Pol. J. Environ. Stud. Vol. 31, No. 5 (2022), 4907-4916
DOI: *10.15244/pjoes/149714*

Original Research

COVID-19 and Air Pollution: Air Quality Impact in 13 Cities of the Jiangsu Province of China

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Received: 26 July 2021
Accepted: 3 May 2022

Abstract

Jiangsu province is one of the economically strong provinces in east China. With the advance of the modernization process, the problem of air pollution in this area is facing a severe challenge under the common role of human activities and regional climate change. While the rest of the world struggles to control COVID-19, China has managed to control the pandemic rapidly and effectively with strong lockdown policies. This study investigates the change in air pollution (focusing on the air quality index (AQI), six ambient air pollutants nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO), particulate matter with aerodynamic diameters ≤10 μm (PM_{10}) and ≤2.5 μm ($PM_{2.5}$)) patterns for different periods in last 5 years. Different pollutants have different behavior identified in this studied which is helping for understanding the pattern of air quality. Short-term health advantages from the COVID-19 pandemic can be attributed to the reduction in air pollution and significant improvement in ambient air quality, which need the government to enact post-COVID environmental regulations.

Keywords: air pollution, COVID-19, particulate matter, China

Introduction

Since the reform and opening up, China's rapid economic growth and urbanization have not only improved the overall national strength and residents' living standards, but also caused serious environmental pollution problems, especially air pollution. The quality of the air environment is deteriorating. The city has also experienced different degrees of haze. The problem of air pollution has caused serious harm to the local ecological environment and human health, and has attracted widespread attention from countries all over the world [1-2].

Pollutants will not only destroy the natural ecology, but also have an adverse impact on human production, life and health. According to data released by the Ministry of Ecology and Environment of China, 85% to 90% of the main pollutants in most cities in China are atmospheric particulate matter [3]. Under stable weather conditions, due to continuous accumulation for a period of time, the formation of haze will

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result in the formation of haze in air pollution [4-5]. Atmospheric particulate matter $PM_{2.5}$ and PM_{10} will affect optical properties, reduce atmospheric visibility, and cause delays in air transportation and obstruction of road traffic. In addition, long-term exposure to $PM_{2.5}$ and PM_{10} particles can cause various diseases such as cardiovascular, asthma, and respiratory systems, which has aroused public anxiety and widespread concern. Tropospheric O_3 is the main atmospheric pollutant that affects human health and ecosystem productivity. Since 2013, the number of days with O_3 as the primary pollutant exceeding the standard has been increasing in many cities in China. The O_3 concentration mainly depends on precursor emissions and meteorological conditions. Tropospheric O_3 is mainly formed by photochemical reactions of volatile organic compounds (VOCs) and nitrogen oxides (NOx) [6]. Other sources include lightning, fire, and long-distance transportation of O_3 precursors. O_3 concentration is affected by meteorological conditions (such as tropopause folds, cut-off low points, etc.), which is mainly achieved by changing the stratospheric-tropospheric cross flux of O_3. Living in cities with high O_3 content, such as Houston or Los Angeles, people's risk of dying from lung disease has increased by more than 30% [7-9]. O_3 also has an adverse effect on crop yields and forest growth. It is also an important greenhouse gas that affects global climate change. NOX is one of the important pollutant gases that form acid rain, and it participates in the formation of photochemical smog, and it also has a local destructive effect on the O_3 layer in the stratosphere. SO_2 is mainly produced by the burning of fossil fuels such as coal and petroleum. Under the catalysis of strong light radiation and certain dust particles, it undergoes a series of photochemical reactions and forms acid rain under the erosion of rain, which causes damage to forests, lakes, and soil. Severe damage, and SO_2 has a strong irritant, and has a strong toxic effect on the respiratory organs of the human body[10]. CO is the most widely distributed and most abundant pollutant in the atmosphere and one of the products of incomplete combustion. It mainly comes from internal combustion engine exhaust and fossil fuel combustion. During the heating season in the city or at intersections with heavy traffic, the CO concentration will reach its peak. In summary, air pollutants have a profound negative impact on human health, the environment and sustainable development [11].

On the basis of studying the spatial and temporal distribution characteristics of air pollutant concentration, analyzing the cause mechanism of air pollution can provide a reasonable reference basis for air pollution prevention and control, and has important scientific significance [12]. Topography, external transportation, meteorological conditions and other factors affect the migration, dilution and diffusion of atmospheric pollutants. A large number of studies have shown that changes in the concentration of air pollutants are inseparable from pollution sources. For example, researchers pointed out that with the rapid advancement of industrialization and urbanization, the population density, urban built-up area, and car ownership continue to increase, resulting in a significant decline in urban air quality [13]. Studies analyzed the summer O_3 pollution in the Yangtze River Delta from 2013 to 2017 and found that traffic and industrial emissions played a major role in the formation of surface O_3. Another research used a one-dimensional continuous Morlet wavelet to analyze the characteristics of air pollution changes in Lanzhou in the past 10 years. The results showed that air pollution was significantly affected by topographical conditions, showing a pattern of "heavier in winter and light in summer". The impact of dust activities causes serious pollution in spring [14-16].

