advantages. Based on this analysis, more efforts in publicity and promotion would better educate fitness practitioners. Meanwhile, their worries and concerns deserve to be addressed adequately by regular return visits and services in later phases.

3) Communicate with property managers in residential communities, underground commercial complexes, supermarkets, and their parking lots to encourage the construction of better underground fitness venues

First of all, it is vital to communicate with the unit in charge of community property management, underground commercial complexes, supermarkets and their parking lots so their concerns can be properly addressed; promote cooperation between academies, businesses and research institutions and the research force from high-learning and scientific research facilities can be utilized to customize underground gyms for residential communities, underground commercial complex, supermarkets and their parking lots. During this process, all sorts of challenges shall be properly and rapidly addressed to better serve body-builders.

Furthermore, the local urban management authority has to be closely involved

for there might be formalities concerning the preparation for the change of purpose for underground parking lots in residential communities, commercial complexes, supermarkets and their parking lots, etc. The whole process has to comply with policies and regulations, with safety dangers properly solved. There shall not be any impact on the original usage. In this way, the public can also be assured.

4) Intensify publicity efforts to guide the consumption outlook of body-builders that doing exercise in underground gyms is a fashion

Radio, television, the Internet new media, etc., can all be engaged to guide the whole nation to do more exercise more actively. Providers shall consider cultivating a new concept that training in underground gyms is further. Opportunities such as the *National Fitness Day*, significant sports competitions and various festival sports events shall be utilized to strengthen the publicity of green and healthy underground spaces in society, leading a new consumption concept of body-builders and advocating a new form of gyms for this century.

5.2. Pathways to Improve the Indoor Air Quality of Fitness Venues in Underground Spaces

5.2.1. Principles of Sterilizing Indoor Air and Improving Air Quality for Underground Space Used as Fitness Venues

The construction plan of an oxygen-enriched and sterilized gym in an underground space, as shown in Figure 1, mainly focuses on indoor air quality with

