Correlation between COVID-19 Infection Rate and Atmospheric Environmental Factors in Seoul Metropolitan City, South Korea

Won Choi

Seoul National University of Science and Technology

Ki-Youn Kim (✉ kky5@seoultech.ac.kr)

Seoul National University of Science and Technology

Research Article

Keywords: Covid-19, PM10, PM2.5, Infection rate, Pandemic

Posted Date: March 22nd, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1383594/v2>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

The purpose of this study is to statistically analyze whether the change in the COVID-19 virus infection rate is affected by atmospheric environmental factors in Seoul metropolitan city of South Korea. The research period of this study is from January 1, 2020 to March 31, 2021. The correlation relationship between the COVID-19 virus infection rate and atmospheric environmental factors such as PM_{10} , $PM_{2.5}$, temperature, and humidity was analyzed by multiple regression analysis. In the correlation between PM_{10} and $PM_{2.5}$ and the COVID-19 virus infection rate, correlation coefficient between PM_{10} and infection rate was $r = 0.114$ ($p = 0.019$), showing a positive correlation. The correlation coefficient between $PM_{2.5}$ and infection rate was $r = 0.147$ ($p = 0.002$), which indicates a higher positive correlation than PM_{10} . In the correlation between thermal factors and infection rate, the correlation coefficients between temperature and infection rate and between relative humidity and infection rate were $r = -0.527$ ($p = 0.000$) and $r = -0.91$ ($p = 0.060$), respectively. Unlike PM_{10} and $PM_{2.5}$, temperature and relative humidity showed a negative correlation with the infection rate. Except for relative humidity, PM_{10} , $PM_{2.5}$ and temperature had statistically significant correlations with the infection rate ($p < 0.05$). Based on the results obtained from this study, it is recommended to avoid outdoor activities as much as possible in weather with high PM_{10} and $PM_{2.5}$ and low temperature and humidity.

1. Introduction

Currently, the world is in a pandemic situation due to the COVID-19 virus pandemic. The COVID-19 virus has suspended worldwide activities in months and has been the leading cause of death for thousands of people in cities around the world (Rodriguez et al., 2020). The COVID-19 virus has been reported as one of the deadliest viruses in the past 100 years (Lu et al., 2020).

The event of COVID-19 first occurred in Wuhan, Hubei Province, China in December 2019 (Fanelli et al., 2020). Since then, it has spread beyond China to the world. COVID-19 is a new type of coronavirus and is a respiratory infection disease (Li et al., 2020). At the beginning of the outbreak, the cause of the epidemic pneumonia was unknown, but the pathogen was identified when the World Health Organization (WHO) announced on January 9, 2020 that it was the coronavirus (Yuki et al., 2020). The COVID-19 virus spreads through droplets between infected people and penetrates and is transmitted through the mucous membranes of the eyes, nose, mouth, and respiratory tract (Chaudhuri et al., 2020; Oldfield et al., 2020). As of July 2021, the cumulative number of infected people worldwide exceeded 180 million and the death toll exceeded 3.9 million.

South Korea has received global attention as an advanced quarantine case for actively responding to the COVID-19 virus (Team et al., 2020). Seoul is the capital of South Korea and is a metropolitan city with a population of about 10 million. The Seoul carried out the quarantine system with the highest intensity and the longest period. Therefore, we tried to reduce the transmission caused by human-to-human contact as much as possible. However, despite the high-intensity quarantine, the number of infected

people is increasing the most in Seoul. As of June 29, 2021, South Korea maintains 150,000 confirmed patients, 2,000 deaths, and 600 daily confirmed patients. Considering that the total population of Korea is 51 million, this figure has an infection rate of 0.3%. And the mortality rate is 1.3% compared to the number of infected people.