A large number of domestic and foreign studies have pointed out that the difference in the concentration of air pollutants is not only affected by local air pollutant emissions, but also inseparable from meteorological elements. Studies have shown that meteorological conditions can reduce $PM_{2.5}$ concentration to a certain extent. The monthly average $PM_{2.5}$ concentration in Wuhan has a significant positive correlation with air pressure, and a significant negative correlation with average wind speed, temperature, relative humidity, and rainfall. Deng et al. analyzed the temporal and spatial variation characteristics of pollutant concentrations in Beijing, Nanjing and Guangzhou and their correlation with meteorological elements, and found that Nanjing's $PM_{2.5}$ and PM_{10}. NO_2, CO, and SO_2 are all negatively correlated with wind speed; Beijing's NO_2, SO_2 and CO are significantly negatively correlated with wind speed, but when wind speed>4 m/s, PM_{10} concentration increases; Guangzhou's NO_2, SO_2 are significantly negatively correlated with wind speed, when wind speed>4 m/s, PM_{10} increases with the concentration of PM_{10}; in addition, the transmission of pollutants is different with different wind directions [17]. Qu et al. [18] uses Chinese provincial panel data from 2000 to 2017 to examine regional differences in the impacts of public participation in environmental behavior (PPEB), other socioeconomic factors related to haze pollution, and public health level (PHL) in China. Shen et al. analyzed found that lockdown during the COVID-19 brings a change in air quality patterns and its useful for environment [19].

COVID-19 had a beneficial environmental impact due to increased air quality. Therefore, the era of epidemic prevention and control is a good time to further examine the primary elements causing urban air quality changes. As a result of the worldwide lockdown that occurred during COVID-19, numerous studies have documented alterations in air quality. Altuwayjiri et al. highlights the changes in chemical properties and oxidative potential $PM_{2.5}$ during the lockdown period in Italy. Both $PM_{2.5}$ and NO_2 showed a reduction during lockdown period due to a decrease in primary emission from road traffic [20]. Elshorbany et al. used remote-sensing data to find reductions in the air pollutants during COVID-19 in USA and identified potential factors in the change of tropospheric ozone (O_3) [21]. Menut et al. studied the change of the air-quality pattern in Western Europe and used the WRFCHIMERE modelling strategy to highlight the major change in NO_2 concentration while there were minor changes in $PM_{2.5}$ concentrations during COVID-19 [22]. Clemente et al. shared the change in PM1 and PM10, and observed temporal variations in PM1 and PM10 concentrations were strongly affected by the frequency of Saharan dust events with a 35% decrease [23].

In this work, the AQI and six ambient air pollutants (NO_2, O_3, sulphur dioxide (SO_2), carbon monoxide (CO), PM_{10}, and $PM_{2.5}$) were assessed before, during and after the 2020 COVID-19 shutdown in the Jiangsu region of China. The relationships between the AQI and air pollutants ($PM_{2.5}$, PM_{10}, SO_2, NO_2, CO and O_3) in each city were also observed with spatiotemporal change analysis. This exercise sought to improve the understanding of changing air quality patterns in each city pre-, during active and post-COVID. Furthermore, correlation analyses between the six air pollutants and the AQI during the three periods were performed to ascertain the sources of air pollutants during and after lockdown. Different studies have already revealed different air quality patterns during active and post-COVID [24, 25]. In Jiangsu, there have been no prior reports focusing on pre-, active and post-COVID periods or on changes in the AQI with six ambient air quality patterns ($PM_{2.5}$, PM_{10}, SO_2, NO_2, CO and O_3). This study is the first to assess the relationships between the concentrations of the six named pollutants and the AQI before, during and after the Jiangsu COVID-19 lockdown. These results would help to identify effective control measures in mitigating air pollution in Jiangsu and China post-COVID.

