INVESTIGATING THE IMPACTS OF AIR QUALITY AND WEATHER INDICATORS ON THE SPREAD OF SARS-COV-2 IN ISTANBUL, TURKEY

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Background/aim: *Air pollution is having a positive impact on the spread of the SARS-COV-2 virus. The effects of meteorological parameters on the spread of SARS-COV-2 are a matter of curiosity. The main purpose of this paper is to determine the association between air quality indexes ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO, and O_3) and weather parameters (temperature, humidity, pressure, dew, wind speed) with the number of SARS-COV-2 cases, hospitalizations, hospital discharges. In this paper, we also focused on determining the impact of air pollution and weather parameters on the number of daily hospitalizations and daily discharges.*

Materials and methods: *It is gleaned daily cases, hospitalizations, hospital discharges, meteorological, and air quality data in Istanbul from Turkey between July 15, 2020, and September 30, 2020. We performed the Pearson correlation analysis to evaluate the effects of meteorological parameters and air quality indexes on the variables related to SARS-COV-2.*

Results: *It is determined a statistically significant positive relationship between air quality indexes such as CO, SO_2, $PM_{2.5}$, PM_{10}, NO_2, and the number of daily confirmed SARS-COV-2 cases. We also observed a negative association between weather parameters such as temperature and pressure and the number of daily confirmed SARS-COV-2 cases.*

Conclusion: *Our study proposes that high air quality could reduce the number of SARS-COV-2 cases. The empirical findings of this paper might provide key input to prevent the spread of SARS-COV-2 across Turkey.*

Key words*: Air quality index, SARS-COV-2, weather parameters.*

1. Introduction

The new Coronavirus (SARS-COV-2) firstly appearing in Wuhan, China, in December 2019 and rapidly has crossed borders, infecting people throughout the whole world. As of October 6, 2020, it is globally reported that there have been 35,347,404 confirmed cases of SARS-COV-2 with 1,039,406 deaths by the World Health Organization [1]. SARS-COV-2 is officially announced as a global pandemic on March 11, 2020 [2]. SARS-COV-2 is essentially contaminated human-to-human via some factors such as transmitted surfaces, close contact, and respiratory droplets. The contamination of SARS-COV-2 is closely similar to other respiratory viruses such as influenza (see, [2-7]). The contagion of viruses may be affected by environmental and meteorological factors such as temperature, humidity, air quality, population density, and use of masks (see [8]).

Recently, many studies in the literature illustrated that air quality, temperature and population density are correlated with the number of SARS-COV-2 cases. [9] mentioned that SARS-COV-2 virus in the air is a threatening factor for humans in Turkey. [10] investigated the number of SARS-COV-2 case relationships with the parameters of weather such as humidity, temperature, and wind speed for eleven cities in Turkey. [10] reported that negative impacts of the average temperature, humidity, and dew point on the approved SARS-COV-2 cases number. [11] emphasized that the number of daily confirmed SARS-COV-2 cases is negatively related to maximum temperature and humidity while it is positively correlated with rainfall and maximum wind. Moreover, it is determined maximum temperature, rainfall, and humidity were significant predictors of daily confirmed cases of SARS-COV-2 in Ghana (see, [11]). It is investigated the relationship between air pollution levels and the risk of SARS-COV-2 in Italy by [12]. It is analyzed the effects of weather indicators on the spread of SARS-COV-2 in Spain by [13]. Investigation of the relationship between temperature and SARS-COV-2 in China is examined by [14]. [15] examined the relationship between the parameters of weather and the rate of mortality due to SARS-COV-2. They demonstrated that the weather parameters are more relevant in predicting the mortality rate of SARS-COV-2 virus when compared to the other demographic variables such as population, age, and urbanization. It was also emphasized that there is a negative relationship between the number of SARS-COV-2 cases in some countries, including the USA, Italy (see [15]). The main climate factor that suppresses the spread of SARS-COV-2 is high solar radiation. High temperatures and wind speed also are potential factors to prevent the spread of SARS-COV-2 (see [16]). [17] evaluated the relationship between environmental parameters and the growth rate of SARS-COV-2. It is expressed that the spread rate of the global pandemic is related to the changes in temperature and found to be the most effective environmental factor that could control the spread by new cases/day with a 1℃ rise in it. The most effective temperature range for the spread of SARS-COV-2 is -6.28 ℃ and 14.51 ℃ (see [17]).

