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Wildfire and COVID-19 pandemic: effect of environmental pollution PM-2.5 and carbon monoxide on the dynamics of daily cases and deaths due to SARS-COV-2 infection in San-Francisco USA

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Abstract. – OBJECTIVE: The wildfire allied environmental pollution is highly toxic and can cause significant wide-ranging damage to the regional environment, weather conditions, and it can facilitate the transmission of microorganisms and diseases. The present study aims to investigate the effect of wildfire allied pollutants, particulate matter (PM-2.5 µm), and carbon monoxide (CO) on the dynamics of daily cases and deaths due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection in San Francisco, USA.

MATERIALS AND METHODS: For this study, we selected San Francisco, one of the regions affected by the wildfires allied pollution in California, USA. The data on the COVID-19 pandemic in San Francisco, including daily new cases and new deaths were recorded from Worldometer Web. The daily environmental pollutants particulate matter (PM-2.5 µm) and carbon monoxide (CO) were recorded from the metrological web "BAAQMD". The daily cases, deaths, particulate matter (PM-2.5 µm) and carbon monoxide were documented from the date of the occurrence of the first case of (SARS-CoV-2) in San Francisco, CA, USA, from March 20, 2020 to Sept 16, 2020.

RESULTS: The results revealed a significant positive correlation between the environmental pollutants particulate matter (PM2.5 µm) and the number of daily cases (r=0.203, *p*=0.007), cumulative cases (r=0.567, *p*<0.001) and cumulative deaths (r=0.562, *p*<0.001); whereas the PM2.5 µm and daily deaths had no relationship (r=-0.015, *p*=0.842). In addition, CO was also positively correlated with cumulative cases (r=0.423, *p*<0.001) and cumulative deaths (r=0.315, *p*<0.001), however, CO had no correlation with the number of daily cases (r=0.134, *p*=0.075) and daily deaths (r=0.030, *p*=0.693). In San Francisco, one micrometer (µg/m3) increase in PM2.5 caused an increase in the daily cases, cumulative cases and cumulative deaths of SARS-COV-2 by 0.5%, 0.9% and 0.6%, respectively. Moreover, with a 1 part per million (ppm) increase in carbon monoxide level, the daily number of cases, cumulative cases and cumulative deaths increased by 5%, 9.3% and 5.3%, respectively. On the other hand, CO and daily deaths had no significant relationship.

CONCLUSIONS: The wildfire allied pollutants, particulate matter PM-2.5µm and CO have a positive association with an increased number of SARS-COV-2 daily cases, cumulative cases and cumulative deaths in San Francisco. The metrological, disaster management and health officials must implement the necessary policies and assist in planning to minimize the wildfire incidences, environmental pollution and COVID-19 pandemic both at regional and international levels.

Key Words:
Wildfire, San Francisco, COVID 19, Prevalence, Mortality

Introduction

Wildland fire occurrences change the weather conditions and environment, developing a hazardous situation for human health and living organisms. The wildfire air contains smoke, gases, dust, fine particles, and particulate matters due to the burning of plants, wood, buildings and other materials. The wildfire smoke is the mixture of "carbon dioxide, carbon monoxide, nitrogen oxides", particulate matter, hydrocarbons and other organic compounds[1]. The wildfire smoke parti-

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cles travel from the actual site of the wildfire over to the country, causing various health problems.

The wildfire allied pollution poses various human health hazards and economical challenges. There is a relationship between wildfire smoke and particulate matter (PM2.5) exposures with various respiratory, cardiovascular illnesses, and mortality. The respiratory morbidity "bronchial asthma, chronic obstructive pulmonary disease, bronchitis and pneumonia". The wild-fire smoke exposure susceptible population includes middle-aged and older adults with acute or chronic respiratory and cardiovascular diseases, pregnant women and children[2]. The same group of people are also susceptible to SARS-COV-2 infection[3,4].

