Research Article

Real-Time Monitoring and Early Warning Algorithm of Ozone + Nitrogen Oxides in High-Density Residential Space Based on Big Data

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In order to monitor ozone and nitrous oxide pollutants in residential space, artificial intelligence algorithm is integrated on the basis of traditional monitoring mode. Through the comparison of system detection accuracy and early warning sensitivity of different detection methods, it can be seen that the application of artificial intelligence detection system can improve the monitoring performance of ozone and realize the timeliness of large-scale monitoring coverage and data update. The accuracy and sensitivity of system detection under the two detection methods are analyzed, and the main harm caused by ozone pollution is analyzed. The significance of monitoring ozone pollution in ambient air is emphasized. The air index of high-density residential space using intelligent big data detection method is obviously superior to previous detection methods in terms of timeliness, accuracy, and early warning sensitivity of the system. It also provides an important data reference for the real-time monitoring and early warning of ozone + nitrogen oxides in high-density residential space, and also makes an important contribution to reducing the impact on residents’ health and living environment.

1. Introduction

In recent years, the main pollutants affecting the ambient air are ozone and nitrogen oxides. It is urgent to solve this problem. Ozone (O₃), also known as superoxide, is an allotrope of oxygen (O₂). At room temperature, it is a light blue gas with special odor. Ozone is mainly distributed in the stratospheric atmosphere at the height of 10–50 km, and the maximum value is between 20–30 km. Ozone can be used to purify air, bleach drinking water, sterilize, treat industrial waste, and as bleach. In terms of the nature of ozone, it can absorb most ultraviolet rays. When the concentration of ozone increases, it will cause respiratory diseases, reduce the function of lungs, and damage the cells. It is easy to infect and aggravate the symptoms of asthma. Ozone is not only a human umbrella, but also a violent poison.

Now more and more scholars focus on how to protect and improve environmental and atmospheric problems. Li Zhutian has accelerated the process of urban industrialization and increasingly serious ozone environmental pollution, and put forward ozone governance and countermeasures [1]. Nitrogen oxides are compounds composed of two chemical elements, nitrogen and oxygen. Nitrogen oxides can stimulate the lungs and cause respiratory diseases. Liang et al. the continuous development and progress of society also brings environmental pollution problems. People’s awareness of environmental protection is constantly strengthened, and air pollution has become the primary problem to be solved. Therefore, research and analysis were performed on the environmental pollution of nitrogen oxides [2]. Li Shan et al. nitrogen oxides have become one of the pollutants in the atmosphere. Analysis and Research were performed on the concentration ratio of nitrogen oxides in the air and reduction and control measures [3]. Human beings can still maintain life after fasting and without water for a few days, but they will die if they cannot breathe air for five minutes. Ozone will affect people’s living environment to a certain extent. The excessive
emission of ozone and nitrogen oxides will not only have a direct impact on the atmospheric environmental quality of the region involved, but also lead to the emergence of a series of environmental protection problems. Through long-distance diffusion, it will have a certain negative impact on the national and even global tropospheric atmospheric environmental quality, resulting in a sharp increase in environmental protection pressure. Based on the previous statistics and analysis data, ozone and nitrogen oxides are far from enough. Use big data to carry out real-time monitoring and early warning algorithm for ozone and nitrogen oxides in residential space, and analyze, study, and explore the relationship between ozone and nitrogen oxides. Although the ozone layer has negative effects, people have known it. But in addition to air monitoring and air pollution prediction, we can make use of conventional manual detection methods and intelligent big data detection methods to solve the problems. We should make our living environment reduce the incidence rate of respiratory diseases and optimize the living environment, so as to prevent and control ozone and nitrogen oxides pollution in China.

At present, the efficiency of large-scale ozone NOx real-time monitoring is still low, and the efficiency of real-time monitoring is still low. If the big data technology can be applied to obtain the mutual law between key data and take it as the feedback of the system, it can not only significantly improve the stability and safety of ozone + NOx real-time monitoring, but also greatly improve the production efficiency. Therefore, under the traditional Internet signal system, it is very important to strengthen the real-time monitoring and early warning algorithm control of space ozone and nitrogen oxides under big data, verify its availability and reliability, and then explore the impact of early warning data on ecological environment detection.

