

Study on the Effect of Plant Configuration on Air Quality in High Density Urban Pocket Parks

Rui Zhang¹, Na Chang^{1*}, Shuting Lu¹, Yutong He¹

¹ Academy of Fine Arts, South China Normal University, Guangzhou, China

Email Address

970496877@qq.com (Rui Zhang), 309784066@qq.com (Na Chang)

*Correspondence: 309784066@qq.com

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Abstract:

In a high-density urban environment, air quality has become one of the important factors affecting human settlements, and plant design is an important way to affect air quality. Different plant configurations also affect the temperature, humidity and negative oxygen ion content acting on the urban environment. These values are important standards for measuring air quality. Taking four pocket parks of similar size in Guangzhou Huacheng Square Pocket Park, Guangzhou Avenue Middle Pocket Park, Haixinsha Asian Games Plaza, and Huacheng Square open space as the research objects, four Kestrel 4500 hand-held automatic weather instruments and portable KEC-900 detectors were used. The air quality of the area was observed, and then GraphPad Prism 8 was used to analyze the impact of the plant configuration of the pocket park on the air quality from the data. The study compared the temperature, wind speed and negative oxygen ion content in the four pocket parks. The comparative analysis and research of this data has provided useful suggestions for the design of high-density urban pocket parks and the optimization of plant configuration structures.

Keywords:

High-Density City, Pocket Park, Plant Configuration; Air Quality, Negative Oxygen Ions

1. Introduction

In the process of rapid urbanization, urban population growth and human activities have caused the fragmentation of the urban landscape, which has changed the urban landscape pattern to a certain extent. [1] The concept of the pocket park originated from the proposal of “New Parks Serving New York City” put forward at the exhibition organized by the New York Park Association in May 1963. Its prototype is small parks distributed in patches in high-density urban centers. Various small green spaces, small parks, small gardens, etc. in the city are common pocket parks around us, also known as pocket parks. system. In the high-intensity and fast-paced urban life, only on a small scale can individuals enjoy high-quality urban life and make up for

the limitation of urban area [2]. While they are now spread across many regions and countries, the most famous example of a pocket park is located in New York City. Here, the famous Perret Park and Greenacre Park were first built in Europe after World War II [3]. Furthermore, they are an important part of the urban green space system, providing space for communication and recreation [4]. Studies have shown that small urban green spaces, such as pocket parks of less than 5000 m² or other forms such as street trees, flower beds or green roofs in urban environments, can provide recreational and experiential benefits [5]. Pocket parks are extremely important to the improvement of high-density cities. They can not only beautify the environment, but also improve air quality and meet the in-depth requirements of "people-oriented" design. It is to make landscape design meet people's physiological and psychological needs and strive to create for the whole society. A convenient and good landscape environment [6].

Over the years, human activities related to urbanization have put enormous pressure on the natural environment. Deterioration of air quality is one of the major environmental problems faced by communities in urban areas, which can have dangerous consequences for human health in the long run [7].

Air pollution is an important issue affecting the health of high-density urban populations. If the concentration of negative air ions in the environment is low, it means that the concentration of small-sized suspended particles in the "free" state is high, reflecting the low cleanliness of the air; otherwise, it shows that the cleanliness of the air is high. The content of negative oxygen ions in the air represents the level of air quality. These extremely low content substances can change our environment, purify the air quality, and even have a very beneficial effect on the human body [8]. There are many factors that cause air pollution in high-density cities. The human factors behind high concentrations of air pollutants include vegetation loss, agricultural waste, and road traffic. Urbanization brings uncertainty to the biodiversity of plant communities [9]. The natural environment and frequent contact with nature are beneficial to human health and well-being [10]. Short-term exposure to forests, urban park gardens, and other (semi-)natural environments reduces stress and depressive symptoms, restores attention fatigue, increases self-reported positive mood, and improves mood and perceived physical and mental health [11]. Improving air quality will have long-term significance for the sustainable development of the city. The concentration of air negative ions in the environment rich in plant greening is higher, and the concentration of air negative ions produced by the multilayer structure of trees, shrubs and grasses is higher than that of other structure types [12].