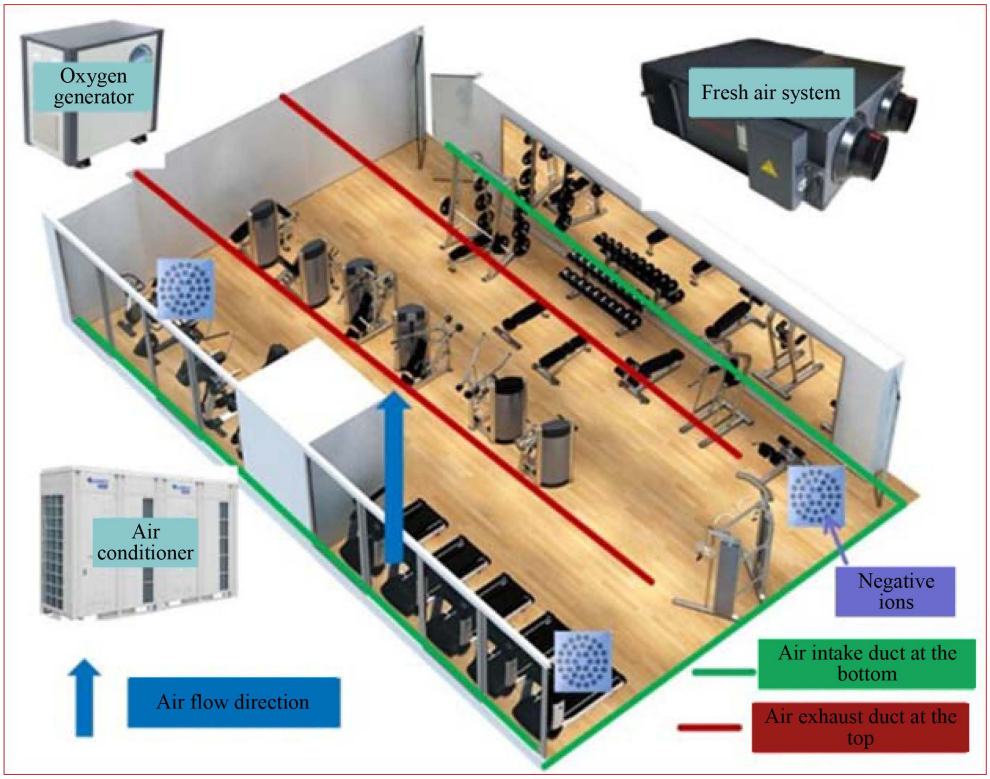

Figure 1. Schematic diagram of the construction of an oxygen-enriched and sterilized gym in underground space.

the help of an intelligent system to sterilize indoor air and improve air quality.

1) It is vital to apply negative ion generators to remove dust, sterilize and disinfect the air, to solve the problems of solid sweat smell and excessive bacteria and viruses in indoor fitness places;

2) Use oxygen generators to create positive pressure environments in indoor fitness places enriched with a high level of oxygen for better air quality;

3) Use HEPA filter in ventilation system to filter out PM2.5 and bacteria in the fresh air, to provide fresh air in indoor fitness places;

4) Ultraviolet lamp and ozonizer can thoroughly and comprehensively sterilize and disinfect indoor air at night or when no one is in the gym;

5) Establish a solution integrating monitors for negative ion, PM2.5, CO, CO_2, total number of bacteria, temperature, humidity and wind speed as well as negative ion generator, oxygen generator, air-conditioning system, fresh air system under computer-based automatic control as the intelligent system in sterilizing indoor air and improving air quality. Please refer to Table 1 for details.

5.2.2. Edge Intelligent Environmental Intervention System

The ambient air intervention system of underground space used as fitness venues comprises edge intelligent computing units, and the ambient air quality supervision information system for urban underground gyms has 5G communication. The system is shown in Figure 2, mainly including an intelligent edge computing unit; ambient air intervention equipment such as a negative ion generator, oxygen generator, and fresh air HEPA system; as well as ambient air parameter sensors such as negative ion sensor, formaldehyde sensor, and CO sensor.

The edge computing unit collects ambient air parameters in real time by various sensors. It controls the working modes of different environmental intervention equipment according to the corresponding ecological control strategies of the fitness venue. It has a typical closed-loop control system, and its design aims

Table 1. Problems to be addressed, schematic design and principles for the intelligent system to enrich oxygen, sterilize air, and improve air quality.

Problems	Reasons	Solutions	Principles	Targets
Strong sweat smell	Bacteria decompose sweat to produce smell plus poor ventilation	Negative ion generator, UV lamp and ozonizer	Negative ions can reduce dust, sterilize and disinfect air	Intelligent system to enrich oxygen, sterilize air, and improve air quality in underground gyms
Excessive bacteria and virus	Untimely disinfection			
Excessive PM 2.5	Isolated space with many body-builders but low utilization rate of fresh air system	O_2 generator	More O_2	
Excessive CO and CO_2				
Low O_2				
Poor ventilation	Higher costs	HEPA filter	Ventilation	
Few ground space	Agglomeration effect of population in big cities	Develop and use underground space	More resilience for areas for "Dual Carbon"	

