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Temporal and Spatial Variations in the Concentration of Negative Ions and Its Influencing Factors in Xinfeng County

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Abstract Based on the data of meteorological elements and concentration of negative ions in the county town station, Luguhe station and Yunjishan station during 2020 -2024, the temporal and spatial variations in the concentration of negative ions and their influencing factors in Xinfeng County were analyzed. The results show that the concentration of negative ions was the highest in summer, followed by spring; it was lower in autumn and the lowest in winter. In terms of diurnal variations, it was higher in the early morning and night, and lower in the noon and afternoon, which was closely related to the diurnal variations of human activities and meteorological conditions. The factors that affect the concentration of negative ions in the air are more complex. Besides meteorological factors, vegetation, altitude, human activities and other factors should be considered.
Key words Concentration of negative ions; Temporal and spatial variations; Influencing factors; Xinfeng County
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Xinfeng County is located in the north-central part of Guangdong Province, with a unique natural ecological environment. Its forest coverage rate is as high as 81.15%, and the air quality rate is 100%. The number of negative ions known as the "air vitamin" in original forests is as high as 100 000 cm^{-3}. In the county, a number of health care bases such as Xinfeng Yuntianhai Forest Health Care Base and Xinfeng Lingnan Red Leaf World Forest Health Care Base have been built. As an important indicator to measure air quality and ecological environment, the concentration of negative ions is of great significance to the development of ecotourism and health care industry in Xinfeng County. The distribution law of concentration of negative ions in different regions and seasons can be understood to build special tourism routes and health care projects in a targeted way, improve resource utilization efficiency, and promote the sustainable development of ecological tourism and health care industry in Xinfeng County.

The research of negative ions in the air can be traced back to the 19th century. In 1889, German scientists Elster and Geitel first discovered the existence of negative ions in the air[1]. In the early 20th century, some scholars began to pay attention to the impact of negative ions in the air on human health. For instance, Russian scholars first confirmed that negative ions in the air have health care effects on the human body in 1903. Since then, the related studies have gradually increased, and the research field has been expanding. Domestic scientists have studied the seasonal and diurnal changes in the concentration of negative ions in the air, and found that it is usually higher in summer and spring, and lower in winter and autumn; it was higher during daytime than that at night[2]. In terms of influencing factors, the influence of meteorological factors and human activities on the concentration of negative ions in the air have been discussed. Meteorological factors such as temperature and humidity are closely related to the concentration of negative ions in the air. Generally speaking, under the conditions of higher temperature and humidity, lower air pressure, more precipitation, and moderate wind speed, the concentration of negative ions in the air is higher[3].

In this study, the temporal and spatial variations in the concentration of negative ions in Xinfang County were comprehensively revealed, and the key factors affecting their changes were deeply analyzed to provide solid theoretical basis and data support for the scientific planning and sustainable development of ecotourism and health care industry in Xinfang County.

1 Data and methods

1.1 Data sources The data of meteorological elements and concentration of negative ions in the county town station, Luguhe station and Yunjishan station during 2020 -2024.

1.2 Research methods SPSS software was used to analyze the correlation between the concentration of negative ions and meteorological factors, calculate correlation coefficient, and determine the correlation between each factor and the concentration of negative ions.

2 Temporal variations in the concentration of negative ions in Xinfeng County

2.1 Characteristics of seasonal changes The concentration of negative ions in the four seasons in three monitoring stations was analyzed statistically. The results show that there were significant differences between different seasons in the concentration of negative ions. In the county town station, the mean concentration of negative ions in summer was the highest (reaching 6 890 ions/cm^3),

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followed by spring (5 710 ions/cm^3). In autumn, it was 4 002 ions/cm^3. In winter, it was the lowest, only 1 767 ions/cm^3 (Fig. 1). In Luguhe station, the average concentration of negative ions was the highest in summer (up to 4 840 ions/cm^3); it was 4 095 ions/cm^3 in spring and 2 275 ions/cm^3 in winter; it was the lowest in autumn, only 1 926 ions/cm^3 (Fig. 2). In Yunjishan station, the average concentration of negative ions was the highest in spring, reaching 2 094 ions/cm^3. It was 2 019 ions/cm^3 in winter and 2 275 ions/cm^3 in autumn; the minimum appeared in summer, only 1 474 ions/cm^3 (Fig. 3).