Presently, the United States of America is facing two major health care challenges: environmental pollution due to the wildfires, and a rapidly increasing number of SARS-COV-2 cases. The incidences of wildfire and SARS-COV-2 cases are not going down. On Sept 19, 2020, the total number of SARS-COV-2 cases in USA are 6,961,270 compared to worldwide total number of cases of SARS-COV-2, 30,906,015 (22.52%). In California, the total number of SARS-COV-2 cases are 781,854, 11.23% of the total number of cases in the USA; moreover, inside California, the number of cases in San Francisco are also increasing[5]. One of the reasons of the rising number of SARS-COV-2 cases in California may be the low air quality and environmental pollution which make California more susceptible to infectious diseases, such as COVID-19[6]. It has already been reported that weather conditions have an impact on the pattern of health and disease[7]. Environmental pollution can facilitate the transportation of microbes, including viral infections[8]. The present study aims to investigate the effect of environmental pollutants particulate matter (PM-2.5) and carbon monoxide on the dynamics of daily cases and deaths due to SARS-COV-2 infection in San-Francisco, CA, USA.

Materials and Methods

The present study was conducted in the "Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia". In this study we selected San Francisco, one of the regions affected by the wildfire allied pollution in California, USA. Data were extracted from publicly accessible databases. The data on COVID-19 pandemic, daily new cases and daily new deaths were collected from the Worldometer Web[5]. The daily information on meteorological conditions, environmental pollution, daily wildfire allied pollutants, particulate matter (PM-2.5) and carbon monoxide (CO) were obtained the metrological Web "BAAQMD"[9]. The daily cases, deaths, pollutants, particulate matter (PM-2.5) and carbon monoxide were recorded from the date of appearance of first case of "SARS-CoV-2" in the San Francisco, from March 20, 2020 to Sept 16, 2020. In San Francisco, the mean particulate matter PM2.5 levels was 48.46±2.83 µg/m3, mean CO was 3.40±0.199 ppm, mean number of daily cases were 57.59±4.45, mean cumulative cases 3939.27±224.5, mean deaths 0.45±0.06 and mean cumulative deaths were 42.83±1.57.

Statistical Analysis

The data was analyzed using R Core Team (2020; R: A language and environment for statistical computing. Foundation for Statistical Computing, Vienna, Austria). Mean ± SEM has been reported for quantitative environmental pollution factors. Normality of data for Normal and Poisson distributions was checked through one-sample Kolmogorov-Smirnov test. Pearson correlation was applied to assess the relationship between various environmental pollution factors at 1% level of significance, whereas, Poisson Regression Analysis was performed to predict the number of cases and deaths with PM2.5 and CO after fulfilling the assumptions. Goodness of Fit tests and Model tests for all regression analysis were significant. An α=0.05 was considered as statistically significant.

Results

In San Francisco, the mean $PM_{2.5}$ was 48.46±2.83 µg/m^3, mean CO was 3.40±0.199 µg/m^3, mean number of daily cases were 57.59±4.45, mean cumulative cases were 3939.27±224.5, mean deaths were 0.45±0.06 and mean cumulative deaths were 42.83±1.57 (Table I).

A significant positive correlation was observed between $PM_{2.5}$ and number of cases (r=0.203, p=0.007), cumulative cases (r=0.567, p<0.001) and cumulative deaths (r=0.562, p<0.001), whereas $PM_{2.5}$ and deaths had no relationship (r=-0.015, p=0.842). In addition, CO was again positively correlated with cumulative cases (r=0.423, p<0.001) and cumulative deaths (r=0.315, p<0.001), whereas, CO had no correlation with