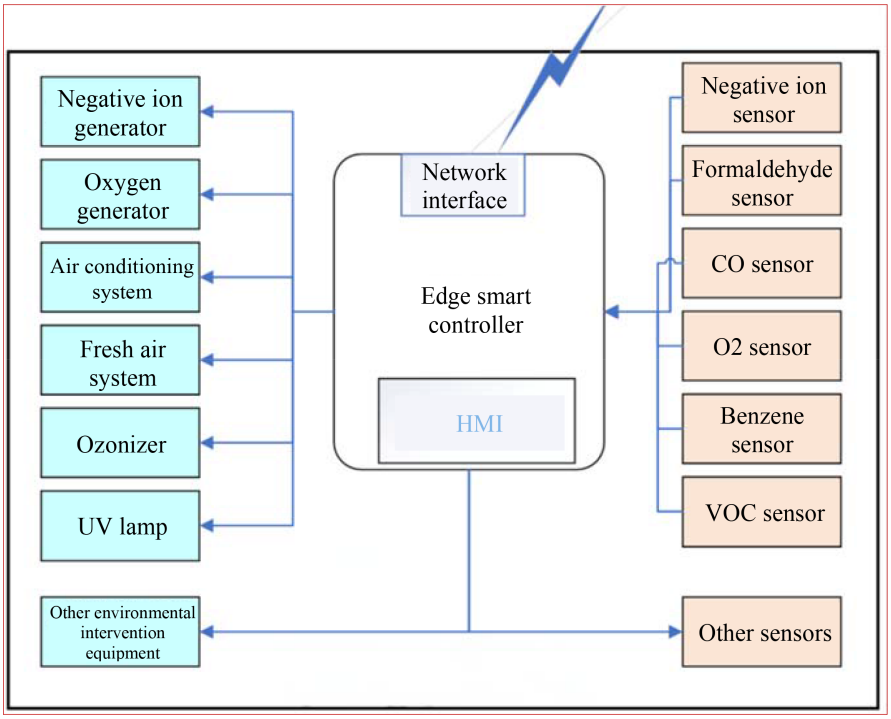

Figure 2. Interface of intelligent system monitoring sterilized indoor air quality.

to ensure health, save energy, and promote greenness and intelligence.

1) Hardware design of the edge system

In the edge system, each sensor has different hardware interfaces and communication protocols falling into either the digital or analog groups. For example, the negative ion sensor (negative ion detector) has MODBUS protocol of RS485 communication interface, and standard analog sensor interface of 0 - 10 V (4 - 20 mA). Formaldehyde sensors in the HCHO series have RS485/232 communication interfaces and accessible protocol commands. The VOC air quality sensor digital type uses UART communication for PWM output, whereas its analog kind applies standard sensor voltage. Therefore, the central control unit of the edge system has rich hardware interface units and flexible hardware expansion or tailoring performance.

Each ambient air intervention device and appliance in the edge system has different controllers or control circuits, such as complex PLC control, voltage control, simple switch control, etc. The hardware interfaces and communication protocols of other edge systems are different. According to the characteristics of underground space environment intervention, the type, quantity and deployment of sensors in the edge system need to be further optimized based on a well-designed environmental dynamics model.

2) Software design of the edge system

Somebody must integrate different control methods of ambient air sensors and intervention devices into the edge computing system. Therefore, it is vital to refer to the industrial control system to choose a real-time operating system with strong stability and high reliability. In the environmental dynamics model, the

change of ecological parameters with environmental intervention equipment is slow, with a sluggish response. An optimized aerodynamic model can produce quicker responses, especially in improving the environment quickly but with a large crowd of visitors.

In designing a control strategy for the ambient air intervention equipment, real-time usage is intelligently predicted and determined based on statistical data such as the frequency of use and the number of users on a large time scale, so that the ambient air equipment can intervene in advance.

3) Data communication of the edge computing system

5G standards are applied to the communication mode design of the edge system for data collection and sharing. The content and data format shall be standardized, mainly including parameters of ambient air, equipment usage, personnel usage, and energy consumption. The edge system also receives ambient air control strategy from the superior through 5G communication.

4) Intelligent HMI design of the edge computing system

HMI displays each device's working status, sensor data, and usage data in real-time, as well as the current ambient air intervention strategy, operation interface, and emergency interface, including various ambient air instruments and sensors, as shown in Figure 2 with more details.

5.2.3. Environmental Supervision Information System for Underground Space Used as Fitness Centers in Urban Areas

Responsible persons shall put an ambient air monitoring information system for underground spaces used as fitness venues in urban areas into place and incorporate it into the information administration system of the authority for a higher social utilization rate of urban underground space, better management and more social benefits.