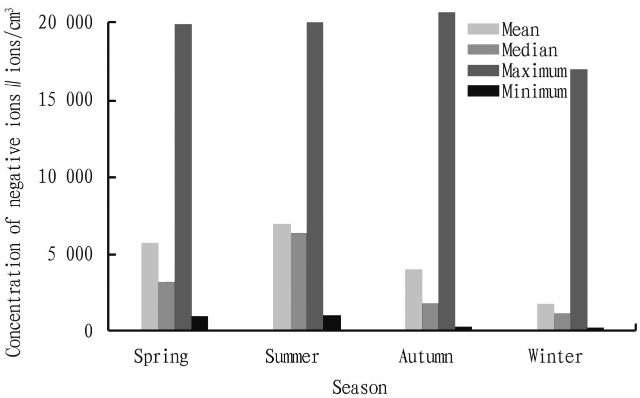

Fig. 1 Changes in the mean, median, maximum and minimum of the concentration of negative ions in the county town station

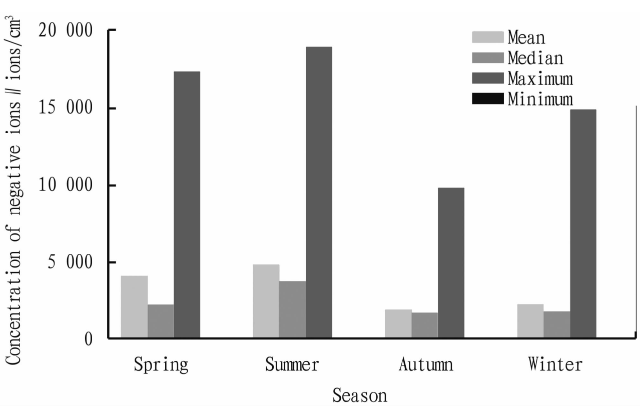

Fig. 2 Changes in the mean, median, maximum and minimum of the concentration of negative ions in Luguhe station

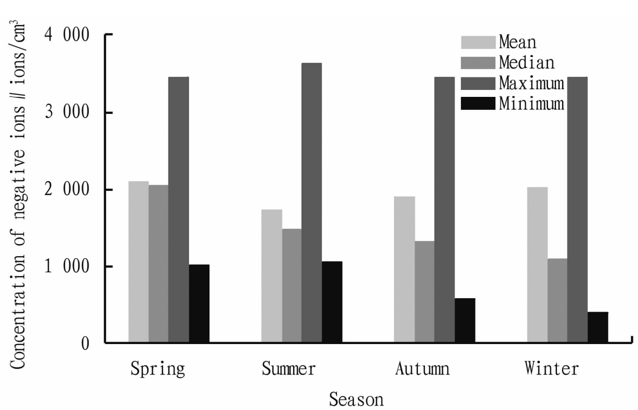

Fig. 3 Changes in the mean, median, maximum and minimum of the concentration of negative ions in Yunjishan station

The three stations basically had the highest concentration of negative ions in summer, which may be due to the high temperature in summer, sufficient light, extremely vigorous plant growth and strong photosynthesis. In the process of photosynthesis, plants release a lot of oxygen and produce abundant negative ions. The high concentration of negative ions in spring might be related to the gradual rise in spring temperature, plant recovery and growth, and the release of negative ions by new green leaves through photosynthesis. Although the growth of plants in spring is not as lush as in summer, with the increase of temperature and sunlight, the physiological activities of plants are gradually active, and the production of negative ions also increases correspondingly. The concentration of negative ions was relatively low in autumn and winter, which may be due to the gradual decay and defoliation of plants in autumn, the reduction of photosynthesis, and the release of negative ions. With the decrease of temperature, the growth rate of plants slows down, and physiological activities weaken; the efficiency of photosynthesis decreases, leading to a decrease in the production of negative ions.