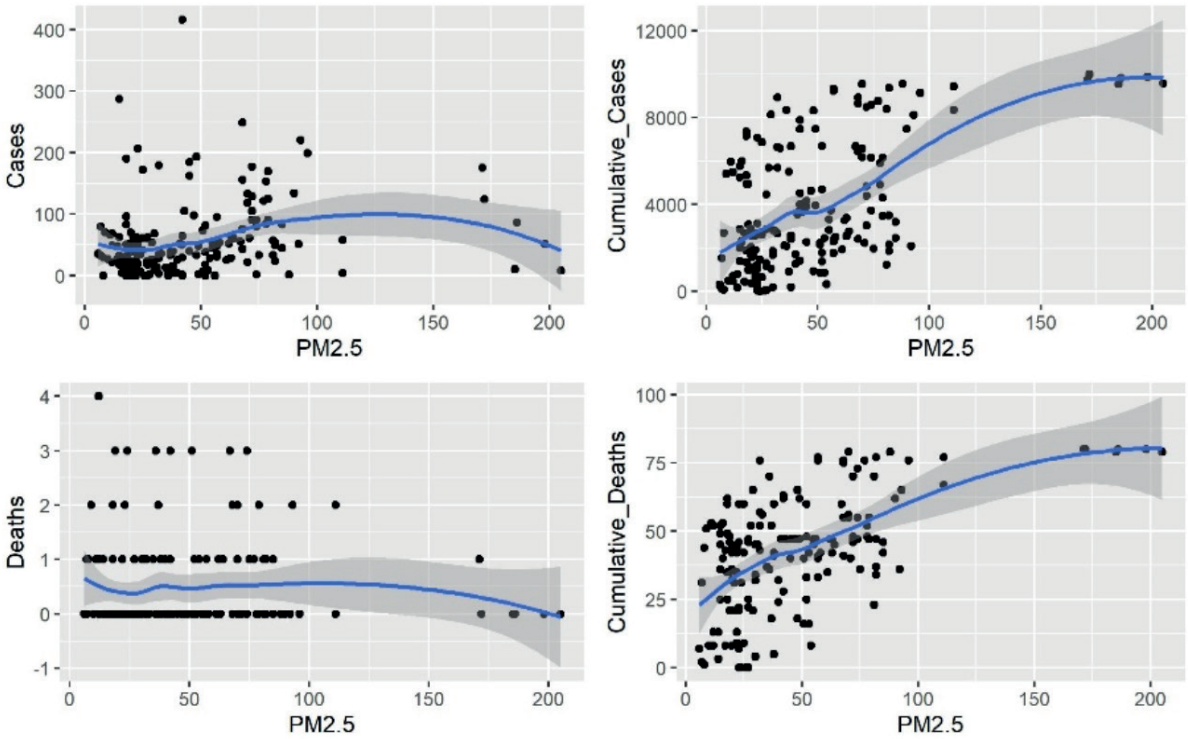

Figure 1. Relationship of $PM_{2.5}$ with cases, deaths, cumulative cases, and deaths.

the number of cases (r=0.134, p=0.075) and deaths (r=0.030, p=0.693). Results are presented in Figures 1 and 2.

Poisson regression results presented in Table II and III showed that with 1 micrometer increase in $PM_{2.5}$ the number of cases (β=0.005, S.E=0.0002, p<0.001), cumulative cases (β=0.009, S.E=0.0001, p<0.001) and cumulative deaths (β=0.006, S.E=0.0003, p<0.001) significantly increased by 0.5%, 0.9% and 0.6% respectively. However, deaths and $PM_{2.5}$ had no significant relationship (β=-0.001, S.E=0.0032, p=0.806). Moreover, with 1 ppm increase in CO level the number of cases (β=0.049, S.E=0.0034, p<0.001), cumulative cases (β=0.089, S.E=0.0003, p<0.001) and cumulative deaths (β=0.051, S.E=0.0039, p<0.001) significantly increased by 5%, 9.3% and 5.3% respectively. Whereas, deaths and CO had no significant relationship (β=0.021, S.E=0.042, p=0.626).

Discussion

Environmental pollution is a growing public health concern. It changes the environment, weather conditions, and increases the risk for

Table I. Mean PM2.5, CO, number of daily cases, cumulative cases, daily deaths, and cumulative deaths in San Francisco.

Parameters	Mean daily cases, deaths and Environmental Pollutants (Mean ± SEM)
Particulate Matter PM2.5 µg/m3	48.46±2.83
Carbon Monoxide (CO) ppm	3.40±0.199
Daily Cases	57.59±4.45
Cumulative Cases	3939.27±224.5
Daily Deaths	0.45±0.06
Cumulative Deaths	42.83±1.57

Data recorded from the first case of appearance of SARS-COV-2 in San Francisco, from March 20, 2020 to Sept 16, 2020. The values are presented in Mean and SEM.