2. Overview of the Study Area and Research Methods

2.1 Development Background and Overview of High-density Urban Pocket Parks

Pocket parks in the high-density city of Guangzhou are currently characterized by wide but uneven distribution, various shapes, strong attachment, small scale and scattered [13]. The main spatial functions include entertainment, rest, and sightseeing. This study selected four experimental locations located in Tianhe District, Guangzhou City (23°13'N and 113°34'E) for data analysis, namely, Guanhuacheng Square Pocket Park (observation point 1), Guangzhou Avenue Middle Pocket Park (Observation point 2) and Guangzhou Asian Games Park (observation point 3), and select the open space in the center of Huacheng Square as a reference plot for plant configuration. The distance between the four experimental sites is relatively close, with a total

distance of 1.9 kilometers, which can meet the standard of two hours as the measurement period. The climatic conditions in Guangzhou are characterized by indistinct four seasons and small daily temperature differences. Plants in these areas grow well due to the abundant precipitation and sunshine in southern China, and due to being in commercial centers, only daily pruning and cleaning are required. In addition, studies have shown that despite the limited space and simple functions of small green spaces, green spaces are still essential for residential outdoor activities [14].

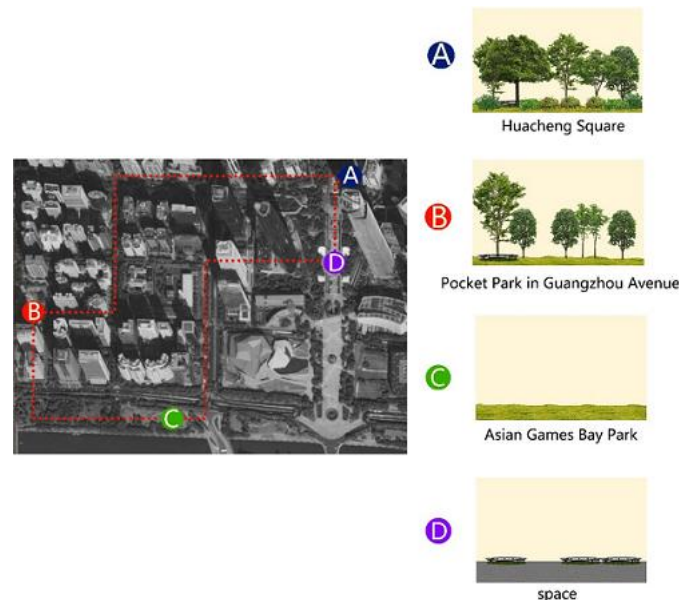


Figure 1. Satellite image of experiment site.

2.2 Research Methods

2.2.1 Experimental research method

The experimental research method is to carry out the experimental design, select the experimental objects, determine the experimental conditions, direct the experiment, and analyze the experimental data. Some of the experiments can be done in the laboratory, and some experiments can be carried out in the field of production due to constraints. When the design experiment is carried out under strict control conditions, it is called a real experiment or a standard experiment; when the actual experiment cannot be carried out due to the lack of conditions, the experiment can still be done, and this kind of experiment is called a simulation experiment [15].

2.2.2 Field investigation method

From the perspective of the implementation of field work, investigation and research can be roughly divided into the following three main stages: a. Preparation stage: clarify the purpose, draw up the outline, select the address of the investigation site, understand the background, collect data, organize division of labor, and prepare for the investigation Equipment and equipment, establishment of rules and regulations; b. On-site inspection stage: permission to enter, establishment of trust and friendly relations, wide-ranging legal investigation, individual interviews, collection of physical data; c. Sorting and analysis stage: classification and analysis, data analysis, comprehensive opinions, and report of inspection results [16].

