Air quality changes and Grey relational analysis of pollutants exceeding standards during the COVID-19 pandemic in Wuhan

Junhong Ji
Liaoning Technical University
Runqi Chang (amandarq@qq.com)
Liaoning Technical University https://orcid.org/0000-0002-6802-942X

Research Article

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Abstract

The COVID-19 has spread widely around the world, and the air quality during that period has changed significantly. On the contrary, air quality also can affect the development of the pandemic. Therefore, it is pretty necessary to study air quality changes during the pandemic. This paper achieves this goal by applying the Over-standard multiples method and Grey relational analysis to study the individual and overall change trends of pollutants in Wuhan during the same period in the past seven years. The result shows that the concentrations of SO2 and O3 increased affected by the pandemic but still meet the standard. However, the pandemic promoted a decrease in PM2.5, PM10, and NO2 concentrations, but it had just reached the standard or even exceeded the standard. This article discussed the feasibility of using Grey relational analysis to analyze pollutants exceeding the standard from an overall perspective and provided new ideas for future research.

Introduction

In December 2019, unknown pneumonia patients appeared in Wuhan. The study found that it was caused by a new coronavirus. World Health Organization (WHO) named the new coronavirus-infected pneumonia as COVID-19. Nowadays, it has spread globally and presents a pandemic trend. (https://www.who.int/). Along with the COVID-19 pandemic, there are increasing medical wastes and medical wastewater. Due to their characteristics of space pollution and latent infection, inappropriate treatment can make them spread viruses and even cause environmental pollution. Besides, to control the pandemic, many countries carried out isolation blockade which reduces people’s social activities and prompted companies to stop production. These can directly reduce air pollutants. On the other hand, there are also some studies showing that air pollutants can affect virus transmission even some health issues (Brandt et al. 2020; Ciencewicki and Jaspers 2007). Hence, it is pretty essential to study air quality changes during the COVID-19 pandemic.

Contemporarily, many scholars have carried out relevant researches in the world. (Dantas et al. 2020; Lal et al. 2020; Li et al. 2020; Nakada and Urban 2020) found that the lockdown reduces the emissions of SO_2, NO_x, $PM_{2.5}$, CO, VOCs, and AQI, even low-to-moderate reduce Aerosol Optical Depth obviously in the corresponding research region. But at the same time, some of them found that ozone increased distinctly. Similarly, (Kerimray et al. 2020) indicated the concentrations of NO_2, $PM_{2.5}$, and CO reduced obviously. But the concentrations of O_3, benzene, and toluene were higher than those before lockdown in Almaty.

Analyzing the findings, scholars have applied a variety of research methods, such as utilizing the cokriging method in ArcGIS, applying the WRF-CAMx modeling system, analyzing pollutants concentrations changes directly, and so on. However, few scholars have applied the Grey relational analysis (GRA) to analyze the changes in air quality during the pandemic. Taking Wuhan as an example, this paper first analyzed the changes in the six monitoring pollutants respectively by introducing an Over-standard multiples method and found that the main pollutants are $PM_{2.5}$ and PM_{10} (PM). Then, this paper utilized GRA to analyze the changes of PM, and analyzed the feasibility of this method. This paper not

only analyzes the impact of the pandemic on air quality but also provides new ideas for analyzing the overall changes in the pollutants exceeding the standard.

Statistics Date And Data

Statistics date

The period analyzed in this article is the first two months of the pandemic. However, starting at 10 am on January 23, Wuhan began to implement isolation blockade and it was during the Spring Festival (SF). Under normal circumstances, People's trip frequency and the possibility of setting off firecrackers will increase. Companies will stop production. These staged behaviors during SF will affect air quality to some extent. Aiming to avoid the impact on the analysis, this article took the Chinese New Year's Eve (NYE) as a breakpoint, and regarded the two months corresponding to the 15 days before and after the NYE's calendar date as the same period.

Data sources

This paper collected data from the Department of Ecology Environment of Hubei Province (http://sthjt.hubei.gov.cn/), Wuhan Ecology and Environment Bureau (http://hbj.wuhan.gov.cn/) and "Atmosphere 110" platform (http://daqi110.com/index.html).