[18] found that there is a positive relationship between SARS-COV-2 incidence and long-term $PM_{2.5}$ exposure. [19] reported a decline in $PM_{2.5}$ concentration of major cities (New York, Los Angeles, Rome, Zaragoza, Dubai, Mumbai, Shanghai, and Beijing) due to less mobility of the population and keep social distancing in order to prevent the spread of SARS-COV-2. The low $PM_{2.5}$ concentrations reflect high air quality and the efforts made in the major cities to control the spread of infection of SARS-COV-2 (see [19]). [20] constructed a mathematical model between mobility patterns and transmission of SARS-COV-2 in the USA. [21] concluded that it is not conspicuous direct associations between the existence of a high level of PM_{10} and the dispersal of the SARS-COV-2 for Lombardy (Italy).

[22] investigated the spatial correlation between PM_{10}, $PM_{2.5}$, and SARS-COV-2 deaths in China and concluded that a higher concentration of PM_{10} and $PM_{2.5}$ positively correlated with deaths due to SARS-COV-2 virus. On the other hand, the growth of SARS-COV-2 pandemic was not correlated with rainfall, humidity, wind speed, NO, NO_2, Ox, and $PM_{2.5}$, while it was significantly associated with daily temperature in Japan (see [3]). [23] reported that high temperature and high relative humidity reduce the activity, continuity, and contamination of SARS-COV-2 for 20 countries including, Turkey, Italy, Russia, Netherlands, US, Spain, Portugal, France, Germany, United

Kingdom, Belgium, India, Iran, China, Brazil, Ecuador, Canada, Switzerland, Peru, and Saudi Arabia. Currently, Turkey is one of the highly affected countries with approximately 329,000 total confirmed cases and more than 8,000 deaths (see [24]). [9] emphasized that population density positively affects the spread of SARS-COV-2 in Turkey. [25] observed that population density is a significant predictor of infection rates of SARS-COV-2 virus. Istanbul is the most crowded city in Turkey, with approximately 15,5 million citizens, one of Europe's most important metropolises. Therefore we preferred to study on Istanbul.

The previous studies provided that meteorological variables and air quality are correlated with the spread of SARS-COV-2 pandemic. [9] emphasized the availability of the positive relationship between population density and SARS-COV-2 cases. Therefore, we prefer to analyze Istanbul, which is the most populous city in Turkey. The motivate of this research is the lack of a special study on the association between weather parameters and the spread of the SARS-COV-2 virus and its relation to air pollution for Istanbul in the literature. In this regard, this study focuses on to determine the association between the confirmed SARS-COV-2 cases, hospitalizations, hospital discharges, and weather parameters such as temperature, humidity, pressure, dew, wind speed, and also examine its correlation between air quality indexes such as $PM_{2.5}$, PM_{10}, O_3 NO_2, SO_2, CO in Istanbul, Turkey. This study aims to assess the impacts of weather conditions and air pollution on the spread of SARS-COV-2 in Istanbul, Turkey.

2. Materials and Methods

2.1. Study Design and Areas

This research was designed to evaluate the relationship between the growth of SARS-COV-2 pandemic and the environmental parameters during the period of the pandemic. The increasing number of confirmed SARS-COV-2 cases led to various measures to be taken to control the spread of the SARS-COV-2 pandemic by the Turkish government. Some of these precautions in Turkey can be listed as follows. Firstly, it was temporarily restricted to entry or exit abroad. It was declared curfews in metropolitan provinces on the weekends. Education was temporarily suspended at all levels. The number of passengers in public transportation was limited. Some places, such as malls, restaurants, cafes, were temporarily closed. The flexible period of working began in public institutions. Other countries around the world also applied similar restrictions as Turkey. It is discussed some restrictions worldwide and international laws in detail by [26].