Methods

Study Area Monitoring Stations

Jiangsu is a province-level administrative region of the People's Republic of China that includes the cities of Nanjing and Hangzhou. In the Yangtze River Delta region on the eastern coast of mainland China, Nanjing, the provincial capital, is located between 30°45’35°08’ north latitude and 116°21’121°56’ east longitude; it shares borders with Shanghai, Zhejiang Province, Anhui Province, and Shandong Province. The province of Jiangsu has a total land area of 107,200 square kilometers. As of the first day of November 2020, the permanent population of Jiangsu Province is 84,748,016, and the province is home to a total of 13 national historical and cultural heritage monuments. Annex A contains a list of the 72 selected air quality monitoring stations in Jiangsu Province. The names of each station as well as their locations and city are listed in the appendix. Fig. 1 depicts the entire province of Jiangsu, with black dots indicating the locations of the stations. The monitoring stations are rotated on a yearly basis; there are currently more than 110 in operation. Because we wanted to ensure data integrity and consistency throughout time, we chose monitoring stations that remained the same year in and year out.

Air Pollutant Data

The mass concentration data of the AQI and ambient atmospheric pollutants ($PM_{2.5}$, PM_{10},SO_2, NO_2, O_3, CO) come from the weather post report (http://www.tianqihoubao.com/). At each monitoring station, ambient $PM_{2.5}$, PM_{10}, NO_2, CO and O_3 concentrations were detected hourly, then provincial daily average and station average per 13 administrative cities were computed from those values.

Statistical Analysis

This study utilized the five year air pollution data of Jiangsu province from 2017 to 2021. This study contains before , after and during COVID-19 periods of Jiangsu in which the air quality data was changing abruptly due to restrictions of COVID-19. We define 2019 as befire COVID-19, 2020 as during-COVID and 2021 after-COVID-19 period. For further assessment, we compared our results from 2017 and 2018 to better

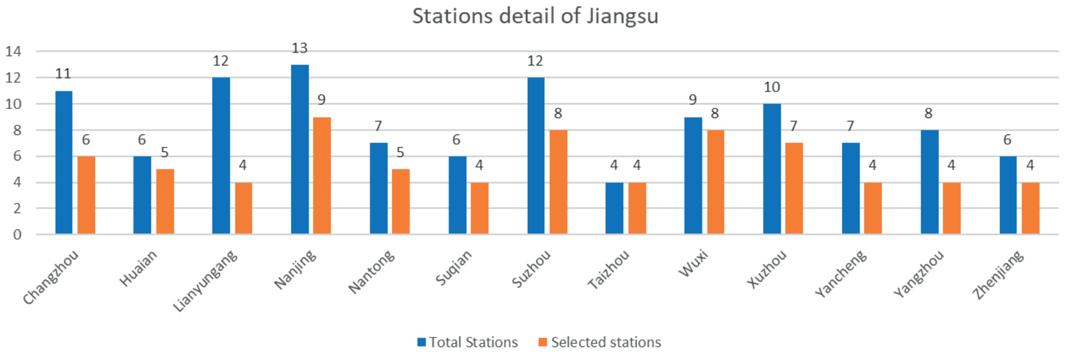

Fig. 1. Total of 72 selected monitoring stations.

evaluate the impact of the changes in air pollutant patterns. Statistical analysis of the data was performed using SPSS software (version 25; IBM Company).

Results and Discussions

Pollution of the atmosphere has a severe impact on environmental quality and global climate change, and as a result, nearly every government is implementing legislation to enhance air quality [26-28]. The problem of air pollution has grown into a significant issue that requires immediate response and has grabbed the attention of both the government and the general public [29-30]. This study is an attempt to identify changes in the pattern of the air quality index and air contaminants. Our research focused on the three COVID-19 periods, which corresponded to the three phases of the new coronavirus epidemic in early 2020 (during COVID), in order to better understand the impact of the most stringent control measures on Jiangsu's air quality. COVID-19 is a coronavirus epidemic that began in early 2020 (during COVID).

Change of O_3

Ozone pollution occurs in the troposphere, closest to the Earth's surface, diffused around us, mixed in the air everyone breathes. Ozone pollution in the troposphere mainly comes from the chemical reactions of nitrogen oxides (NOX) and volatile organic compounds (VOCs) in sunlight, usually in late spring and summer and autumn when it is clear and cloudy. Surface ozone is extremely destructive. Structurally, the ozone molecule (O_3) has only one more oxygen atom than the oxygen molecule (O_2). But this oxygen atom is very unstable, causing ozone to easily decompose at room temperature. Oxygen atoms generated by ozone decomposition have strong oxidizing power, which can not only damage cell membranes and inactivate proteins, but also degrade DNA and RNA, and strike cells in all directions.