Statistical data and reference standard

This article discussed the average monthly concentration of $PM_{2.5}$, PM_{10}, SO_2 and NO_2, the 95th percentile of the daily average of CO (CO), and the 90th percentile of the maximum daily average concentration of O_3 for 8 hours (O_3). The actual data is shown in Table 1.

This article took the Chinese GB3095-2012 Environmental Air Quality Standards as a reference standard(Environmental Air Quality StandardsGB3095-20122012).

Table 1 Pollutant concentrations and corresponding reference standards for concentration limits in Wuhan during the same period in 2014-2020

Statistics Date	$PM_{2.5}$ ($\mu g{\cdot}m^{-3}$)	PM_{10} ($\mu g{\cdot}m^{-3}$)	$S0_2$ ($\mu g{\cdot}m^{-3}$)	NO_2 ($\mu g{\cdot}m^{-3}$)	CO ($mg{\cdot}m^{-3}$)	O_3 ($\mu g{\cdot}m^{-3}$)
2014.1	185	192	57	82	2.3	95
2014.2	91	84	21	45	2.1	64
2015.2	110	119	24	59	2	98
2015.3	100	100	21	53	1.5	101
2016.1	107	122	21	49	2	76
2016.2	94	121	20	43	1.8	112
2017.1	90	113	14	54	1.8	73
2017.2	73	96	14	57	1.6	100
2018.2	68	94	12	54	1.5	96
2018.3	50	83	9	57	1.4	128
2019.1	94	104	9	56	1.8	70
2019.2	64	72	7	35	1.4	67
2020.1	60	70	7	37	1.4	80
2020.2	38	46	8	21	1.2	102
Reference standards for concentration limits	35	70	60	40	4	160

Methodology

Method of over-standard multiples

To analyze the specific situation of each pollutants, this article introduced the method of over-standard multiples and utilized the over-standard multiples (OSM) to describe the degree of air pollution. The calculation formula is as follows: (see Equation 1 in the Supplementary Files)

Grey relational analysis

Grey relational analysis is part of the grey system theory (Morán et al. 2006) and can be used to explore the degree of correlation between systems. When analyzing, the known data are usually constructed into several sequences according to the evaluation purpose. Secondly, select a sequence that can be regarded as a reference, with others to be evaluated are called comparison sequences. (See Equations and Calculations in the Supplementary Files)

In this article, regarding the concentration limits as a reference sequence and the pollutant concentrations on the statistics date as comparative sequences, the GRD of them directly reflects the air quality. The greater the GRD, the better the air quality.

Results

Changes in the concentration of each pollutant

As shown in Figure 1, the GRD of most of the pollutants have decreased compared with 2014, that is, the concentration of pollutants has dropped. However, in the second month, the concentration of O_3 has increased. Furthermore, the concentrations of O_3 in these two months, and the concentrations of $SO_{2,}$ O_3 in the second month is higher than last year. Besides, the GRD of $SO_{2,}$ O_3, and CO is negative which means the concentrations of these pollutants are in line with the standard. The concentrations of NO_2

have also reached the standard in the past two years. However, the OSM of $PM_{2.5}$ and PM_{10} has always been pretty large which means $PM_{2.5}$ and PM_{10} are the main pollutants exceeding the standard.

Changes in pollutants exceeding the standard

To analyze the changes of main pollutants PM exceeding the standard from an overall perspective, this paper introduced GRA. The result is as follows: (See Figure 2)

As shown in Figure 2, according to the change trends of GRD, it is found that the concentration of PM has improved significantly compared with 2014. Comparing with last year, the situation is the same.

Discussion And Conclusions

In terms of methods, the OSM can not only show the trends of pollutant concentration changes but also intuitively show the degree of pollutants exceeding the standard. Comparing the two analysis results in section 4, it is found that when GRA is used to analyze the over-standard of pollutants from an overall perspective, the analysis result is good for a single whole. But when the comparative analysis between groups is performed, the result is not ideal. According to formulas 2 and 3, although the correlation degree of pollutants depends on the actual concentration of it, it is also affected by the minimum and maximum concentrations in the same group. Therefore, it is not feasible to compare the concentration according to the correlation between different groups.