2.2 Characteristics of diurnal variations Taking the county town station as an example, the concentration of negative ions in different time periods in a day was analyzed. It is found that it showed obvious regular fluctuations (Fig. 4). In the early morning (00:00 – 06:00), the concentration of negative ions was relatively high, with an average of 6 455 ions/cm^3. It may be because there were fewer human activities during this period, and the atmosphere was relatively stable, providing a good environment for the generation and accumulation of negative ions. At night, although the respiration of plants would consume part of oxygen, it would also release a certain amount of negative ions, so that the concentration of negative ions could be maintained at a high level.

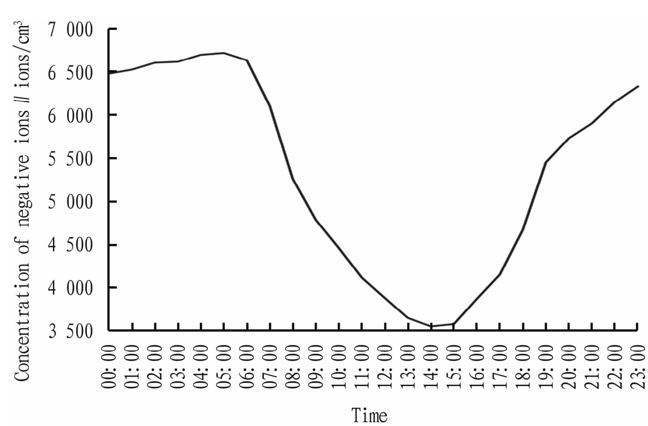

Fig. 4 Diurnal variations in the concentration of negative ions in the county town station

As the sun gradually rose (06:00 – 15:00), the average concentration of negative ions began to decrease gradually, dropping to 4 470 ions/cm^3. This may be because with the increase of the altitude angle of the sun, the temperature gradually increased, and the air convection intensified, thus reducing the concentration of negative ions. In addition, human activities gradually increased in the morning, such as the increase of traffic flow, beginning of industrial production activities, *etc.* These activities would release a large number of pollutants, such as automobile exhaust, industrial exhaust gas, *etc*., and these pollutants would react with negative ions to reduce the concentration of negative ions.

In the afternoon (15:00 – 23:00), the concentration of negative ions continued to rise, reaching 5 088 ions/cm^3 on average. With the gradual decrease of temperature, the air convection was weakened, and the diffusion rate of negative ions was also slowed down, so that the concentration of negative ions rose. Besides, plants still carried out photosynthesis in the afternoon and continued to release negative ions, which also played a certain role in the increase of the concentration of negative ions. As the sun gradually set, the temperature dropped, and the air humidity increased, which was conducive to the formation and stability of negative ions.

3 Analysis of meteorological factors affecting the concentration of negative ions in Xinfeng County

SPSS analysis software was used to analyze the Pearson correlation between the concentration of negative ions and meteorological factors (temperature, humidity, air pressure, precipitation, wind speed, *etc*.) and calculate the correlation coefficient (Table 1 – Table 3).

3.1 Yunjishan station Seen from the correlation coefficient, the correlation between meteorological factors and the concentration of negative ions was very poor. The *P* value of the average temperature, minimum temperature and maximum temperature was less than 0.05, indicating that the correlation between these meteorological factors and the concentration of negative ions was significant. Although the absolute value of the correlation coefficient was small, this correlation was real. The *P* values of other meteorological factors were all more than 0.05, showing that the correlation between these meteorological factors and the concentration of negative ions was not significant.