On the other hand, social activities have also been affected by SARS-COV-2 pandemic. Some organizations such as conferences, theater, cinema, concert, and wedding were banned until a second announcement. National football leagues were postponed. One of the most crowded metropolises in Europe is Istanbul, which is essentially affected by SARS-COV-2 pandemic. Istanbul is Turkey's most populous city, mostly topped the list of the number of cases SARS-COV-2 in Turkey. We motivated for this study due to a lack of research on the relation between air pollution and some variables related to SARS-COV-2, such as the number of cases, the number of hospitalizations, and discharges due to SARS-COV-2 for Istanbul province. Thus, Istanbul is chosen as the area of study due to it is the most affected province by SARS-COV-2, and the most crowded city in Turkey.

In this regard, it is considered the analysis period from July 15 to September 30, 2020, to evaluate the correlation of the pandemic growth with the environmental and meteorological factors.

The main aim of this study is to determine the association between weather parameters and air quality and the spread of SARS-COV-2 pandemic. Unlike other investigations, this paper provides the relationship of air quality and weather parameters with some parameters regarding SARS-COV-2, such as the number of cases, hospitalizations, and discharges from the hospital rather than an only association between the number of SARS-COV-2 cases and air pollution or weather parameters. The temperature (℃), humidity (%), air pressure, dew point (℃), and wind speed (mph) are chosen as meteorological indicators. Further, $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO are determined as air quality indexes to assess air pollution of the province.

2.2. Data Collection

We consider analyzing variables regarding weather and air quality into four periods. The data of these variables are collected based on four timeframes, namely on the day of the case, within 3, 7, and 14 days of the case since the incubation period of SARS-COV-2 virus varies from 1 day to 14 days. The data related to SARS-COV-2 cases, hospitalizations, and discharges from the hospital were collected from (https:// covid19.saglik.gov.tr). Daily air quality and meteorological measurement data were obtained from [27]. In this research, it is used the maximum available data of all variables from 15th July to 30th September 2020.

2.3. Statistical Analysis

Pearson correlation coefficient is a statistic that measures linear correlation between two variables. In this study, Pearson correlation is used to determine the correlation between air quality indexes or meteorological indicators and variables regarding SARS-COV-2 (cases, hospitalizations, and discharges from the hospitals). Pearson coefficient correlation is estimated using the following formula:

$$r_{Pearson} = \frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{\sqrt{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}\sqrt{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2}},$$

where n is sample of size. The statistical tests are applied using R software, and the significance level of 0.05 was considered.

3. Results

The descriptive results are given in Table 1. From Table 1, it is observed that the daily number of cases varied between 99 and 268 from July, 15 to September, 30 in Istanbul.

Table 1. Descriptive statistics

Variables	n	Mean	Std. Dev.	Min	Max	p_5	p_{95}	Skewness	Kurtosis
SARS-CoV-2 variables									
Daily case	78	183.9487	4.0311	99	268	117.7	249.1	-0.069	-0.790
Number of new hospitalizations	78	57.8462	15.7067	27	123	31.95	82.10	0.787	2.770
Number of new hospital discharges	78	62.1026	24.5703	25	114	30.9	110.0	0.541	-0.872
Air quality index									
CO	78	126.4679	139.9968	58.60	500.0	60.2650	500.0	2.184	3.181
SO_2	78	95.4141	130.2914	39.1	500	40.395	500.0	2.751	6.039
PM_{10}	78	188.4872	301.7965	44	999	47.95	999	2.301	3.525
$PM_{2.5}$	77	60.9740	18.8092	30	116	36.6	17	1.164	1.368
O_3	78	87.6705	77.8564	27.30	476.7	42.9	287.12	3.258	11.487
NO_2	78	98.6705	128.9549	24.5	500	31.26	500	2.759	6.125
Weather parameters									
Temperature	78	29.4064	2.4457	20	34.5	24.975	33	-1.057	2.638
Dew	78	20.0128	1.5373	16	23	17	22	-0.644	-0.121
Humidity	78	91.3679	4.6570	79.5	100	82	100	-0.388	-0.254
Pressure	78	1014.8128	3.2266	1008	1022	1009.9	1021	0.144	-0.317
Wind Speed	78	8.3667	1.8438	3.30	14.10	3.79	11.35	-0.259	1.888