2.3 Research point design

This experimental measurement is carried out during the day when life is relatively active. On a sunny and breezy day in September 2022, four experimental sites were selected, and five observation points were selected as research objects in the experimental points composed of different plants, respectively. Arbor-shrub-grass type (Pocket Park in Huacheng Square), Arbor-grass type (Pocket Park in Guangzhou Avenue), and grass type (Asian Games Bay Park). And choose the hard open space without plant configuration (Huacheng Square open space square) as the reference place to compare the experimental data. For five consecutive days (days) from 8:00 am to 18:00 pm, the portable KEC-900 detector was used to measure the concentration of positive and negative ions in the air every 2 hours. The test instrument was calibrated before use to eliminate the deviation between instruments. Kestrel 4500 hand-held automatic meteorological instrument measures wind speed, temperature and humidity and other meteorological indicators synchronously. The observation height is 1.3~1.5m above the ground. The test instrument is calibrated before use to eliminate the deviation between instruments. Three readings are taken for each observation point As replicates, average values were taken as final data. Each measurement and analysis is carried out simultaneously, so that the test values of four sample areas are obtained for comparison and analysis.

2.4. Data processing

GraphPad Prism 8 was used to conduct statistical analysis and chart processing of the experimental data, and one-way ANOVA was used to analyze the influence of different vegetation structures on air negative ions and air particles, including the relationship between air negative ions, air particles and different influencing factors.

3. Data Collection and Analysis

3.1 The impact of plant configuration structure in the pocket park on air quality

3.1.1 Effects of different plant configurations on the concentration of negative oxygen ions

(1) Observation site-basic situation

Table 1. Plant configuration of Huacheng Square Pocket Park (A).

serial number	plant configuration	plant type	growth habit
1	Nageia nagi (Thunberg) Kuntze	arbor	It prefers humid areas without stagnant water, the most suitable annual average temperature is 18°C-26°C, bamboo and cypress are weak in cold resistance
2	Antidesma bunius (Linn.)	arbor	Like sunny, well-drained, deep and fertile sandy loam soil
3	Bambusa multiplex (Lour.) Raeusch. ex Schult. 'Alphonse-Kar' R. A. Young	shrub or tree-like bamboo plant	Like warm and humid climate, with strong drought resistance and cold tolerance
4	Schefflera heptaphylla (Linnaeus) Frodin	tree or shrub	Prefers a warm, humid, semi-sun growing environment, likes wetness and dreads dryness

5	<i>Aglaia odorata</i> Lour.	evergreen shrub or small tree	When seedlings are more shade-tolerant, they are positive when they grow up, prefer warm and humid climates, and are afraid of cold; suitable for growing in fertile, loose, slightly acidic sandy soil rich in humus
6	<i>Hibiscus rosa-sinensis</i> Linn.	evergreen shrub	It likes warmth and humidity, requires sufficient sunlight, and is not tolerant to shade, cold, and drought.
7	<i>Ixora chinensis</i> Lam.	shrub	Likes humid and hot climate, not resistant to low temperature, likes acidic soil
8	<i>Ruellia simplex</i> C.Wright	herb	It likes a warm, humid and sunny environment, is resistant to high temperature and drought, and has no strict requirements on light and soil
9	<i>Ophiopogon bodinieri</i> Levl.	herbs	Prefers a humid environment, strong cold resistance
10	<i>Ficus microcarpa</i> Linn. f.	arbor	Like sunny, warm and humid climate, not cold-resistant, not drought-tolerant, relatively water-resistant
11	<i>Cinnamomum camphora</i> (L.) presl	evergreen tree	Likes light, slightly shade-tolerant; likes warm and humid weather, not strong cold resistance, not strict requirements on soil, more resistant to water and humidity
12	<i>Ficus religiosa</i> L.	arbor	Like light, like high temperature and high humidity, not resistant to frost, strong anti-pollution ability
13	<i>Codiaeum variegatum</i> (L.) A. Juss.	shrub or arbor	Like high temperature, humidity and sunny environment, not cold-resistant
14	<i>Michelia figo</i> (Lour.) Spreng	evergreen shrub	Prefers fat, sexually prefers half shade, grows best in weak shade
15	<i>Garcinia subelliptica</i> Merr	arbor	Likes high temperature and humid climate, likes light, tolerates half shade, salt resistance, drought resistance, wind resistance
16	<i>Ulmus americana</i> L.	deciduous tree	Light-loving, drought-tolerant, cold-resistant, barren-resistant, regardless of soil, strong adaptability
17	<i>Excoecaria cochinchinensis</i> Lour.	evergreen shrub	Prefers warm, suitable for growing in fertile, well-drained sandy loam environment
18	<i>Duranta erecta</i> L.	shrub	Prefers warm, sunny, cool and ventilated environment, slightly shade tolerant, poor cold resistance, more fertile, poor growth in barren land, resistant to water and humidity, not resistant to drought
19	<i>Ilex rotunda</i> Thunb	evergreen shrub	It likes warm, humid and sunny environments, the soil requirements are not strict, and the adaptability range is wide
20	<i>Alpinia zerumbet</i> (Pers.) Burt. et Smith	deciduous shrub	Sun-loving, heat-loving, see dry see wet, not cold-resistant