2. Related Concepts and Literature Review

2.1. Current Situation of Ground Ozone Pollution. Ozone is formed by the photochemical reaction of nitrogen oxides and hydrocarbons in the atmosphere irradiated by the sun. Therefore, it is more lethal when it is sunny, there is high temperature, and low humidity. Ozone is widely used in people’s daily life and can be used in the disinfection of food and water resources. The so-called ozone pollution and photochemical smog are inseparable. The daily ozone pollution actually refers to photochemical smog. However, when the concentration of ozone around human living areas exceeds a certain limit, it will inevitably cause pollution such as ash and photochemical smog, which will seriously affect human normal production and life.

In recent years, with the rapid development of urbanization in China’s industrial production (such as spraying, printing, and oil refining), oil and gas volatilization, solvent use, and plant release and so on, high concentration ozone occurs frequently with pollution events and PM2.5. Liuxinai et al. aimed to analyze the research and current situation of ground ozone pollution in recent years, explore research trends and research directions, and provide a more comprehensive reference for future air pollution research [5]. The environmental pollution caused by them has attracted more and more attention from the public and relevant government departments, and has become the primary serious pollutant in major cities. In terms of the current situation, ozone pollution is bound to continue to deteriorate in the future, which will seriously endanger human health and the ecological and natural environment. However, due to the non-linear relationship between ozone and its precursors, ozone pollution is still the focus and one of the difficulties of air pollution control in major urban agglomerations in China. Zhao et al. The formation of ozone is mainly the emission of nitrogen oxides (NOx) and volatile organic compounds (VOCs), which is formed in high temperature and strong light weather. The key to solve the problem of ozone pollution is to reduce the emission of the two pollutants together. [4] introduced the research progress of near surface ozone pollution at home and abroad: the main research methods and progress of near surface ozone pollution in China were introduced in detail from the aspects of the change characteristics of ground ozone concentration, the main controlling factors of ozone pollution, the chemical reaction activity of precursor VOCs, emission sources, and the health effects of ozone exposure on people in recent years. In view of the shortcomings of the existing research, this paper summarizes and points out the future research trend [4]. Liu et al. aim to analyze the research and current situation of ground ozone pollution in recent years, explore the research trend and research direction, and provide a more comprehensive reference for future air pollution research [5].

2.2. Correlation between Ozone (O3) and Nitrogen Oxides (NOx). Nitrogen oxides (NOx) have a serious destructive effect on the ozone layer, which is mainly reflected in the depletion of ozone in the process of its reaction with ozone and breaking the balance of the ozone layer. Wang Wenjing (2022) ozone has become one of the primary pollutants affecting China’s ambient air quality [6]. In Zhou Jing (2018), nitrogen oxides will react with ozone, [7] that is, react with O3 to produce O2, reducing O3 and damaging the ozone layer. NOx reacts with ozone in the ozone layer and consumes a large amount of ozone; NOx reacts with ozone in the stratosphere to produce nitric oxide and oxygen; Nitric oxide reacts with ozone to produce nitrogen dioxide and oxygen, so as to break the ozone balance, reduce the ozone concentration, and lead to the depletion of the ozone layer. This reaction will deplete ozone in the stratosphere, break the ozone balance, lead to an increase in ground ultraviolet radiation, and bring a series of problems to the earth’s ecological environment and human survival. Nitrogen oxides participate in the “secondary photochemical reaction” in the atmospheric environment and are one of the “culprits” of ozone generation.

The “important force” causing ozone pollution is the made sources” (VOCs): one-time pollutants emitted by coal, motor vehicle exhaust, and petrochemical industry-nitrogen oxides. VOCs are a kind of important gaseous pollutants widely existing in the atmosphere. They not only have a direct impact on human health and ecological environment, but also
generate secondary pollutants by participating in atmospheric and photochemical reactions. Peroxyacetyl nitrates, esters, and organic aerosols are all important factors leading to air pollution. Cao et al. so far, the control of anthropogenic VOCs is still a short board in China’s atmospheric environment management. China is waiting to build an effective control mechanism of anthropogenic VOCs [8].

