

CORRELATION BETWEEN LONG-TERM EXPOSURE TO PM_{2.5} AND COVID-19 PANDEMIC IN IRAN

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1. INTRODUCTION

Several studies have suggested that mortality due to COVID-19 is correlated with long-term exposure to criteria air pollutants. This is because the exposure to high concentrations of air pollutants causes reduced immunity of the cardiovascular and respiratory systems (EPA 2020), and, therefore, the SARS-CoV-2 can damage the respiratory system of an infected patient more severely (Conticini et al. 2020; Cui et al. 2003; Lippi et al. 2020; Persico and Johnson 2020; Zhu et al. 2020). Several studies have investigated the association between exposure to PM_{2.5} and the mortality rate of COVID-19 outbreak in the United States (Croft et al. 2020; Wu et al. 2020), Italy (Conticini et al. 2020; Fattorini and Regoli 2020; Lippi et al. 2020; Remuzzi and Remuzzi 2020), and China (Wang et al. 2020; Yao et al. 2020; Zhu et al. 2020). A review of these studies suggests that the correlation between the PM_{2.5} concentration and the infection and mortality of the COVID-19 patients is positive and significant (Moradtabal and Danesh Yazdi 2020).

In this study, for the first time, we investigated the correlation between exposure to long-term ambient PM_{2.5} and the COVID-19 hospitalization and death rate at the sub-national (provincial) levels in Iran. For 31 provinces in Iran, the daily averaged PM_{2.5} concentrations from the ambient air quality monitoring stations were collected and processed to calculate the 3-year average of the

annual PM_{2.5} concentrations. Also, the number of hospitalization and the mortality cases due to the COVID-19 pandemic in Iran from March to August 2020 were considered as the outcome at the province level. The correlation between the long-term exposure to three-year averaged PM_{2.5} concentrations and the rate of hospitalization and rate of mortality in provinces are studied through cross-section analysis.

2. CASE STUDY

Iran, with an area of 1,648,195 km² is located in the Middle East. Over 83 million inhabitants are living in 31 provinces of Iran.

2.1 Air Pollution in Iran

Iran is among the countries with the high level of annual PM_{2.5} concentration (WHO 2016). The population-weighted average annual PM_{2.5} concentration in urban and rural areas of Iran is estimated to be as high as 42 µg/m³ (WHO 2016), 3.5 times the WHO air quality guidelines.

The high concentration of particulate matter in Iran is partly because of mobile sources and the frequent dust storms.

Figure 1 shows the three-year average annual concentration of PM_{2.5} in different provinces in Iran.

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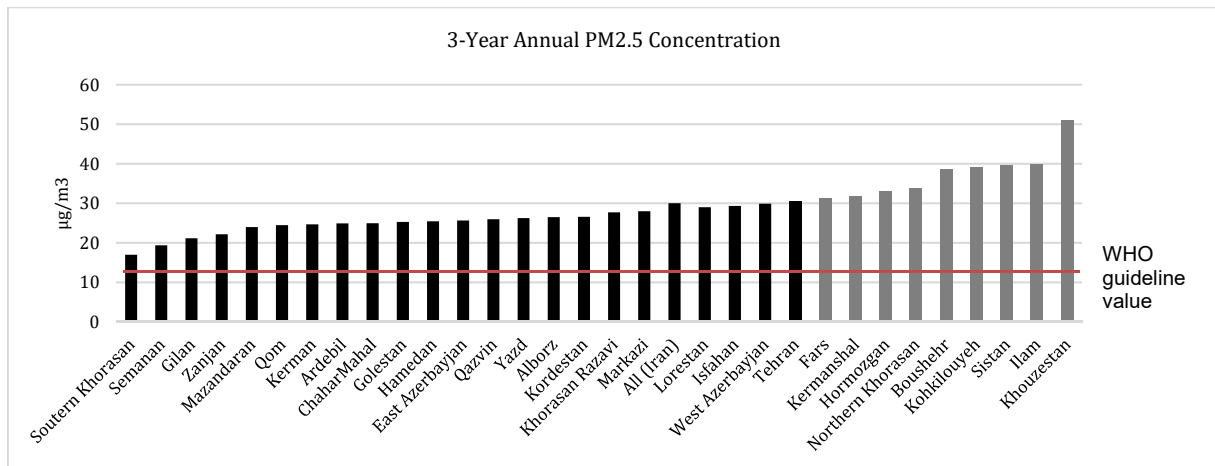


Figure 1. Three-year annually-averaged PM_{2.5} concentration in different provinces in Iran

2.2 COVID-19 Pandemic in Iran

Iran, with over 32,000 death cases due to COVID-19 is ranked 10th among the most severely hit countries from the pandemic. The country is

experiencing the third peak of the pandemic with over 562,000 infected cases. Figure 2 shows the fluctuations in the daily death rates from the COVID-19 in Iran.