(2) Observation site-basic situation

Table 2. Plant configuration of Guangzhou Avenue Central pocket park (B).

Experimental ground	plant configuration	plant type	growth habit
1	<i>Ficus microcarpa</i> Linn. f.	arbor	Like sunny, warm and humid climate,

			not cold-resistant, not drought-tolerant, relatively water-resistant
2	Mangifera indica L.	evergreen arbor	It likes temperature, good light and is afraid of cold, more drought-tolerant, and likes a warm and sunny environment; it is required to grow in loamy and sandy soil with deep soil layer, rich organic matter, good drainage and loose texture
3	Schefflera heptaphylla (Linnaeus) Frodin	arbor or shrub	Prefers a warm, humid, semi-sun growing environment, likes wetness and dreads dryness
4	Nephrolepis auriculata (L.) Trimen	epiphytic or native plants	Prefers warm, humid and semi-shady environments
5	Ophiopogon bodinieri Levl.	herbs	Prefers a damp environment, strong cold tolerance, not cold resistant, more drought tolerant, barren resistant
6	Axonopus compressus (Sw.) Beauv.	perennial herb	Prefers tropical high temperature and humid environment, relatively shade tolerant
7	Cinnamomum japonicum Sieb.	evergreen arbor	Like sunshine, like warm and humid climate and fertile moist soil
8	Cordyline fruticosa (L.) A. Cheva	upright shrub	Like hot and humid climate environment, not cold-resistant
9	Zephyranthes candida (Lindl.) Herb.	perennial herb	Likes fertile soil, likes full sunlight, tolerates semi-shade and low humidity, and is more cold-tolerant
10	Terminalia neotaliala Capuron	deciduous arbor	Light-loving, semi-shady, high-temperature and humid climate, deep-rooted, wind-resistant, anti-pollution, long lifespan
11	Ficus deltoidea Jack	perennial evergreen arbor	It likes a warm and humid environment, requires sufficient sunlight, is more resistant to cold and shade, and requires fertile and well-drained soil
12	Syngonium podophyllum Schott	evergreen herb	Likes high temperature and humidity, strong adaptability, healthy growth, can adapt to different light environments, not resistant to severe cold

(3) Observation site-basic situation

Table 3. Plant configuration of Guangzhou Haixinsha Asian Games Park (C).

Experimental ground	plant configuration	plant type	growth habit
1	Terminalia neotaliala Capuron	deciduous arbor	Like light, slightly shade-tolerant; like warm climate, not strong cold resistance; like fertile, moist and well-drained calcareous soil, drought-tolerant, afraid of waterlogging
2	Zoysia tenuifolia Willd. ex Trin.	perennial herb	It likes warm climate and moist soil environment, and also has strong drought resistance, but poor cold resistance and shade tolerance

3.1.2 Effects of different plant configuration structures on temperature and wind speed

(1) Temperature comparison of four observation plots

The experimental data selects the data of three consecutive days in five days for analysis, and compares the temperature, wind speed and negative oxygen ion data from September 26, 2022 to September 28, 2022. The average temperature in Guangzhou reaches its highest value in August-September. Due to the special climate in 2022, the continuous rainfall in August has a great impact on data collection. In order to ensure the scientificity and stability of the data in Figure 2, the data observation time is selected in September 2022. According to the weather in 2022, the temperature in September 2022 will still be the highest, reaching the experimental standard.