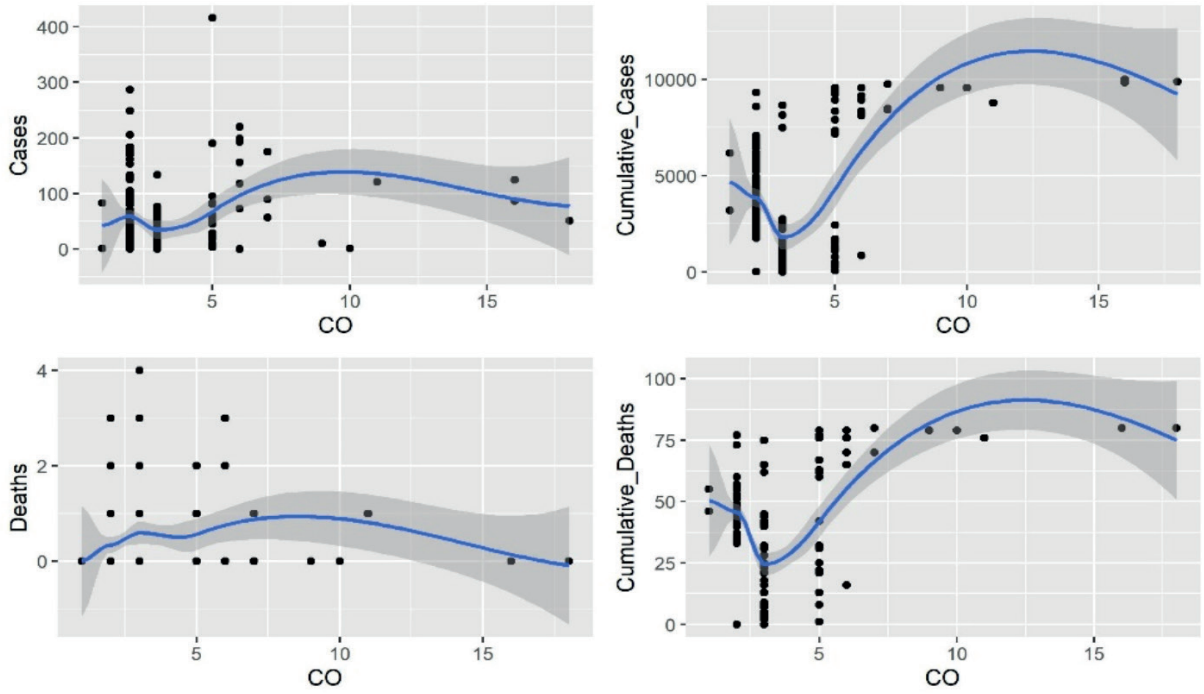

Figure 2. Relationship of CO with cases, deaths, cumulative cases, and deaths.

respiratory, cardiovascular, endocrine and nervous system diseases[10,11]. Environmental pollutants have various sources of emission, biological, physical, chemical characteristics and spreading behaviors. PM-2.5 μm describes fine inhalable particles with diameters that are generally 2.5 μm and smaller which can be emitted from various sources, including power plants, motor vehicles, wood burning, sand storms, and wildfires[12].

The people with chronic lung disease, older individuals, pregnant women and children are at the greatest risk due to environmental pollution, including wildfire pollution. The currently rising incidence of wildfires in the surroundings of San Francisco, California are causing pollution which is posing a significant threat to social and environmental development, health care system and economies. The major pollutant components of wildfire are smoke, particulate matter (PM-2.5) and carbon monoxide (CO)[1].

The present study findings are showing increasing epidemiological trends of COVID-19 cases and deaths with wildfire allied environmental pollutants PM.2.5 and carbon monoxide in San Francisco, California.

Literature has acknowledged that the environmental pollution increases the incidence and mortality of SARS-COV infection. Kan et al[13] reported that the coronavirus outbreak increased by a prominent 6% with a relative risk of mortality for each 10 micrograms per cubic meter increase in the mean of total respirable partic-

Table II. Poisson Regression-Particulate matter PM2.5 with cases, deaths, cumulative cases and deaths.

Parameters	Intercept	β	S.E	Exp (β)	*p*-value
Number of Cases	3.782	0.005	0.0002	1.005	$p<0.001$*
Number of Deaths	-0.745	-0.001	0.0032	0.999	$p=0.806$
Cumulative Cases	7.784	0.009	0.0001	1.009	$p<0.001$*
Cumulative Deaths	3.427	0.006	0.0003	1.006	$p<0.001$*

**statistically significant at 5% level of significance; S.E.=Standard Error; β=Coefficient Estimates; Exp (β)=Exponentiated Values.

Table III. Poisson Regression-Carbon Monoxide with cases, deaths, cumulative cases, and deaths.