Viruses are generally known to have both biological and inanimate properties (Doerbecker et al., 2011). Viruses cannot proliferate on their own without hosts and simply exist in an inanimate state of protein and nucleic acid masses (Buttner et al., 1997). Particulate matter in the air can be a carrier of viruses as well as bacteria (Carugno et al., 2018; Groulx et al., 2018; Su et al., 2019; Tao et al., 2020; Otmani et al., 2020). It is reported that PM_{10} and $PM_{2.5}$ among air pollution plays a role in facilitating the spread of the virus (Mishra et al., 2020; Adhikari et al., 2020; Hashim et al., 2021). In a study conducted in California in the United States, studies have been conducted that air pollutants are correlated with COVID-19 (Bashir et al., 2020).

The Seoul of South Korea, is a metropolitan city with a population of 10 million and serious air pollution worldwide (Kumbhakar et al., 2021). Air pollution in Seoul is known to have a serious proportion and risk of PM_{10} and $PM_{2.5}$ among various air pollutants (Choe et al., 2018). Therefore, it is estimated that PM_{10} and $PM_{2.5}$ in Seoul will also affect the spread of the COVID-19 virus, and that the high concentration of PM_{10} and $PM_{2.5}$ will be very advantageous for the spread of the COVID-19 virus. However, no studies have been conducted so far on the correlation between PM_{10} and $PM_{2.5}$ concentration in Seoul and the infection rate of COVID-19. Therefore, the purpose of this study is to examine the daily changes in Seoul's COVID-19 infection rate and atmospheric environmental factors through statistical correlation analysis, and use it as basic data for setting up COVID-19 prevention methods according to air quality conditions in the future.

2. Method

2.1. Subject

The Seoul metropolitan city, where about 10 million people live in the study target area, was selected as the study area. The average annual population of Seoul was about 9,668,000 in 2020 and 9,589,000 in 2021, which was substituted for the calculation of the COVID-19 infection rate. Data on the number of confirmed cases of COVID-19 virus infection in Seoul were obtained through the state-run Public Data Portal (<http://www.data.go.kr>). The number of confirmed cases on the same day was the number of reported cases from 0:00 to 24:00. For the concentration data of PM_{10} and $PM_{2.5}$, the daily average data provided by "Air Korea (www.airkorea.or.kr)" operated by the Ministry of Environment was used. The daily average data of fine dust concentration used as an mean concentration in Seoul is the average value calculated from 0:00 to 24:00 monitored at the Jung-gu Metropolitan Office, which is designated as an urban atmospheric measurement network by the National Institute of Environmental Research. Daily average data of Seoul provided by the Meteorological Administration were utilized for temperature and

relative humidity data. The application period of this study data is from January 1, 2020 to March 31, 2021.

2.2. Data analysis

The daily COVID-19 virus infection rate was calculated by dividing the number of confirmed daily COVID-19 virus infections by the number of people in Seoul. Daily data of average PM_{10} and $PM_{2.5}$ concentration and COVID-19 virus infection rate were reviewed by delaying the infection date by 2 days in consideration of the COVID-19 virus incubation period and test time.

The data obtained from this study were statistically analyzed with the SPSS program (IBM, version 25). Pearson correlation analysis was performed to determine the relative influence between COVID-19 infection rate, PM_{10} , $PM_{2.5}$, temperature, and relative humidity, and the correlation between COVID-19 infection rate and respective variables was visualized through a simple scatter plot graph. In addition, multiple regression analysis was conducted to understand the causal relationship between variables. The tolerance (TOL) and variance inflation Factor (VIF) values which represent multicollinearity were indicated to show that there is no multicollinearity. The statistical significance test was set at the significance level of 0.05. The model equation of multiple regression analysis applied to this study is shown in < Figure 1 >.