2.3. Traditional Ozone + NOx Monitoring and Early Warning System. At present, the conventional manual detection methods for monitoring and early warning of ozone and nitrous oxide substances in China are mainly gas phase titration and infrared absorption spectroscopy.

Gas phase titration mainly uses the principle of rapid reaction between ozone and nitric oxide to generate nitrogen dioxide, designs a gas phase titration reaction system, and calculates the concentration of component ozone mixed gas by accurately measuring the depth change of nitric oxide standard gas participating in the reaction. Yang and Wang ozone pollution is closely related to the law of daily production and life, and shows a certain lag compared with the concentration of precursors such as nitrogen oxides and carbon monoxide. Relevant departments should carry out gas phase titration, strengthen the monitoring, and actively do a good job in the prevention and control of ozone pollution in the air [9].

Infrared absorption spectroscopy is referred to as infrared spectroscopy for short. When infrared light with a certain frequency or energy is used to irradiate the collected air samples, once the vibration frequency of a molecular group is consistent with the external infrared radiation frequency, the energy of light is transmitted to the molecules through the change of molecular dipole moment. The sample is irradiated by mid-infrared light with continuous wavelength, which causes the transition between molecular vibration energy levels, thus generating infrared spectrum. According to the infrared absorption spectrum of the compound, qualitative and quantitative analysis of the structure of the reagent is carried out. The group absorbs infrared light of a certain frequency to produce a vibrational transition. The infrared absorption spectrum of the air sample can be obtained by recording this process with an instrument. Qin and Zhang designed a nitrogen oxide gas concentration detection system based on the principle of infrared spectral absorption and differential absorption technology [10].

3. Hardware Design of Ozone + NOx Real-Time Monitoring and Early Warning System in High-Density Residential Space Based on Big Data

In order to let the public and relevant government departments know the changes of ozone pollution in advance and enable residents to take corresponding preventive measures in time, it is necessary to accurately grasp the law of ozone pollution through high-density and large-scale monitoring. The traditional ozone + NOx monitoring and early warning system is composed of gas detection and alarm controller and fixed ozone monitor. The fixed ozone monitor is installed in high-density residential space, and its core component is gas sensor. Through the combination of air quality data and climate meteorological data, the content of ozone + nitrogen oxides in the air is finally obtained. Monitor and control each monitoring point based on the data of gas and fluid movement in the atmosphere. The logic of the above data acquisition system is shown in Figure 1.

In Figure 1, it can be seen that the collection of air quality data mainly depends on O3 and NOx monitoring probes, which requires very high monitoring probes, and can provide reliable test performance for gas, such as stability and sensitivity. And it is easily affected by interference factors such as environment and personnel, and the numerical process of obtaining the results is very slow. With the popularization of artificial intelligence technology, the sensitivity of satellite remote sensing monitoring is much higher than that of traditional monitoring methods. By monitoring the object from a long distance, the monitoring of the object is completed according to the electromagnetic wave reflected by the object. The logic of satellite remote sensing monitoring data acquisition system is shown in Figure 2:

In Figure 2, the data logic diagram of the ozone + NOx real-time monitoring and early warning system of high-density residential space with big data is constructed. Through multiple types of monitoring probes and real-time monitoring of ozone concentration, and each monitoring probe has the function of no signal communication, the probe information data extracted from the frame is systematically modeled and analyzed after three-dimensional modeling, and the corresponding data analysis results are output by the fuzzy neural network system. In the three-dimensional modeling system of relevant data input, the function of fuzzy neural network to analyze and process the collected data information can be realized.

With the popularization of data artificial intelligence technology, the sensitivity of satellite remote sensing monitoring is much higher than that of the traditional monitoring methods. By monitoring objects from a long distance, the monitoring of objects is completed according to the electromagnetic waves reflected by the objects. The application of artificial intelligence technology will carry out real-time ground monitoring, real-time satellite remote sensing, and air quality model simulation, so as to realize the integration of multi-source big data such as meteorological reanalysis data, and realize large-scale and high-density complete space-time coverage and near real-time update. It also provides important data support for the real-time monitoring and early warning of ozone + NOx in high-density residential space, so as to minimize the impact of ozone and NOx pollution on residents.