High concentrations of ozone in the environment can strongly irritate the mucous membranes of our eyes and respiratory tract, induce respiratory diseases, and also cause skin aging and premature death. When photochemical pollution was first observed in Los Angeles, the United States in July 1943, many citizens said they felt "stinging in their eyes, and their throat felt as if they had been scratched when breathing", mistakenly thinking that they had been attacked by poisonous gas from the Japanese army; one in December 1952 In the photochemical smog incident, more than 400 elderly people over the age of 65 in Los Angeles died due to ozone pollution. Possible health threats from ozone pollution (indicated in orange) include premature death, impairment of growth and development in young children and tissue regeneration in adults, induction of lung cancer and various respiratory and cardiovascular diseases. Ozone pollution also has adverse effects on plants. Ozone's oxidation can inhibit photosynthesis

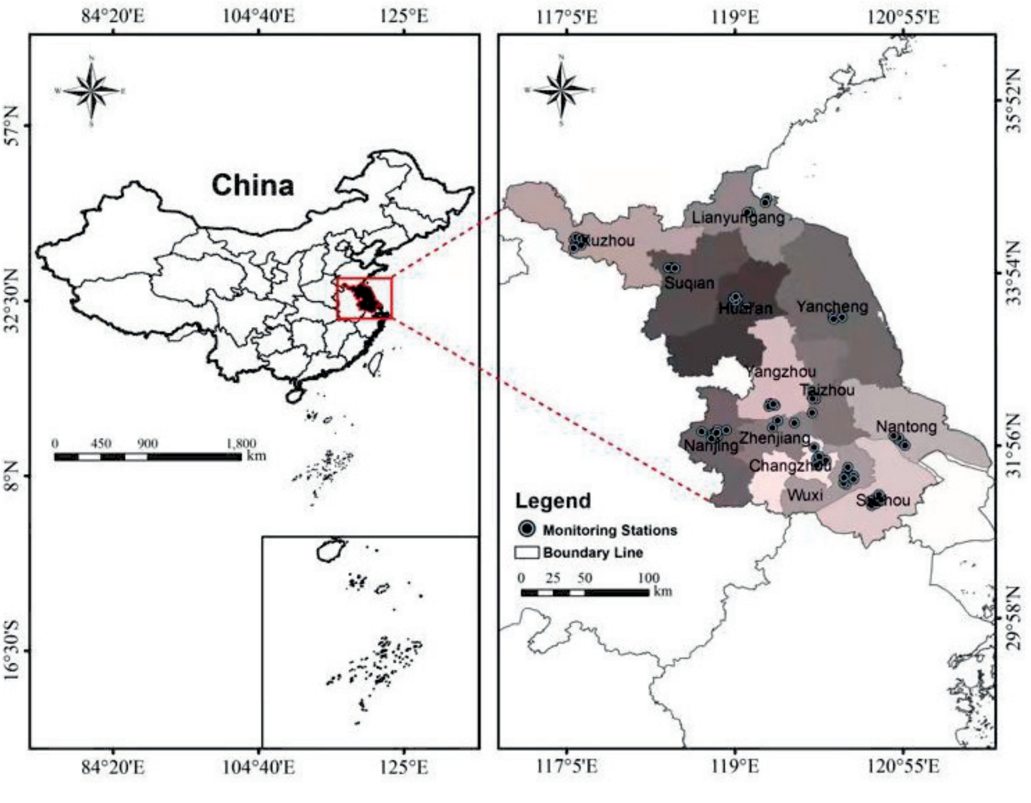

Fig. 2. Study area of Jiangsu with locations of monitoring stations in each city.

in plants, and even lead to necrotic lesions or signs of bleaching on plant leaves, ultimately resulting in reduced crop and forest yields. It is estimated that in 2015 alone, ozone pollution caused production losses of major crops and forests in China to be as high as US$18.6 billion and US$52.2 billion. From Fig. 3, in 2021 average ozone is as follows in: Changzhou = 54.6 μg/m^3, Huaian = 59.81 μg/m^3,