3. Results

3.1. Correlation relationship analysis between COVID-19 virus infection rate and atmospheric environmental factors

As shown in the Table 1, in the correlation between PM_{10} and $PM_{2.5}$ and COVID-19 infection rate, the correlation coefficient between PM_{10} and infection rate was $r = 0.114$ ($p = 0.019$), showing a positive correlation. The correlation coefficient between $PM_{2.5}$ and infection rate was $r = 0.147$ ($p = 0.002$), which showed a higher positive correlation than PM_{10} . In the correlation between temperature and relative humidity and infection rate, temperature and infection rate showed a high negative correlation with $r = -0.527$ ($p = 0.000$), and the infection rate with relative humidity was $r = -0.91$ ($p = 0.060$), which was lower than temperature. As a result of statistical analysis, it was found that the correlation of the COVID-19 virus infection rate with all other factors except relative humidity was statistically significant ($p < 0.05$).

Table 1
Correlation analysis of COVID-19 infection rate, PM₁₀ and PM_{2.5}, temperature, and relative humidity in Seoul.

	Infection rate	PM ₁₀	PM _{2.5}	Temperature	Relative humidity
Infection rate	1				
PM ₁₀	0.114* (0.019)	1			
PM _{2.5}	0.147** (0.002)	0.780** (0.000)	1		
Temperature	-0.527** (0.000)	-.186** (0.000)	-.179** (0.000)	1	
Relative humidity	-0.091 (0.060)	-.206** (0.000)	-.052 (0.285)	.500** (0.000)	1
*p < 0.05, **p < 0.01					

3.2. Simple scatter plot between COVID-19 virus infection rate and atmospheric environmental factors

As indicated in the Fig. 2, atmospheric environmental factors such as PM₁₀ and PM_{2.5}, temperature and relative humidity, which are expected to affect the change in the COVID-19 infection rate, was presented on the X-axis as independent variables and the COVID-19 infection rate affected by them was presented on the Y-axis as a dependent variable. Based on the graph showing upwards to the right, it was confirmed that the COVID-19 infection rate increased as the concentrations of PM₁₀ and PM_{2.5} increased. On the other hand, in the temperature and relative humidity, a graph descending to the right appeared, confirming that the COVID-19 infection rate decreased as the temperature and relative humidity increased. This finding was contrary to the results of multiple regression analysis. As a result of the distribution of scatter plot, when the concentration of PM₁₀ and PM_{2.5} increases the COVID-19 infection rate also increases at the same time, while when the temperature and relative humidity increase the COVID-19 infection rate tends to decrease.

3.3. Multiple regression analysis between COVID-19 infection rate and atmospheric environmental factors

As shown in the Table 2, it was analyzed that when the concentrations of PM₁₀ and PM_{2.5} increased by 1 / , the COVID-19 infection rate increased by 8.83×10^{-7} and 2.32×10^{-6} , respectively. When the relative humidity rises by 1%, the COVID-19 infection rate increases by 1.53×10^{-5} . On the other hand, in the case

of temperature, it was analyzed that the COVID-19 infection rate decreased by 6.47×10^{-5} when the temperature increased by 1°C .

Table 2. Multiple regression analysis of COVID-19 infection rate, PM_{10} and $\text{PM}_{2.5}$, temperature, and relative humidity in Seoul.

Variable	Non-standardized coefficient		Standardized coefficient	t(p)	TOL	VIF
	B	SE	β			
(Constant)	0.001	0.000		2.492* (0.013)		
PM_{10}	8.825E-7	0.000	0.020	0.303 (0.762)	0.362	2.760
$\text{PM}_{2.5}$	2.316E-6	0.000	0.030	0.453 (0.650)	0.369	2.709
Temperature	-6.466E-5	0.000	-0.633	-13.370** (0.000)	0.723	1.383
Relative humidity	1.530E-5	0.000	0.231	4.792** (0.000)	0.697	1.435
$F(p)$	49.186(0.000 ^b)					
adj.	0.319					

* $p < 0.05$; ** $p < 0.01$

t(p)