Table 2 provides the results of Pearson correlation tests are conducted to determine the relationship between air quality index and the spread of SARS-COV-2. Firstly, the air index PM_{10} is the most correlated with the number of daily cases. A statistically significant positive relationship was observed between the number of cases on that day and the PM_{10} observed 7 days ago (r = 0.532). The air index having the second-highest correlation with the daily number of cases is $PM_{2.5}$. A positive correlation was determined between the $PM_{2.5}$ value observed 14 days ago and the number of daily cases (r = 0.517). It can be concluded that the high degree of PM_{10} and $PM_{2.5}$ allows the spread of SARS-COV-2. The height of PM_{10} and $PM_{2.5}$, two of the most important indicators of air pollution, was associated with the increasing number of SARS-COV-2 cases. Moreover, O_3 is the air quality index that has the highest negative relationship with the daily number of cases. It is determined the negative correlation between the daily number of cases and O_3 observed on the day (r=-0.469). It is observed that the air quality indexes observed 7 days ago generally are more related to the number of daily cases compared to the others. This situation may have occurred due to the incubation period of the SARS-COV-2 virus. Secondly, O_3 has the highest correlation with the number of hospitalized patients. O_3 value observed 3 days ago having a negatively effect on the daily number of hospitalized patients (r=-0.283). CO is one of the two air quality indices associated with the daily number of hospitalized patients. There is a negative correlation between the daily number of hospitalized patients and the CO value observed 7 days ago (r = -0.246)(Table 2). Thirdly, O_3 observed 3 days ago highest positively correlated with the daily number of discharges from the hospital among air quality indexes (r=0.429). $PM_{2.5}$ has the highest negative relationship with the daily number of people discharged from the hospital. $PM_{2.5}$ observed on that day has a statistically significant association with the daily number of discharges (r=-0.385). Thus, high O_3 has a positive influence on the number of daily discharges, while high $PM_{2.5}$ has a negative effect.

Table 2. Correlation analysis between air quality index and SARS-COV-2

	Air quality index	Daily case	Number of new hospitalizations	Number of new hospital discharges
On the day	CO	0.302**	0.140	-0.285*
	SO_2	0.235*	0.009	-0.254*
	PM_{10}	0.344**	-0.002	-0.263*
	$PM_{2.5}$	0.439**	-0.093	-0.385**
	O_3	-0.469**	-0.268*	0.303**
	NO_2	0.278*	-0.027	-0.250*
3 days ago	CO	0.338**	-0.183	-0.181
	SO_2	0.275*	-0.132	-0.208
	PM_{10}	0.325**	-0.154	-0.229*
	$PM_{2.5}$	0.365**	-0.135	-0.384**
	O_3	-0.405**	-0.283*	0.429 👎👎
	NO_2	0.312**	-0.182	-0.255*
7 days ago	CO	0.394**	-0.246*	-0.231*
	SO_2	0.421**	-0.158	-0.183
	PM_{10}	0.532**	-0.107	-0.099
	$PM_{2.5}$	0.330**	-0.055	-0.325**
	O_3	-0.288*	-0.031	0.167
	NO_2	0.417**	-0.170	-0.201
14 days ago	CO	0.194	-0.009	-0.148
	SO_2	0.331**	0.014	-0.107
	PM_{10}	0.276*	0.175	-0.007
	$PM_{2.5}$	0.517*	-0.028	-0.132
	O_3	-0.135	-0.054	-0.003
	NO_2	-0.285*	-0.039	-0.145

*indicates significance at the 5% level, and ** indicates significance at the 1% level.

When the relationship between weather indicators and the spread of SARS-COV-2 is evaluated according to Table 3. First of all, the pressure is the most associated with the number of daily cases. The pressure observed 7 days ago statistically significant positive relationship with the number of cases (r = 0.592). Maximum temperature observed 7 days ago highest negatively correlated the number of cases on the day (r=-0.552). Furthermore, it is determined a statistically significant relationship between maximum humidity and the number of daily cases (Table 3). The maximum humidity observed 3 days ago has the highest positive correlation with the number of daily hospitalizations (r=0.317). Secondly, it can be concluded that there is no significant association between the maximum temperature and the number of hospitalizations. Lastly, it is clearly seen that maximum pressure negatively affected the number of discharges from the hospital. Thus, the weather parameters such as temperature, dew, and humidity have a negative effect on the number of the daily case while the pressure is positively affected. On the other hand, there is no relationship between wind speed and the spread of SARS-COV-2.