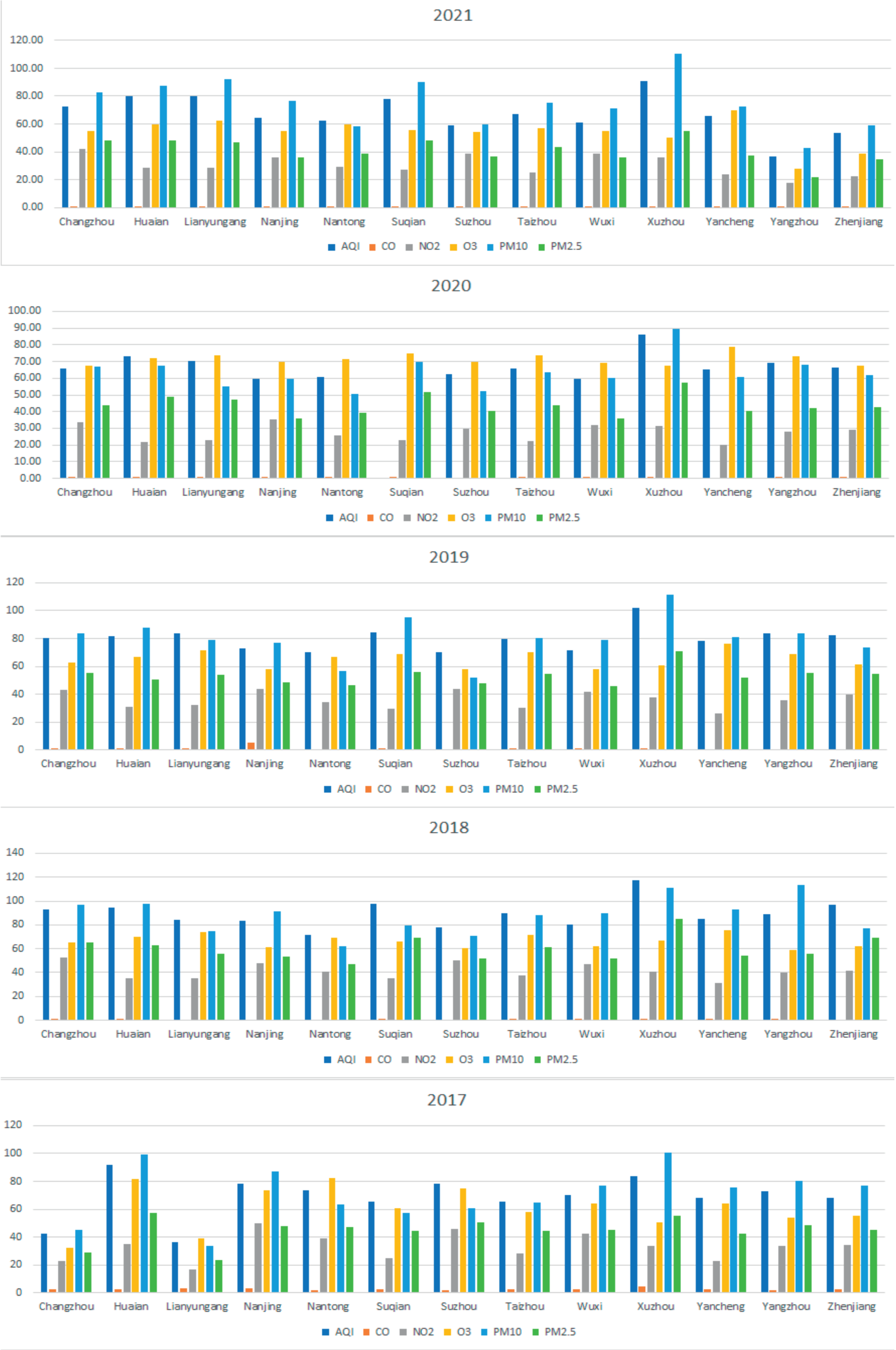

Fig. 3. Yearly change of air quality pattern in different cities of Nanjing.

Lianyungang = 62.66 µg/m^3, Nanjing = 54.98 µg/m^3, Nantong = 59.42 µg/m^3, Suqian = 55.75 µg/m^3, Suzhou = 54.21 µg/m^3, Taizhou = 56.93 µg/m^3, Wuxi = 54.74 µg/m^3, Xuzhou = 50.33 µg/m^3, Yancheng = 69.93 µg/m^3, Yangzhou = 27.57 µg/m^3 and Zhenjiang = 38.91 µg/m^3. Simliarly, in 2020 average ozone is different cities is: Changzhou = 67.27 µg/m^3, Huaian = 72.17 µg/m^3, Lianyungang = 73.47 µg/m^3, Nanjing = 69.71 µg/m^3, Nantong = 71.72 µg/m^3, Suqian = 74.74 µg/m^3, Suzhou = 69.6 µg/m^3, Taizhou = 73.48 µg/m^3, Wuxi = 68.96 µg/m^3, Xuzhou = 67.39 µg/m^3, Yancheng = 79.02 µg/m^3, Yangzhou = 73.16 µg/m^3 and Zhenjiang = 67.69 µg/m^3. The change in 2020 is higher than as record in 2019 in different cities. Ozone in 2019 is: Changzhou = 62.85 µg/m^3, Huaian = 66.92 µg/m^3, Lianyungang = 71.71 µg/m^3, Nanjing = 57.67 µg/m^3, Nantong = 67.11 µg/m^3, Suqian = 68.87 µg/m^3, Suzhou = 58.18 µg/m^3, Taizhou = 70.08 µg/m^3, Wuxi = 58.31 µg/m^3, Xuzhou = 60.51 µg/m^3, Yancheng = 76 µg/m^3, Yangzhou = 68.51 µg/m^3 and Zhenjiang = 61.69 µg/m^3.