From the perspective of pollutant concentrations, during the COVID-19 pandemic, the concentrations of O_3 and SO_2 mainly showed an upward trend, especially in the second month, that is, after the lockdown. However, it still did not exceed the concentration limits. The concentrations of NO_2 had dropped, but it had only been reached the standard in the past two years. The increase in O_3 concentration could be due to the decrease in PM and NOx (Sharma et al. 2020). Although some enterprises stopped production in the second month, considering the increase in SO_2 concentration mainly related to industrial emissions in China(Wang. and Huang. 2015), it may be that the sharp increase in shipments of medical products and medical wastes led to an increase in SO_2 concentration.

According to the result of GRA, the situation of pollutants exceeding the standard had improved. However, it should be noted that although the concentrations of $PM_{2.5}$ and PM_{10} had decreased, it is still close to or even exceeded the limits. Furthermore, during the lockdown, their concentrations were lower than before, the first month. The main reasons for the decrease in $PM_{2.5}$, PM_{10}, and NO_2 concentrations are the shutdown of the enterprise and the reduction of vehicle exhaust emissions (Liu. 2017; Zheng. et al. 2014) that are mainly caused by quarantine blockade during the pandemic.

Furthermore, some scholars have pointed out that when the society fully resumes and the economy recovers, the improvement in air quality will not last forever, or even worse than before the pandemic

(Quirin 2020; Wang and Su 2020). Hence, scholars should learn from the experiences during the pandemic and formulate environmental protection measures suitable for normal implementation.

Declarations

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Conflicts of interest

The authors declare no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

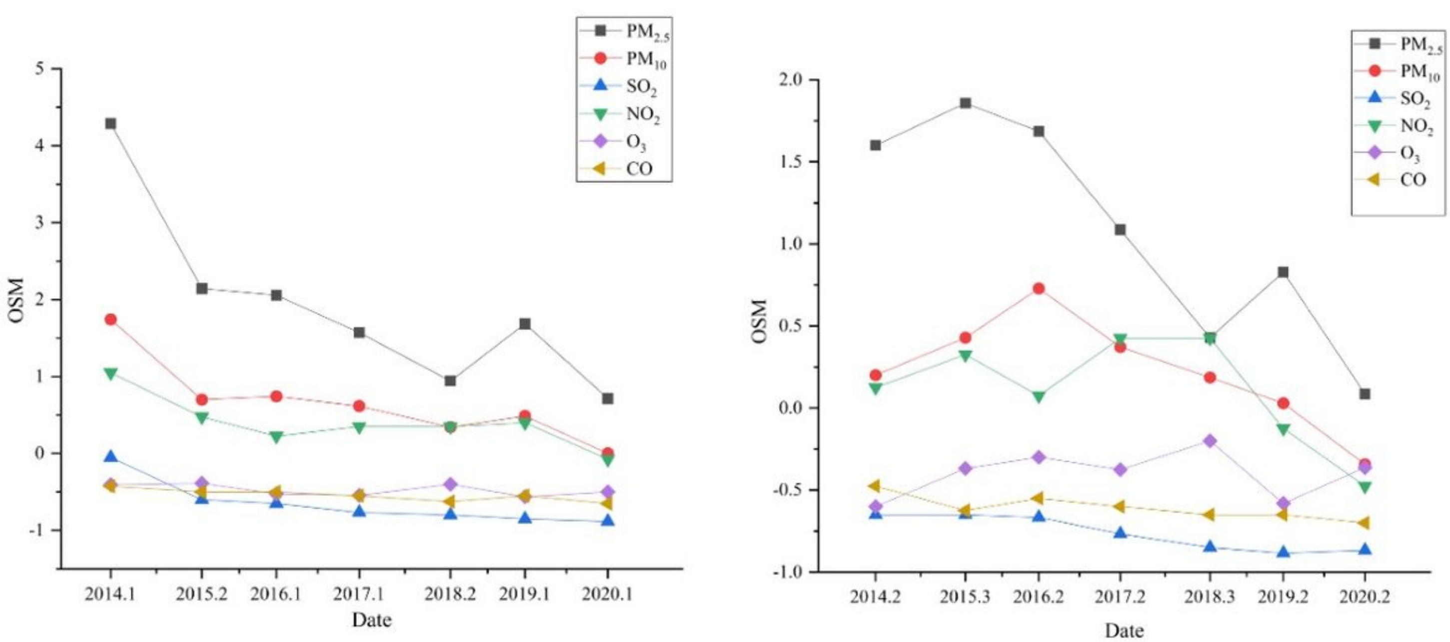

Figure 1

a Changes of six pollutants' over-standard multiples in Wuhan during the same period in 2014-2020. b Changes of six pollutants' over-standard multiples in Wuhan during the same period in 2014-2020