Jul - Dec 2022												
City	Jul		Aug		Sep		Oct		Nov		Dec	
Hong Kong	159	[-59%]	615	[+36%]	171	[-47%]	50	[-58%]	131	[+236%]	26	[-10%]
Macao	148*	[-49%]	397	[+20%]	57	[-75%]	153	[+104%]	95	[+144%]	32	[+3%]
Guangzhou	209	[-14%]	210	[-22%]	43	[-79%]	26	[-61%]	127	[+243%]	15	[-55%]
Shantou	290	[+30%]	244	[-14%]	78	[-48%]	28	[-18%]	119	[+170%]	32	[-22%]
Shanwei	172	[-43%]	418	[+22%]	45	[-78%]	14	[-87%]	169	[+483%]	74*	[+208%]
Heyuan	149	[-31%]	134	[-45%]	26	[-82%]	4	[-91%]	140	[+259%]	27*	[-41%]

Figure 2. Rainfall month map of Guangdong Province in 2022.

Source: The data comes from the Hong Kong Observatory

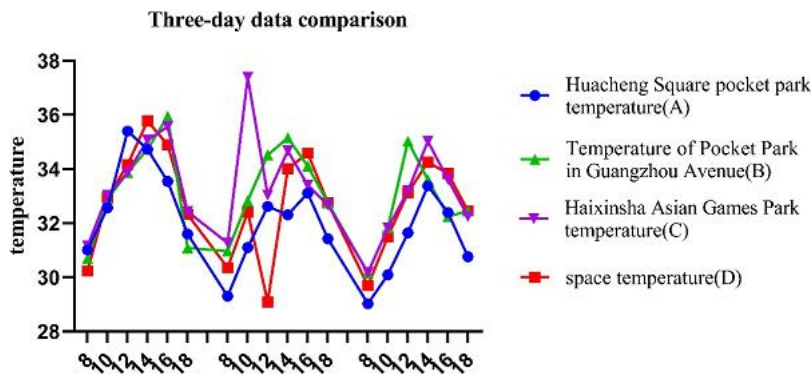


Figure 3. Three-day temperature comparison.

(2) Comparison of wind speed in four observation plots

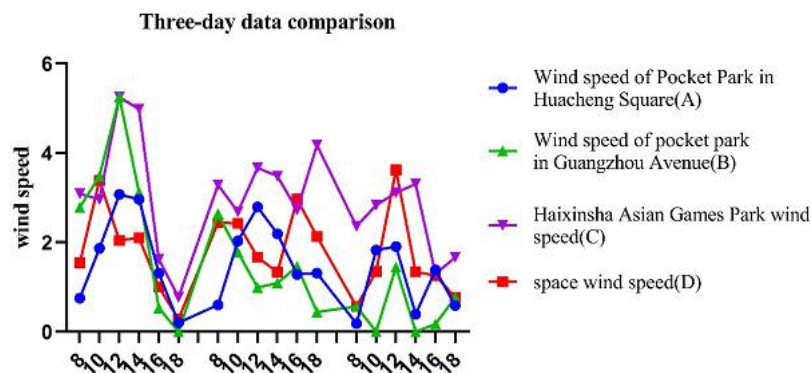


Figure 4. Three-day wind speed comparison.