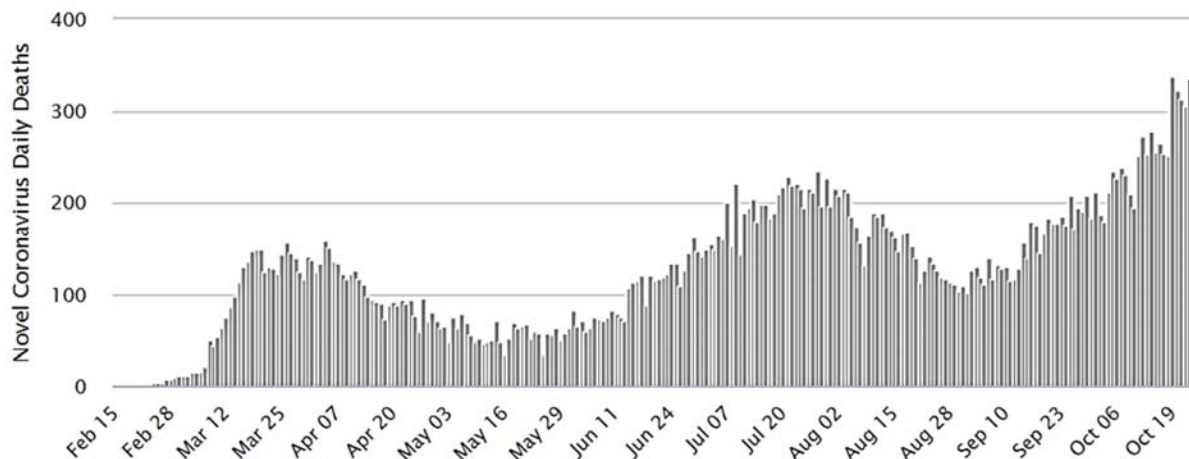


Figure 2. Temporal variation of daily death cases from the start of the pandemic (Worldmeters 2020)

3. METHODOLOGY

In this study, the correlation between the exposure to long-term PM_{2.5} concentrations and the No. Death (number of death cases per 100,000 inhabitants) and the No. Hospitalization (number of serious (hospitalized) cases per 100,000 inhabitants) was evaluated via Spearman and Kendall Correlation tests. The sign of the correlation is studied by checking the sign of both

the Spearman Correlation Coefficient (ρ -value) and the Kendall Correlation Coefficient (Kendall's τ -b). Also, the significance of the correlations is investigated by checking the p-value of the Spearman Correlation Coefficient and the Kendall Correlation Coefficient. The correlations are assumed significant if the p-values of the estimated correlation coefficients are less than 5%.

4. RESULTS and DISCUSSIONS

4.1 Whole-Sample Results

The rates of the death cases and hospitalized cases versus the 3-year-average PM_{2.5} concentrations in 31 provinces of Iran are depicted in Figure 3.

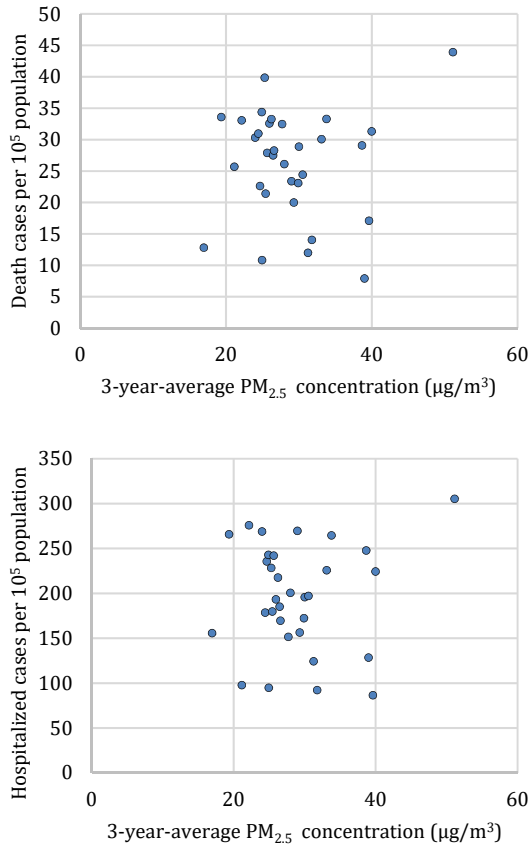


Figure 3. Rates of death (top) and hospitalized (bottom) cases versus the 3-year-average PM_{2.5} concentration

The correlation test results show that, when analyzing the whole sample of provinces, there are no statistically meaningful correlations between the death rates nor the hospitalization rates with the 3-year-average PM_{2.5} concentrations in Iran. The results of the correlation tests are presented in Table 1. High p-values in Table 1 show the low significance of the correlation results.