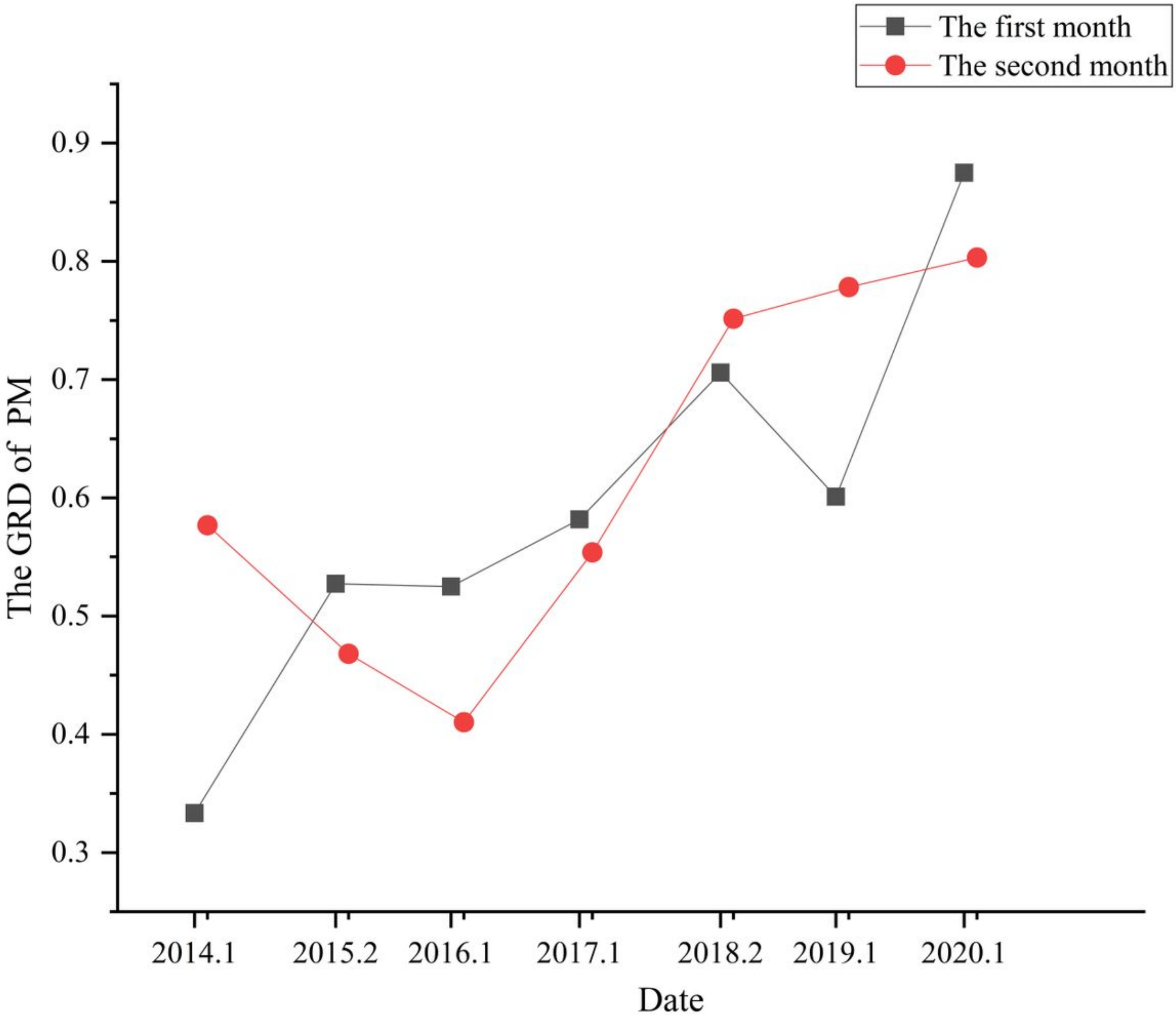

Figure 2

Fig. 2 Changes in the grey relational degree of PM in Wuhan during the same period in 2014-2020

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.xlsx

- EquationsandCalculations.pdf