Therefore, assuming that the population of Seoul is 10 million, the increase in PM_{10} and $\text{PM}_{2.5}$ concentrations by 1 / and the increase in relative humidity by 1% mean that the number of COVID-19 confirmed patients in Seoul increases by about 8, 20, and 153, respectively. On the other hand, it can be seen that when the temperature rises by 1°C , the number of COVID-19 confirmed patients in Seoul decreases by about 600. In terms of the standardization coefficient, it was analyzed that PM_{10} , $\text{PM}_{2.5}$ and relative humidity had a positive effect of 0.02, 0.03 and 0.231, respectively, on the COVID-19 infection rate, while the temperature had a negative effect of -0.633 on it. However, the concentrations of PM_{10} and $\text{PM}_{2.5}$ were not a variable that had a significant effect on the infection rate ($p > 0.05$), whereas temperature and relative humidity were variables that had a significant effect ($p < 0.05$).

4. Discussion

Based on the results obtained from this study, the correlation analysis showed that PM_{10} , $PM_{2.5}$, and temperature were statistically significant with the COVID-19 infection rate. However, statistical significance of COVID-19 infection rate was found in temperature and humidity in the regression analysis. Considering the specificity of the epidemic data, there are special situations such as mass infection, in which the number of infected people suddenly increases (Kang, 2020). Therefore, it can be explained that the analysis results between correlation and regression showed different significance since the raw data were inconsistent and their concentration was low. In special circumstances, data need to be corrected. However, in this study, the original data were not corrected and used as it is in order to reflect real situation at the time in Seoul, South Korea.

The concentration of PM_{10} and $PM_{2.5}$ in Seoul is based on a nationally operated monitoring station. The PM_{10} and $PM_{2.5}$ concentration monitoring station and the location of COVID-19 infection in Seoul were not considered in this study. Thus, it is predicted that more accurate research results can be obtained if the PM_{10} and $PM_{2.5}$ monitoring station and the location of the infected person are matched and analyzed.

Mean concentrations of PM_{10} and $PM_{2.5}$ in Seoul used in this study are the official data of air concentration in Seoul. However, considering that the spread of the virus is mainly caused by droplet transmission indoors, it is difficult to grasp the cross-sectional relationship between the concentration of PM_{10} and $PM_{2.5}$ in the atmosphere and virus infection (Li et al., 2020).

In addition, in this study, environmental variables were analyzed for correlation with COVID-19 infection rate only with PM_{10} and $PM_{2.5}$ concentration, temperature, and humidity, but the factors affecting viral infection are more diverse. For example, the route of movement of infected people, the use of multi-use facilities, gender, age, and wearing a mask are variables to be considered (Plohl et al., 2021; Lim et al., 2021).

During the pandemic period caused by COVID-19, it was found that the concentration of PM_{10} and $PM_{2.5}$ in China decreased due to reduced air pollutants emissions from transportation and industries (Wang et al., 2020 ; Chen et al., 2020). South Korea, which is influenced geographically by the west wind, is highly related to the atmospheric situation in China (Park et al., 2018). Therefore, it is estimated that the decrease in industrial air pollutants emissions in China during the Pandemic period had a decrease in the concentration of PM_{10} and $PM_{2.5}$ in South Korea (Ma et al., 2020).

Fine dust itself is harmful to health. PM_{10} and $PM_{2.5}$ has even become a more harmful air pollutant as it acts as a carrier of the COVID-19 virus (Rohrer et al., 2020; Zoran et al., 2020). The previous study reporting the association between air pollutants and daily deaths by COVID-19 in Iran from March to August 2020 also confirmed that air pollution was significantly associated with an increase in the mortality rate of COVID-19 and observed that improved air pollution could reduce the risk of mortality

(Norouzi et al., 2021). Therefore, more beneficial results will be obtained if the research on the correlation between air pollution and virus infection rate is conducted in depth and more variables and social phenomena are considered than this study.