Table 3. Correlation analysis between meteorological parameters and SARS-COV-2

	Weather indicators	Daily case	Number of new hospitalizations	Number of new hospital discharges
On the day	Temperature	-0.402**	0.058	0.190
	Dew	-0.195	-0.228*	-0.018
	Humidity	-0.038	0.309**	0.193
	Pressure	0.243*	-0.055	-0.290*
	Wind Speed	-0.180	0.103	0.057
3 days ago	Temperature	-0.518**	-0.076	-0.031
	Dew	-0.377**	-0.026	-0.007
	Humidity	-0.166	0.317**	0.088
	Pressure	0.309**	0.011	-0.386**
	Wind Speed	-0.080	0.053	0.218
7 days ago	Temperature	-0.552**	-0.112	0.130
	Dew	-0.344**	-0.190	-0.044
	Humidity	-0.256*	0.135	0.089
	Pressure	0.592**	0.233*	-0.133
	Wind Speed	0.107	0.054	0.074
14 days ago	Temperature	-0.139	-0.103	0.067
	Dew	0.060	0.063	0.123
	Humidity	-0.106	0.111	0.204
	Pressure	0.257*	-0.098	0.097
	Wind Speed	0.205	0.185	0.214

*indicates significance at the 5% level, and ** indicates significance at the 1% level.

When Table 2 is investigated, one of the first striking features is that the highest relationships generally appeared before 7 days. Also, when Table 2-3 are examined, it is clearly seen that the relationship between the number of cases and observed variables 14 days ago is less than variables measured at other time intervals. Although CO, SO_2, PM_{10}, $PM_{2.5}$, and NO_2 generally has a positive relationship with the daily case. There is a negative relationship with the number of new hospital discharges. In addition, no statistically significant relationship was found between many variables and the number of new hospitalizations. O_3 is known as a natural disinfectant that does not leave any residue. In this study, it is also determined that O_3 has a negative relationship with the daily case. However, it has a positive relationship with the number of new hospital discharges. This feature of O_3 can be a good research subject for future studies. From Table 2, it is also seen that the highest relationship is determined between PM_{10} and daily case for before 7 days.

From Table 3, it can be seen that the temperature is a negative relationship with the daily case. The highest relationship between daily case and temperature is determined 7 days ago. There is no relationship between temperature and number of new hospitalizations, and number of new hospital discharges. Observed maximum dew 3, 7 days ago is negatively affected the daily cases. Humidity has a positive relationship with the number of new hospitalizations for the same day and before 3 days. From Table 3, highest positive relationship is found between daily case and pressure observed 7 days ago. Also, the pressure measured on the day and 3 days ago has a negative effect on the number of new hospital discharges. In Table 3, it is seen that there is no relationship between wind speed and all weather parameters for all situations.

4. Discussion

The aim of this study is to determine the effects of air pollution and weather parameters on the spread of SARS-COV-2. Unlike previous studies, which aimed to only assess the correlation between air pollution or meteorological indicators and SARS-COV-2 cases, this paper provides the effects of weather parameters and air quality indexes on some parameters related to SARS-COV-2, such as confirmed cases, hospitalizations, discharges from the hospital due to SARS-COV-2.