What is puzzling is that, during the pandemic, when society reduced emissions of nitrogen oxides (NOx), which can generate ozone, why did ozone concentrations rise instead? In fact, the principle of this has long been explained in the academic world: different from air pollutants such as NOx and PM$_{2.5}$ directly emitted by human activities, surface ozone is a secondary pollutant generated by a variety of air pollutants through complex chemical reactions. Therefore, the impact of environmental change on ozone pollution will be more difficult to predict [31]. The product of this complex chemical reaction is not only ozone, but also NO. In turn, NO reacts quickly with ozone and decomposes it. So since ozone will be quickly consumed after it is generated, how does ozone in the air accumulate? This is mainly because of volatile organic compounds (VOCs), which can react with NO and prevent it from decomposing ozone, while promoting the generation of ozone (Fig. 4).

Change of NO$_2$

As one of the basic pollution items in ambient air pollution, nitrogen dioxide (NO$_2$) has been continuously monitored, restricted and treated. As for the source of nitrogen dioxide (NO$_2$), let's first understand its transformation process. First of all, usually 78% of clean air is nitrogen (N$_2$), which is very stable, and 21% is oxygen, which is very active. Under certain conditions, such as high energy, high temperature, heating, etc., nitrogen and oxygen will react to form nitric oxide and nitrogen oxides. Among them, nitric oxide can easily react with oxygen in the air to form nitrogen dioxide. Secondly, the gaseous forms of nitrogen oxides include: nitric oxide, nitrogen dioxide, nitrous oxide, etc. When nitrogen oxides encounter light, humidity, heat and other conditions, they will be converted into nitric oxide and nitrogen dioxide. The nitric oxide is then converted into nitrogen dioxide. So, in addition to nitrogen dioxide itself, nitric oxide and nitrogen oxides are also converted into nitrogen dioxide. Well, the sources of these three are related to the following: natural phenomenon: are lightning and microbial life activities, industry related: fossil fuel combustion, coal, oil combustion, industrial production, thermal power station, metal casting, coal-fired boiler,

Aerospace related: spacecraft, supersonic aircraft, car related: automobile exhaust, high temperature engine, indoor related: gas usage, cooking, smoking, military related: nuclear testing. The above all involve the emission of nitrogen oxides, nitric oxide, and nitrogen dioxide to varying degrees, and then react on the environmental air pollution parameter of nitrogen dioxide through chemical changes. However, for the current sources of nitrogen dioxide pollutants in my country, it is mainly caused by the combustion of fossil fuels and vehicle exhaust. During COVID-19, the change of nitrogen decreased during 2020 time period while increased in 2021. In 2021 the NO$_2$ is as follows: Changzhou = 41.8 µg/m^3, Huaian = 28.6 µg/m^3, Lianyungang = 28.82 µg/m^3, Nanjing = 36.28 µg/m^3,

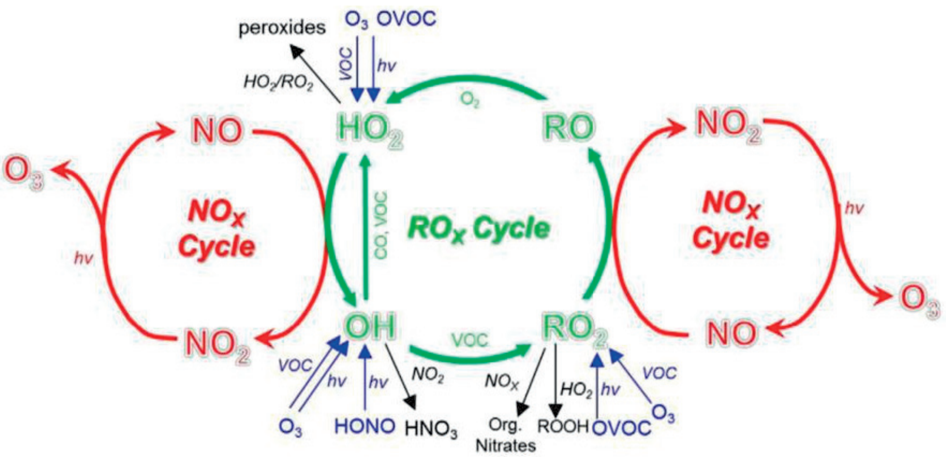

Fig. 4. Mechanism of Ozone generation [32].