5. Conclusion

As a result of statistical analysis of accredited data in Seoul, South Korea for 15 months from January 2020 to March 2021, the COVID-19 infection rate showed a statistically significant positive correlation with the concentrations of PM_{10} and $PM_{2.5}$ ($p < 0.05$). On the other hand, the COVID-19 infection rate showed a negative correlation with temperature ($p < 0.05$) and relative humidity ($p > 0.05$). Therefore, based on the results of this study, it can be recommended that one way to prevent COVID-19 infection in Seoul is to avoid outside activities as much as possible when the concentration of PM_{10} and $PM_{2.5}$ is high and the temperature is low. Although it is not possible to directly present infection prevention measures, the finding that the COVID-19 infection rate has a significant correlation with PM_{10} and $PM_{2.5}$ and air temperature would be applied as basic data to suggest lifestyle patterns to the public during the pandemic.

Declarations

-Ethics approval and consent to participate (Human Ethics, Animal Ethics or Plant Ethics)

Not Applicable

-Consent for publication

All writers agreed to the posting.

-Availability of data and materials

The data and materials used in this document are available because they used public data.

-Competing interests

We don't have a competitive interest.

-Funding

Not Applicable

-Authors' contributions

Won Choi wrote most of the manuscript and Ki-Youn Kim reviewed it.

-Acknowledgements

All authors approve the submission of this manuscript.

References

1. Adhikari, Atin; Yin, Jingjing. Short-term effects of ambient ozone, PM_{2.5}, and meteorological factors on COVID-19 confirmed cases and deaths in Queens, New York. *International journal of environmental research and public health*, 2020, 17.11: 4047.
2. Bashir, Muhammad farhan, et al. Correlation between environmental pollution indicators and COVID-19 pandemic: a brief study in Californian context. *Environmental research*, 2020, 187: 109652.
3. Buttner, M., et al. Detection of virus or virus specific nucleic acid in foodstuff or bioproducts—hazards and risk assessment. *Viral Zoonoses and Food of Animal Origin*, 1997, 57-66.
4. Carugno, Michele, et al. PM₁₀ exposure is associated with increased hospitalizations for respiratory syncytial virus bronchiolitis among infants in Lombardy, Italy. *Environmental research*, 2018, 166: 452-457.
5. Chaudhuri, Swetaprovo, et al. Modeling the role of respiratory droplets in Covid-19 type pandemics. *Physics of Fluids*, 2020, 32.6: 063309.
6. Chen, Hui, et al. Impact of quarantine measures on chemical compositions of PM_{2.5} during the COVID-19 epidemic in Shanghai, China. *Science of the Total Environment*, 2020, 743: 140758.
7. Choe, Seung-Ah; Jun, Yoon-Bae; Kim, Sun-Young. Exposure to air pollution during preconceptional and prenatal periods and risk of hypertensive disorders of pregnancy: a retrospective cohort study in Seoul, Korea. *BMC pregnancy and childbirth*, 2018, 18.1: 1-10.
8. Doerrbecker, Juliane, et al. Inactivation and survival of hepatitis C virus on inanimate surfaces. *The Journal of infectious diseases*, 2011, 204.12: 1830-1838.
9. Fanelli, Duccio; Piazza, Francesco. Analysis and forecast of COVID-19 spreading in China, Italy and France. *Chaos, Solitons & Fractals*, 2020, 134: 109761.
10. Groulx, Nicolas, et al. The Pollution Particulate Concentrator (PoPCon): a platform to investigate the effects of particulate air pollutants on viral infectivity. *Science of the Total Environment*, 2018, 628: 1101-1107.
11. Hashim, Bassim Mohammed, et al. Impact of COVID-19 lockdown on NO₂, O₃, PM_{2.5} and PM₁₀ concentrations and assessing air quality changes in Baghdad, Iraq. *Science of the Total Environment*, 2021, 754: 141978.