(3) Comparison of negative oxygen ions in four observation plots

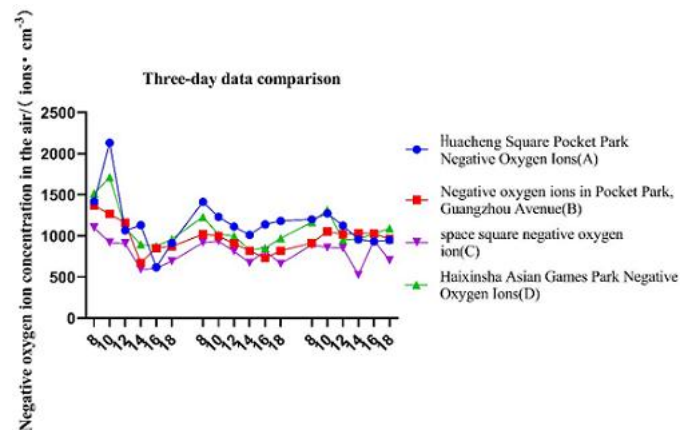


Figure 5. Three-day negative oxygen ion comparison.

3.1.3. Data summary and comparison

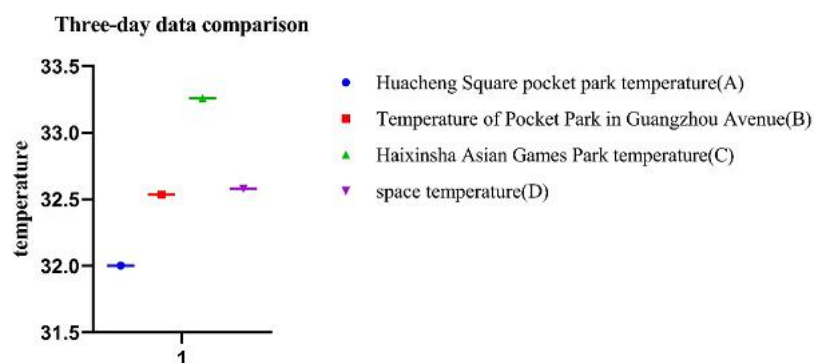


Figure 6. Three-day average temperature comparison.

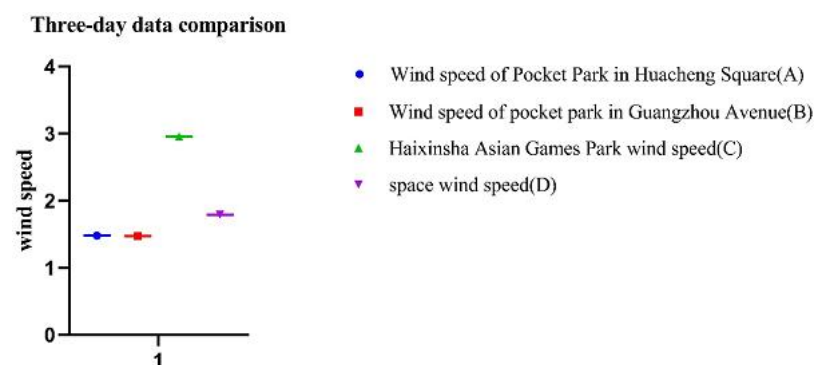


Figure 7. Comparison of three-day average wind speeds.

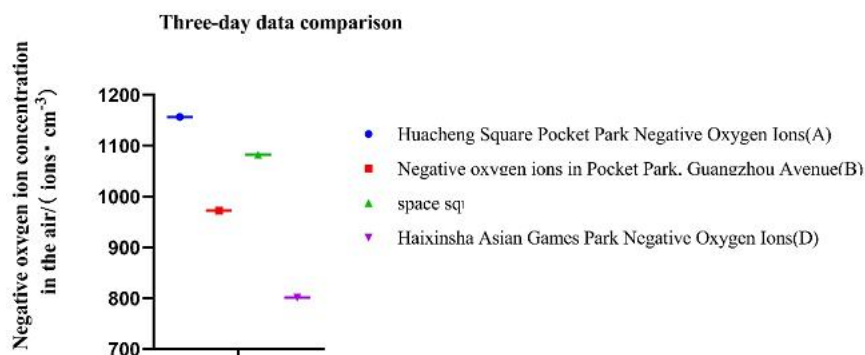


Figure 8. Comparison of three-day average air negative oxygen ion concentration.