4. Simulation Evaluation and Statistical Method of Big Data Early Warning Algorithm Efficiency

In order to verify the effectiveness of this algorithm, this study uses the linear regression method to calculate the $R^2$
value under SPSS, the Spearman algorithm to calculate the correlation, and the bivariate t-test to calculate the T value and P value. The data source is all available data in the air quality of a city and its surrounding areas from January 1, 2021 to January 1, 2022, and the relevant ozone + NOx early warning effects are compared.

The statistical method of $R^2$ value is the ratio of regression residual to mean residual, as shown in formula:

$$R^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2} = \frac{1}{n} \sum_{i=1}^{n} x_i.$$  \quad (1)

$\bar{x}$: to investigate the arithmetic mean of sample sequence; $x_i$: the ith regression value in the series $x_i$: enter a value for the ith in the sequence; $n$: the number of samples investigated;

Spearman correlation algorithm, such as formula (2):

$$\rho_s = \frac{\sum_{i=1}^{N} (R_i - \bar{R})(S_i - \bar{S})}{\sqrt{\sum_{i=1}^{N} (R_i - \bar{R})^2 \sum_{i=1}^{N} (S_i - \bar{S})^2}}.$$  \quad (2)

$R_i$ and $S_i$: they are the observed values i Level of value; $\bar{R}$ and $\bar{S}$: they are variables x and y Average grade of; $N$: the total number of observations;

In the simulation and evaluation application of big data early warning algorithm efficiency, through the calculation and analysis of the correlation between $R^2$ value of linear regression method and Spearman algorithm, it is considered that the data results have consistency and correlation.

Ozone + NOx in high-density residential space is a typical ambient air pollutant. With the continuous expansion and deepening of the scope and degree of ozone + NOx pollution, the harm of pollution is great. In recent years, citizens’ awareness of environmental protection has begun to strengthen, and ozone + NOx pollution in high-density residential space has received enough attention. Nowadays, big data early warning algorithm is used for real-time detection, so as to better detect air quality. In order to detect ozone + nitrogen oxides in high-density residential space in real time, this study uses conventional manual detection methods and intelligent big data detection methods to detect ozone + nitrogen oxides. It is now PM25. Analyze and compare the detection accuracy of ozone and nitrogen oxides, and chart the data results to obtain the results in Table 1.

In Table 1: through two different detection methods PM2.5, By comparing the detection accuracy of ozone and NOx, it is found that, using conventional manual monitoring methods, it can be seen that PM2.5 the accuracy of detection is higher than that of intelligent big data detection method. The detection accuracy of intelligent big data detection method in ozone and nitrogen oxides is higher than that of the conventional manual detection methods.

In order to better compare the results of detection data, we use two different detection methods to achieve the accuracy of air pollutants. Draw the following Figure 3 according to the data in the above table to better understand the data.

In Figure 3, according to the test data results, the conventional manual detection method is compared with the intelligent big data detection method. Effect of conventional manual detection method on PM2.5 is better than the intelligent big data detection method, while the intelligent big data detection method has a slightly higher detection accuracy of ozone + NOx pollutants. The intelligent
Big data detection method in this study needs to further improve the detection accuracy of ozone + NOx in high-density residential space.

Now, in order to protect health, we have established a big data early warning system for ozone + nitrogen oxides in high-density residential space. For air PM2.5, Ozone and nitrogen oxides analyze the received data, and receive early warning in time in the data analysis and processing results. Once a data in the air exceeds the standard, it will trigger the alarm, which is convenient for the control of air quality and climate and meteorology. Now, for ozone + NOx in high-density residential space, this study uses conventional manual detection methods and intelligent big data detection methods to detect the early warning sensitivity of ozone + NOx. Now, according to the sensitivity of receiving early warning, analyze and compare the data results, and make a chart to get the following Table 2:

Table 2 shows the system early warning sensitivity of different detection methods. Through two different detection methods, early warning data are received within 2 seconds, 2~4 seconds, 4~6 seconds, and more than 6 seconds. The early warning sensitivity is compared. By comparing the early warning sensitivity, it is found that the sensitivity difference value of the two different detection methods is low in 2 seconds, and the difference value increases significantly when the time is greater than 6 seconds, which also shows that the early warning sensitivity of the intelligent big data detection method is higher than that of the conventional manual detection method.