As shown in Figure 3, the edge system of each underground location is

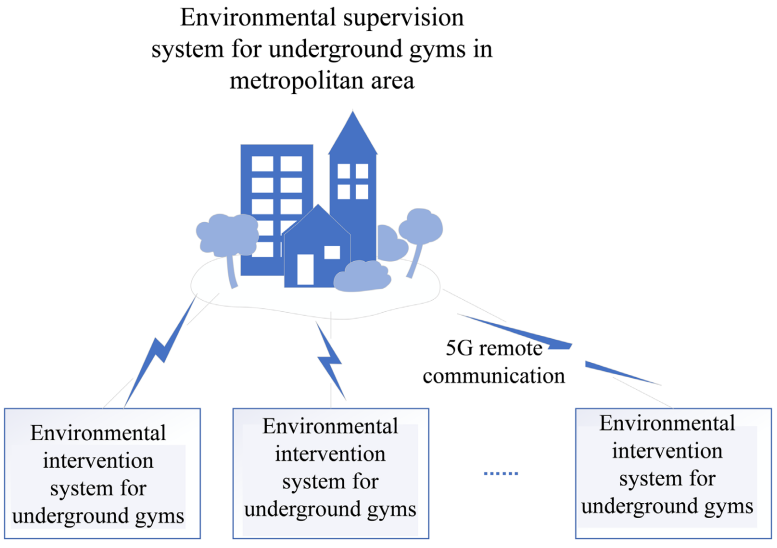

Figure 3. Schematic diagram of the ambient air monitoring system for underground space used as fitness venues.

interconnected by 5G. The ambient air monitoring information system captures valuable information from underground gyms. It uses big data to analyze, process, classify, predict, and optimize parameters in urban fitness venues, thus forming an effective digital and intelligent system and a regulatory platform. With the long-term support of big data, the system would optimize the control strategy of ambient air to reduce equipment's energy consumption, improve equipment utilization rate, and create more social benefits.

In conclusion, the role of the ambient air supervision information system in underground gyms should:

1) apply big data for urban underground gyms;

2) analyze the satisfaction rate of body-builders based on big data;

3) produce long-term decisions based on quantitative analysis of the social benefit for underground gyms with the help of big data.

6. Conclusions

Underground space will be developed into gyms as an effective mode of utilization and exploitation. According to the *Outline for Building a Leading Sports Nation*, the rational use of underground space is encouraged and somebody shall incorporate fitness venues and facilities into the three-dimensional planning of land and spans at all levels across the country. Properly and coordinately addressing legal and regulatory issues of underground space, three-dimensional planning of land and locations, and property rights issues would significantly contribute to China's quality development of underground spaces.

Meanwhile, the selection of fitness venues preferring underground spaces is in line with China's primary national conditions of rapid urbanization, and such a choice can effectively address challenges faced by big Chinese cities. Moreover, it can improve land use efficiency, increase urban space resilience, and give full production to underground spaces in contributing to the "Dual Carbon" target. Building underground gyms is expected to make the "15-minute fitness circle" a reality soon, satisfying people's need to exercise at any time and in the most convenient places.

Science and technology support sports development as a variety of ambient air intervention instruments can be applied such as negative ion generators for dust reduction, sterilization, and disinfection, and the elimination of sweat smell; oxygen generators for creating an oxygen-enriched environment; HEPA filters for ventilation in the gym; ultraviolet lamps and ozonizers for overall sterilization and disinfection when there is no one inside. These can root out key issues such as poor indoor air quality, strong sweat smell, and excessive bacteria and viruses in traditional fitness venues.

With a better design scheme, the intelligent system to improve air quality in underground gyms by enriching oxygen and sterilizing indoor air integrates various instruments to achieve automatic control and real-time monitoring of indoor air quality, to create a worry-free, O_2-enriched and odorless underground

space for fitness venues with neither bacteria nor virus.

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Data Availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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