Nantong = 29.18 µg/m^3, Suqian = 26.91 µg/m^3, Suzhou = 38.42 µg/m^3, Taizhou = 25.28 µg/m^3, Wuxi = 38.41 µg/m^3, Xuzhou = 36.04 µg/m^3, Yancheng = 23.85 µg/m^3, Yangzhou = 17.51 µg/m^3 and Zhenjiang = 22.1 µg/m^3. During 2020 the NO_2 is: Changzhou = 33.63 µg/m3, Huaian = 21.57 µg/ m^3, Lianyungang = 22.63 µg/m^3, Nanjing = 35.1 µg/m^3, Nantong = 25.99 µg/m^3, Suqian = 22.66 µg/m^3, Suzhou = 29.92 µg/m^3, Taizhou = 22.35 µg/m^3, Wuxi = 32.21 µg/m^3, Xuzhou = 31.62 µg/m^3, Yancheng = 19.97 µg/m^3, Yangzhou = 28.17 µg/m^3 and Zhenjiang = 29.31 µg/m^3.

Change of $PM_{2.5}$

Particulate matter ($PM_{2.5}$ and PM_{10}) is an important pollutant. The amount of environmental particulate matter originating from industrial soot and dust is decreasing year by year, while the proportion of fugitive dust in the total amount of environmental particulate matter is increasing day by day, which has now become one of the important factors causing urban particulate matter pollution. The effects of atmospheric particulate matter on the respiratory system depend on the concentration, composition and size of the particulate matter. Among them, particle size is one of the most important properties of particulate matter, which can determine the final deposition site and deposition amount in the respiratory system. As shown in the figure, most of the particles with aerodynamic diameter greater than 10 µm are trapped in the nasal cavity and throat, while particles smaller than 2 µm can be deposited in the lungs, which are the most harmful to the human body, such as PM_1 and $PM_{2.5}$.

The deposition of particulate matter in the lungs is an important factor to reveal the correlation between particulate matter exposure and disease morbidity and mortality, and to evaluate its toxicity. The understanding of particulate matter deposition is beneficial to reduce health risks. Computational fluid dynamics (CFD) can effectively predict the transport and deposition characteristics of particulate matter in the human respiratory system which will provide important help in studying the toxicological mechanism of particulate matter, the process of dispersion, and the resulting health effects. At present, environmental epidemiological studies (time series studies, cohort studies, case-control studies, cross-sectional studies, and cohort studies) are often used to evaluate the acute and chronic health effects of particulate matter on the respiratory system.

PM_{10} in different cities is recorded as follows in 2021: Changzhou = 82.52 µg/m^3, Huaian = 87.46 µg/m^3, Lianyungang = 92.14 µg/m^3, Nanjing = 76.92 µg/m^3, Nantong = 58.32 µg/m^3, Suqian = 90.46 µg/m^3, Suzhou = 59.55 µg/m^3, Taizhou = 75.08 µg/m^3, Wuxi = 71.42 µg/m^3, Xuzhou = 110.77 µg/m^3, Yancheng = 72.69 µg/m^3, Yangzhou = 42.57 µg/m^3 and Zhenjiang = 58.8 µg/m^3. While in 2020 it is: Changzhou = 67.07 µg/m^3, Huaian = 67.63 µg/m^3, Lianyungang = 55.09 µg/m^3, Nanjing = 59.66 µg/m^3, Nantong = 50.48 µg/m^3, Suqian = 69.59 µg/m^3, Suzhou = 52.17 µg/m^3, Taizhou = 63.56 µg/m^3, Wuxi = 60 µg/m^3, Xuzhou = 89.39 µg/m^3, Yancheng = 60.49 µg/m^3, Yangzhou = 68.23 µg/m^3 and Zhenjiang = 62 µg/m^3.

$PM_{2.5}$ in different cities is as follows in 2021: Changzhou = 47.92 µg/m^3, Huaian = 48.38 µg/m^3, Lianyungang = 46.7 µg/m^3, Nanjing = 35.95 µg/m^3, Nantong = 38.96 µg/m^3, Suqian = 48.11 µg/m^3, Suzhou = 36.38 µg/m^3, Taizhou = 43.32 µg/m^3, Wuxi = 35.93 µg/m^3, Xuzhou = 55.26 µg/m^3, Yancheng = 37.02 µg/m^3, Yangzhou = 21.73 µg/m^3, Zhenjiang = 34.9 µg/m^3. Simliarly during 2020 the change in pattern is: Changzhou = 43.78 µg/m^3, Huaian = 48.6 µg/m^3, Lianyungang = 47.09 µg/m^3, Nanjing = 35.74 µg/m^3, Nantong = 39.35 µg/m^3, Suqian = 51.98 µg/m3, Suzhou = 40.23 µg/m^3, Taizhou = 43.57 µg/m^3, Wuxi = 36.03 µg/m^3, Xuzhou = 57.45 µg/m^3, Yancheng = 40.33 µg/m^3, Yangzhou = 42 µg/m^3 and Zhenjiang = 42.91 µg/m^3.