Scientists emphasized that moisture is an important factor in preventing the spread of SARS-COV-2 [28]. In the literature, most investigations (33 out of 61) suggest a negative relationship between SARS-COV-2 and temperature in various countries such as the US, Japan, Ghana, Spain, Italy, China. Similarly, many papers (13 out of 27) present a negative impact of humidity in worldwide. Another study shows that other weather parameters such as wind speed, rainfall, and radiation clearly did not relate to SARS-COV-2 (see [29]). [16] discussed the association between weather parameters (temperature, humidity, solar radiation, wind speed, and precipitation) and SARS-COV-2 infection in the State of Rio de Janeiro, Brazil. They concluded that solar radiation strongly negatively correlated with the incidence of SARS-COV-2. [30] indicated that tropical temperatures had a negative linear correlation with the number of confirmed SARS-COV-2 cases in Brazil. [8] investigated the impacts of meteorological parameters on SARS-COV-2 in New Jersey, USA. They found maximum temperature negatively correlated, while humidity and air quality ($PM_{2.5}$) positively affect the spread of SARS-COV-2 in New Jersey. It was observed the higher is the number of SARS-COV-2 cases, the higher average wind speed in 14 days, on the other hand, it was concluded that the lower the temperature on a day, the higher is the number of SARS-COV-2 cases on that day. Moreover, the higher number of SARS-COV-2 cases is closely related to the crowd in a city of Turkey (see [10]). [9] reported that population, population density and wind speed are positive correlated with the number of SARS-COV-2 cases for 81 of Turkey cities.

On the other hand, previous studies have determined that respiratory infectious diseases are correlated with environmental air pollutants (see, [31-35]). [36] found that there is a statistically significant association between environmental factors (PM_{10}, $PM_{2.5}$, SO_2, CO, NO_2) and SARS-COV-2 cases and deaths in California. Environmental pollutants are significantly associated with the number of SARS-COV-2 cases and deaths in California (see [36]). [31] and [35] reported positive correlations of $PM_{2.5}$, PM_{10}, NO_2 and O_3 with the number of SARS-COV-2 cases, however, a negative relationship was determined for SO_2 for China. The results of many studies (see [8,18,19,22]) indicate $PM_{2.5}$ and PM_{10} positively affect the spread of SARS-COV-2. These results are providing evidence that air quality and weather parameters such as temperature and humidity are actually important to control the spread of SARS-COV-2 pandemic.

Our findings supported previous studies. First of all, it is observed the highest positive correlation between before 7 days maximum PM_{10} and daily SARS-COV-2 cases among air quality indexes (r=0.532).

It is well-known that O3 has a very high oxidation power. It is observed before 3 days maximum O_3 has the most negative effect on the number of daily new hospitalizations (r=-0.283). Further, it is clearly seen that examined all air quality indexes are closely related to the number of new discharges from the hospital due to SARS-COV-2. Secondly, it is observed many statistically significant correlation between meteorological indicators and SARS-COV-2 parameters such as cases, hospitalizations, discharges from the hospital. Before 7 days, maximum temperature has one of the most negative impact on the number of confirmed SARS-COV-2 cases in meteorological indicators (r=-0.552). Before 3 days, maximum pressure has the highest level of negative effect on the number of discharges from the hospital due to SARS-COV-2 (r=-0.386). Before 7 days, maximum humidity negatively affects the number of SARS-COV-2 cases (r=-0.256), and wind speed clearly does not affect the number of SARS-COV-2 cases as the results of previous studies (Table 3). As it can be clearly seen from Table 1, this may be due to the low wind speed (approximately 8 mph on average). Our study provides new evidence that air pollution and weather parameters affects the spread of SARS-COV-2 pandemic. Unlike the previous study, one of the important advantages of this study is that the association between air pollutants or weather parameters and SARS-COV-2 pandemic is evaluated in many ways.

5. Conclusion

In conclusion, we are motivated to study the impacts of weather parameters and air quality on the number of SARS-COV-2 cases, hospitalizations, and discharges from the hospital. We present new evidence that air quality indexes such as maximum CO, SO_2, $PM_{2.5}$, PM_{10}, and NO_2 have a positive effect on the number the SARS-COV-2 cases, whereas O_3 negatively affects it. In weather parameters, maximum temperature, dew point, and humidity negatively correlated the number of SARS-COV-2 cases while pressure positively related to it. On the other hand, it is not determined a statistically significant correlation between wind speed and SARS-COV-2 cases. It is concluded that examined weather parameters have an impact on the spread of SARS-COV-2 within 7 days. It is generally observed that weather parameters before 14 days have not an impact on SARS-COV-2 parameters. We recommend the authors, who will study the relationship between the spread of SARS-COV-2 and weather parameters, to analyze the meteorological indicators 7 days ago and the SARS-COV-2 data of that day.

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