12. Kang, yun-jung. Lessons learned from cases of COVID-19 infection in South Korea. *Disaster medicine and public health preparedness*, 2020, 14.6: 818-825.
13. Kumbhakar, Subal C., et al. Efficiency in reducing air pollutants and healthcare expenditure in the Seoul Metropolitan City of South Korea. *Environmental Science and Pollution Research*, 2021, 28.20: 25442-25459.
14. Li, Wei, et al. Chest computed tomography in children with COVID-19 respiratory infection. *Pediatric radiology*, 2020, 1.
15. Li, Yuqing, et al. Saliva is a non-negligible factor in the spread of COVID-19. *Molecular oral microbiology*, 2020, 35.4: 141-145.
16. Lim, Yong Kwan, et al. The impact of environmental variables on the spread of COVID-19 in the Republic of Korea. *Scientific reports*, 2021, 11.1: 1-5.
17. Lu, Hongzhou; STRATTON, Charles W.; TANG, Yi-Wei. Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle. *Journal of medical virology*, 2020, 92.4: 401.
18. Ma, Chang-Jin; Kang, Gong-Unn. Air quality variation in Wuhan, Daegu, and Tokyo during the explosive outbreak of COVID-19 and its health effects. *International Journal of Environmental Research and Public Health*, 2020, 17.11: 4119.
19. Mishra, Richa, et al. Particulate matter (PM₁₀) enhances RNA virus infection through modulation of innate immune responses. *Environmental Pollution*, 2020, 266: 115148.
20. Norouzi, Nima; Asadi, Zahra. Air pollution impact on the Covid-19 mortality in Iran considering the comorbidity (obesity, diabetes, and hypertension) correlations. *Environmental Research*, 2022, 204: 112020.
21. Oldfield, Eric; Malwal, Satish R. COVID-19 and other pandemics: How might they be prevented?. *ACS infectious diseases*, 2020, 6.7: 1563-1566.
22. Otmani, Anas, et al. Impact of Covid-19 lockdown on PM₁₀, SO₂ and NO₂ concentrations in Salé City (Morocco). *Science of the total environment*, 2020, 735: 139541.
23. Park, Yu-mi, et al. Characterizing isotopic compositions of TC-C, NO₃--N, and NH₄+N in PM_{2.5} in South Korea: Impact of China's winter heating. *Environmental pollution*, 2018, 233: 735-744.
24. Rodriguez-Urrego, Daniella; Rodriguez-Urrego, Leonardo. Air quality during the COVID-19: PM_{2.5} analysis in the 50 most polluted capital cities in the world. *Environmental Pollution*, 2020, 115042.
25. Rohrer, Mario; Flahault, Antoine; Stoffel, Markus. Peaks of fine particulate matter may modulate the spreading and virulence of COVID-19. *Earth Systems and Environment*, 2020, 4.4: 789-796.
26. Su, Wei, et al. The short-term effects of air pollutants on influenza-like illness in Jinan, China. *BMC public health*, 2019, 19.1: 1-12.
27. Tao, Ru-jia, et al. PM_{2.5} compromises antiviral immunity in influenza infection by inhibiting activation of NLRP3 inflammasome and expression of interferon-β. *Molecular Immunology*, 2020, 125: 178-186.

28. Team, Quarantine Management, et al. Coronavirus disease-19: quarantine framework for travelers entering Korea. *Osong public health and research perspectives*, 2020, 11.3: 133.
29. Wang, Pengfei, et al. Severe air pollution events not avoided by reduced anthropogenic activities during COVID-19 outbreak. *Resources, Conservation and Recycling*, 2020, 158: 104814.
30. Yuki, Koichi; Fujiogi, Miho; Koutsogiannaki, Sophia. COVID-19 pathophysiology: A review. *Clinical immunology*, 2020, 215: 108427.
31. Zoran, Maria A., et al. Assessing the relationship between surface levels of PM_{2.5} and PM₁₀ particulate matter impact on COVID-19 in Milan, Italy. *Science of the total environment*, 2020, 738: 139825.

Figures

$$Y = B_0 + B_1X_1 + B_2X_2 \cdots + B_iX_i + \epsilon$$

Figure 1

Equation of multiple regression model

Figure 2

The scatter plots of the correlation between COVID-19 infection rate and environmental factors (PM₁₀, PM_{2.5}, Temperature and Relative humidity)