4. Conclusions and Design Suggestions

4.1. Conclusion

(1) The four observation plots selected this time are located near Huacheng Square in Tianhe District, Guangzhou City. The surrounding environment of the observation plot Sanhaixinsha Asian Games Park is relatively open, and its geographical location is close to the Pearl River. According to the data chart, the three-day average negative oxygen ion concentration is second only to Huacheng Square Pocket Park, which has the most abundant plant configuration. Due to the impact of the surrounding water environment in Haixinsha Asian Games Park, the relative humidity in the air is higher.

(2) Analysis from the perspective of plant composition: the Pocket Park of Huacheng Square is dominated by the plant structure of arbor-shrub-grass, the Pocket Park of Guangzhou Avenue is dominated by the plant structure of arbor-grass, and the plant configuration in the Pocket Park of Huacheng Square is more abundant, and more plant species. On the basis of the similar surrounding environment, there is no big difference in wind speed between Huacheng Square Pocket Park and Guangzhou Avenue Middle Pocket Park, which are 1.480m/s and 1.473m/s respectively; the temperatures are 32.003°C and 32.536°C respectively. The data shows that the negative oxygen ion content of Huacheng Square Pocket Park with richer plant configuration is as high as 1156.667ions/cm³; the negative oxygen ion content of Guangzhou Avenue Middle Pocket Park reaches 972.333 ions/cm³. There is no plant configuration in the open space of the reference site, the wind speed is 1.79m/s, the temperature is 32.58°C, and the negative oxygen ion content in the air is 801.389ions/cm³, among which the negative oxygen ion content is the lowest among the four sample plots. Haixinsha Asian Games Park is close to the water environment, and the plant configuration is dominated by a single grass structure, which can ensure the circulation of high-density urban strokes and the relative humidity in the air, and also meet the functional needs of crowd activities in Haixinsha Asian Games Park. Due to the relatively open geographical location, simple plant composition, and frequent crowd flow activities, the observation data shows that the average temperature and wind speed of Haixinsha Asian Games Park are the highest in three days, with an average temperature of 33.259°C, an average wind speed of 2.959m/s, and an average negative oxygen ion content. It is 1082.444 ions/cm³. According to the observation data, it can be concluded that the wind speed and the concentration of negative air ions are related to the species structure and configuration of the plant community. The concentration of negative air ions in different vegetation structures is different. The more complex the vegetation structure, the higher the negative ion content in the air.

(3) The observation site is located in Tianhe District, Guangzhou City. Guangzhou is located on the subtropical coast, and the Tropic of Cancer passes through Conghua. It has an oceanic subtropical monsoon climate, characterized by warm and rainy weather, sufficient light and heat, long summer and short frost season. Accompanied by the high floor area ratio of high-density urban buildings and other issues, the impact of urban microclimate on the quality of human settlements continues to intensify [18]. Green spaces can regulate the microclimate in high-density cities to a certain extent. According to research, configuring green spaces with complex arbor-shrub-grass patterns in high-density cities can significantly improve the microclimate [19]. The climatic conditions in Guangzhou are suitable for plant growth, and the subtropical monsoon climate has a rich variety of plants, which is conducive to the

composition of a variety of plant configuration structures. Different multi-layer plants can be selected according to different geographical environments, which can meet local conditions and improve air quality at the same time. The purpose of beautifying the environment.

4.2. Design suggestions

(1) Appropriately increase or develop small green parks and reduce unnecessary hard squares or paving.

(2) Taking the negative air ion concentration value of the natural environment as a reference standard, construct a reasonable and suitable plant configuration according to different geographical environments and climatic conditions in high-density cities, and use arbor-shrub-grass multi-layer plant configuration structure, Maximize air quality.

(3) Consider the shelter area according to the needs of plants and space functions, keep the light, and ensure the use and flow of people.

(4) Reasonably use water elements to design pocket parks, make full use of the effect of water on the promotion of air negative ions, and enhance air cleanliness.

(5) Use the plant configuration structure in the pocket park to introduce breeze, increase the humidity in the air, and increase the comfort of the body.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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