According to the findings, the air quality in Jiangsu improved dramatically throughout the epidemic prevention and control period compared to the preceding three years. This is clearly in line with the pandemic prevention and control measures implemented in Jaingsu, namely traffic restrictions, closed community management, and enterprise production and operation control [33-35]. These severely limited people's production and living activities, which is closely tied to the reduction in pollution. The progressive application of the aforementioned strategies has reduced urban pollution sources and pollutant emissions that affect ambient air quality. However, due to restricted management and a rather dense population, the demand for heating expanded tremendously [36-38]. As a result, the concentration of particulate matter in Jiangsu increased slightly after traffic restrictions were implemented. Due to the needs of social life, the order and scope of the above measures' implementation have gradually slowed in Hubei, and production and living activities have gradually resumed. The difference in daily average AQI has gradually decreased when compared to the same period in previous years. This study also clarifies how to manage the quality of the air we breathe [38]. The findings show that a temporary social blockade cannot reduce pollution from all sources. The number of pollution days of O_3 and $PM_{2.5}$ increased during certain periods due to an increase in fireworks emissions and coal combustion. As a result, the future environmental protections in Jiangsu Province should continue to focus on reducing emissions through technological innovations in industry, transportation, and living activities. The elimination of pollution sources may not be an effective strategy for energy conservation and emission reduction [39].

Suggestions and Policy recommendation for stack holders for reducing air pollution:

To effectively improve the atmospheric environment in the central urban areas, it is necessary to continue the battle against air pollution. We believe that there are different aspects of air pollution prevention and control that need to be emphasized:

1. Strict environmental access. One is not to build new enterprises with excessive emissions of air pollutants, and the other is to develop green industries and limit the production and expansion of high-energy-consuming industries.

2. Speed up the adjustment of industrial structure. The first is to prevent and control industrial emissions that exceed the standard, and pay close attention to the operation of desulfurization and denitrification equipment. The second is to strictly control the emission of odors, strengthen the construction of deodorization projects, and carry out real-time publicity for areas that have strong social reactions.

3. Strengthen the control of motor vehicle pollution. The first is to increase the elimination of yellow-label vehicles and old vehicles. The second is to further accelerate the implementation of new energy vehicles. The third is to further strengthen the supervision and management of vehicle exhaust emissions. The fourth is to explore and advocate low-carbon and green travel systems and mechanisms to effectively reduce pollution emissions.

4. The prevention and control of fugitive dust is often unremitting. One is to strengthen the supervision of construction dust. The second is to strengthen the supervision of road construction dust.

5. Increase publicity and education. Widely carry out publicity and education on air pollution prevention and control, popularize scientific knowledge on air pollution prevention and control, give full play to the participation of the whole people and the supervision role of the news media, and improve the mechanism for citizen participation and supervision.

6. Increase punishment. Regularly publish the list of enterprises that exceed the standard emissions, form a strong legal environment that cannot pollute, dare not pollute, and cannot afford to pollute, and create a good atmosphere in which the whole society attaches great importance to air pollution environmental protection and participates in environmental construction.

Conclusion

It is clear that COVID-19 has had a significant impact on air quality patterns: It included 13 cities with varying COVID-19 numbers and air pollution levels, which allowed us to observe the possible association between air pollution and COVID-19 and the change in pattern is shown in Fig. 7; Second, this is one of the few initiatives in China that focuses on the impact of air pollution on COVID-19's three stages: prevention, mitigation, and adaptation (pre-COVID, active COVID and post-COVID). A variety of exposure methods, including average pollutant concentrations and other environmental factors, were used to capture both average levels of air pollution and abnormal changes in pollution levels. Third, we used a variety of methods to reflect exposure. However, if the post-COVID data from all stations is examined, the findings could be improved and a more complete picture of the shifts in air quality patterns could be provided. In the future, if socio-economic indicators are linked to data on air pollutants, this could help us better understand how COVID-19 is affecting the country's economic growth and development.

Acknowledgments

The authors are grateful for the financial support provided by the Jiangsu Planned Projects for Postdoctoral Research Funds Project under Grant 2020Z113 and Hainan University Research Fund (Project No.: KYQD (ZR)-22065).

Conflict of Interest

The authors declare no conflict of interest.

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