Table 1 Results of the correlation tests for the sample of whole provinces in Iran

	PM2.5 vs No. Hospitalized	PM2.5 vs No. Death
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Spearman Correlation	Coefficient (p-value)	0.168	0.117
	(p-value)	0.365	0.528
Kendall Correlation	Coefficient (Kendall's c-b)	0.133	0.088
	(p-value)	0.299	0.496

Our results show that 3-Year Annual PM_{2.5} have a non-significant correlation for - No. Hospitalized and No. Death in the provinces in both Spearman and Kendall correlation. However, the magnitude of the correlation coefficients are higher in the Spearman correlation test.

4.2 Adjusted-Sample Results

Western provinces of Iran experience high frequency of dust storms which increases the level of PM_{2.5} concentrations due to natural dust in these regions. Figure 4 shows the distribution of the frequency of the frequency of dust-storms over Iran (Alizadeh-Choobari et al. 2016).

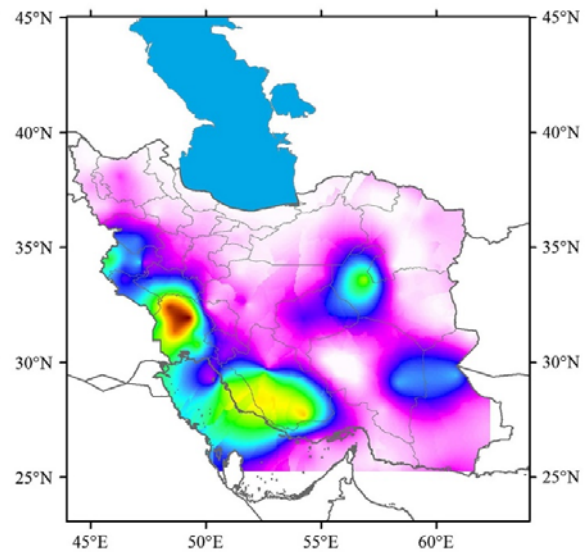


Figure 4 Frequency of dust-storms in Iran

The grayed columns in Figure 1 show the provinces which are subject to frequent dust storms in the west, southwest, and east of Iran (Kermanshah, Hormozgan, Bushehr, Kohgilouyeh and Boyer Ahmad, Sistan and Balouchestan, and Khuzestan). In these provinces, very high annual

PM_{2.5} concentrations have resulted from natural dust storms.

Omitting these provinces from the sample, the correlation results show quite positive and significant correlations between the death rates as well as the hospitalization rates with the 3-year-average PM_{2.5} concentrations in Iran. Table 2 shows the correlation results for the reduced sample, after omission of the provinces which are subject to frequent dust storms during a year.

Table 2 Results of the correlation tests for the reduced sample of provinces in Iran

		PM _{2.5} vs No. Hospitalized	PM _{2.5} vs No. Death
Spearman Correlation	Coefficient (ρ-value)	0.530	0.4347
	(p-value)	0.013	0.048
Kendall Correlation	Coefficient (Kendall's τ-b)	0.405	0.3158
	(p-value)	0.01	0.049

As a result, the statistically significant positive and moderate correlation among long-term exposure to pollution and COVID-19 hospitalization and death rates are observed for the provinces with PM_{2.5} concentrations less than 30 µg/m³.

6. CONCLUSION

In this study, we investigated the correlation between exposure to long-term ambient PM_{2.5} and the COVID-19 death rate at the sub-national (provincial) levels in Iran. Daily averaged PM_{2.5} concentrations from the ambient air quality monitoring stations were collected and processed to calculate the annually-averaged concentrations. Also, the number of mortality cases due to COVID-19 from March to August was considered as the outcome at the province level. Our results support the conclusion of the previous research works in other countries that the long-term exposure to higher concentrations of PM_{2.5} increases the risk of the lethality of the COVID-19 cases. Moreover, it is shown that this conclusion is valid only for the provinces with PM_{2.5} originated from anthropogenic emissions. Therefore, our results suggest the hypothesis that the PM_{2.5} concentrations from natural dust do not contribute to the increased rate of mortality of the COVID-19 pandemic.

Due to the lack of access to data of potential confounding factors, just the existence of a

meaningful correlation between exposure to PM_{2.5} and No. death and hospitalization was investigated in this research work. Many confounding factors must be considered for reliable assessment of the association between the death rates and the hospitalization rates with the 3-year-average PM_{2.5} concentrations in Iran. The main confounding factors are the level of access to health care systems, the level of access to affordable COVID-19 tests, the meteorological conditions, the state of public awareness and engagement of the local communities, age, and sex profiles of the communities. Also, access to more detailed air quality reports and COVID-19 statistics can increase the number of samples and therefore will result in more significant outcomes. The results of this study may be further elaborated in future research works by addressing the mentioned shortcomings.

Also, investigation of the short-term exposure to high concentrations of PM_{2.5} and other relevant pollutants on the mortality from COVID-19 is suggested to be subjected to future research works.

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