Table 1 Correlation between meteorological elements and the concentration of negative ions in Yunjishan station

Meteorological element	Pearson correlation coefficient	*P* value
10-minute wind speed	0	0.96
2-minute wind speed	–0.01	0.81
Daily rainfall at 20:00	0.01	0.85
Extreme wind speed	0	1.00
Mean temperature	–0.17	0
Daily temperature range	–0.03	0.26
Maximum wind speed	0.01	0.63
Minimum temperature	–0.15	0
Maximum temperature	–0.18	0
Humidity	0.01	0.73

3.2 County town station Seen from the correlation coefficient, the average temperature, minimum visibility, maximum temperature and minimum temperature had a good correlation with negative ions. Except the *P* value of extreme wind speed and maximum wind speed was more than 0.05, the correlation between other meteorological factors and the concentration of negative ions was statistically significant.

Table 2 Correlation between meteorological elements and the concentration of negative ions in the county town station

Meteorological element	Pearson correlation coefficient	*P* value
10-minute wind speed	–0.197	0
2-minute wind speed	–0.188	0
Daily rainfall at 20:00	0.171	0
Extreme wind speed	0.022	0.389 6
Mean temperature	0.420	0
Average visibility	–0.117	0
Daily temperature range	–0.215	0
Sunshine duration	–0.160	0
Relative humidity	0.376	0
Evaporation capacity	–0.090	0.000 5
Maximum wind speed	–0.017	0.515 1
Minimum visibility	–0.397	0
Minimum temperature	0.458	0
Maximum temperature	0.333	0

3.3 Luguhe station From the correlation coefficient, it is seen that the average temperature, minimum temperature and maximum temperature had a high correlation with the concentration of negative ions in Luguhe station. Except the *P* value of the maximum wind speed was greater than 0.05, the correlation between other meteorological factors and the concentration of negative ions was statistically significant.

In summary, the changes in the concentration of negative ions were not determined by a single meteorological factor but by the interaction of several different meteorological factors.

Table 3 Correlation between meteorological elements and the concentration of negative ions in Luguhe station

Meteorological element	Pearson correlation coefficient	*P* value
10-minute wind speed	–0.14	0
2-minute wind speed	–0.10	0
Daily rainfall at 20:00	0.07	0.04
Extreme wind speed	0.16	0
Mean temperature	0.41	0
Daily temperature range	–0.16	0
Maximum wind speed	0.03	0.40
Minimum temperature	0.43	0
Maximum temperature	0.35	0

4 Conclusions

In terms of seasonal variations, the concentration of negative ions was the highest in summer, followed by spring; it was lower in autumn and the lowest in winter. In summer, high temperature, high humidity, abundant precipitation and long sunshine duration are conducive to the formation and stability of negative ions. In winter, low temperature, low humidity and short sunshine duration are not conducive to the formation and diffusion of negative ions. The diurnal variations in the concentration of negative ions showed obvious regular fluctuations. It was higher in the early morning

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lightning risk assessment method based on regional lightning protection (semi-circular method) to assess the lightning risk of wind farms. In addition, it is a new method and a new exploration to comprehensively evaluate the lightning protection status of wind farms based on six indicators (three compliance, two innovation and one effect) including design basis compliance, product compliance, protection method compliance, product innovation, technology innovation and lightning damage (protection effectiveness), and to divide them into three levels of high, moderate and low risk.

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and night, and lower in the noon and afternoon, which was closely related to the diurnal variations of human activities and meteorological conditions. In the early morning, due to less human activities and plant photosynthesis, the concentration of negative ions increased. At noon, because of strong solar radiation, high temperature, and severe air convection, the concentration of negative ions reduced. In the evening, with the decline of human activities, the concentration of negative ions rose again.

The factors that affect the concentration of negative ions in the air are more complex. Besides meteorological factors, vegetation, altitude, human activities and other factors should be considered.

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