In order to better compare the early warning sensitivity results of two different detection methods, the following Figure 4 is drawn according to the data in the above table, which is convenient for data analysis and comparison.

In Figure 4, through the visualization of system early warning sensitivity of different detection methods, it is obvious that the longer the time is, the higher the data of intelligent big data detection method is than that of the manual detection method. It shows that the use of artificial intelligence detection system is more conducive to people’s prevention and control in advance, and has promoted the prevention and control of ozone pollution.

5. Discussion

With the rapid development of society, the situation of air pollution is becoming more and more serious, and ozone is
one of the main reasons affecting the ecological environment. In order to avoid the further deterioration of ozone pollution, it is necessary to monitor ozone and nitrogen oxides in real time and provide first-hand data for the prevention and control of ozone pollution. Lu did a good job in the monitoring of ozone pollutants in the urban atmosphere to provide strong guidance for the specific practice of urban ozone monitoring and pollution. The change characteristics and the influencing factors of ozone in the atmosphere are analyzed, and the specific strategies for comprehensive treatment of ozone are put forward [11]. After analyzing and exploring the relationship between ozone and nitrogen oxides, it is considered that reducing the air pollution quality of high-density residential space can optimize the living environment and improve the quality of human high-density residential space.

Zhang in the era of big data, environmental protection is inseparable from information construction. Environmental monitoring and early warning system is an indispensable technical support in environmental monitoring and supervision. Applying big data technology to the process of atmospheric environment monitoring can greatly improve the ability of environmental governance [12]. Chen xiangru Introducing big data means to explore the characteristics of air pollutant emissions in eco-cities. Analyze the influencing factors of air pollution in the target city, upload the pollutant monitoring data in real time by using the automatic monitoring points, and combine it with the source analysis report of the Environmental Protection Bureau to count the main pollutants in this area. Through data analysis, the time variation characteristics of pollutant discharge are obtained [13]. Li wangxia (2018) Ozone is a secondary pollutant produced by the combination of photochemical reaction of volatile organic compounds and nitrogen oxides under the action of sunlight. After people inhale ozone, it will lead to serious inflammation of lungs and respiratory tract, especially for children and the elderly. It is necessary to monitor ozone, and put forward effective prevention measures [14]. Under the big data analysis technology, it not only realizes the platform application centered on high-density residential environment data, but also can monitor, analyze, and process the collected data, so that people can intuitively understand the environmental status of high-density residential space, but also provide scientific decision support for environmental protection departments, which plays an important role in urban construction, ecosystem, human health, and so on.

6. Summary

According to the above experiments, under the improvement of the quality assurance test of conventional manual detection methods and intelligent big data detection algorithms, the measured data is quite reliable. Firstly, the related concepts of air ozone and nitrogen oxides are discussed, their basic sources are analyzed, and a clear scheme is given for the actual influencing factors of ozone. This study compares the conventional manual detection methods with...
intelligent big data detection methods, such as comparing the system detection accuracy and system early warning sensitivity under the two detection methods, analyzes the main harm caused by ozone pollution, and emphasizes the significance of ozone pollution monitoring in the ambient air. The results show that the air index of high-density residential space under the intelligent big data detection method is significantly better than the previous detection methods in terms of timeliness, accuracy, and early warning sensitivity of the system. The application of artificial intelligence detection system can improve the monitoring performance of ozone, achieve large-scale monitoring coverage and timely data update, and provide important data reference for real-time monitoring and early warning of ozone + nitrogen oxides in high-density residential space, and also reduce the impact on residents' health and living environment. It provides a scientific basis for further improving atmospheric quality and providing mankind with a greener, more harmonious, and healthier atmospheric environment. While deepening the understanding of ozone pollution and enhancing people's awareness of environmental protection, it has played an important role in reducing ozone pollution in the atmosphere and promoting the sustainable and healthy development of society.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

The authors declare that there are no conflicts of interest in this paper.

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