Parameters	Intercept	β	S.E	Exp (β)	*p*-value
Number of Cases	3.782	0.005	0.0002	1.005	$p<0.001$*
Number of Deaths	-0.745	-0.001	0.0032	0.999	$p=0.806$
Cumulative Cases	7.784	0.009	0.0001	1.009	$p<0.001$*
Cumulative Deaths	3.427	0.006	0.0003	1.006	$p<0.001$*

**statistically significant at 5% level of significance; S.E.=Standard Error; β=Coefficient Estimates; Exp (β)=Exponentiated Values

ulate matter (PM-10), which also comprises of PM-2.5 and larger particles. Similarly, Croft et al[14] demonstrated increased rate of hospitalization and emergency department visits for culture-negative pneumonia and influenza linked with increased PM-2.5 concentrations among residents of metropolitan urban areas of New York, USA. More recently, Croft et al[15] reported that short-term increases in particulate matter (PM2.5) from traffic and various combustion sources are a potential risk for increased rates of influenza hospitalizations and hospital visits. The authors further found that biomass burning was associated with laboratory confirmed cases of influenza.

Earlier studies[16,17] have also established a link between high levels of ambient fine particles, particulate matter PM-2.5 and respiratory infections. Similarly, the present study results revealed a significant positive correlation between the environmental pollutants PM2.5 and number of daily cases, cumulative cases and deaths. We also found a positive correlation with CO and cumulative cases, along with cumulative deaths of SARS-COV-2.

The literature[18,19] showed that environmental and climate conditions possibly affect the transmissibility of SARS-COV-2 infection. The SARS-COV-2 can be easily transported through the air and air pollutants. Air is a highly suitable transmission method through which microbial agents may move around the environment and various regions; bacteria, fungi, viruses, parasites, and spores can be components of the bioaerosol[20]. The environmental particulate matters play a role as a carrier of numerous microorganisms including viruses. The particulate matters increase the effectiveness of the viruses spread and provide suitable environment for its persistence[21]. Moreover, PM-2.5 along with microorganisms can be easily inhaled deep into the lungs, mainly those which are smaller than 2.5 microns (PM2.5 and ultrafine particulate matters). This facilitates the virus to enter, develop within the respiratory tract and cause infections[21].

Bianconi et al[22] investigated the risk of particulate matter exposure, namely PM2.5 and PM10, with the COVID-19 cases and deaths across Italian regions. The authors demonstrated that the exposure to PM2.5 and PM10 was related to COVID-19 cases and deaths. They also concluded that particulate matter pollution plays a role in the outbreak of COVID-19 cases in Italian regions.

Zhu et al[23] found a significant positive relationship between air pollutants including PM2.5, PM10, CO, O3 with COVID-19 infection. In another study, Frontera et al[24] reported that the regions with high concentration of air pollutants, PM-2.5 and NO_2 have higher incidence and mortality due to SARS-CoV-2 infection. The authors also summarized that PM-2.5 exposure correlates with alveolar ACE-2 receptor overexpression leading to more severe infection of COVID-19 and high ambient NO_2 may cause extensive lung injury in COVID-19 pneumonia associated with a worse outcome. Similarly, the present study findings show an increasing epidemiological trend of COVID-19 cases and deaths with wildfire allied environmental pollutants in San-Francisco, California.

The science community has started a debate about the link between PM pollution and COVID-19 pandemic[25,26]. The discussion is supported by evidence[27] showing that exposure to PM pollution has been found to be particularly high in the wildfire regions where an excess of COVID-19 cases and deaths have been reported. The PM exposure has been causally linked to several organ dysfunctions mostly involving the respiratory system[26] and also the severe course of COVID-19.

The literature has established some pathophysiological and epidemiological links between PM exposure and viral infections[8]. Moreover, there is an association between airborne pollution and COVID-19 incidence[22]. The environmental pollution particulate matters act as a carrier of the infection, impair the immunity, making the peo-

ple more susceptible to pathogens, and as a worsening pathogenic factor for the disease[20]. These are the few studies strengthening the linkage between the wildfire pollutants particulate matter (PM-2.5μm) and carbon monoxide (CO) ppm on the epidemiological dynamics of COVID-19 cases and mortality. The present study findings highlighted that particulate matter (PM2.5) are the best sources of carrier or transport vector for SARS-COV-2 virus. Moreover, carbon monoxide is a highly toxic gas which can damage the lungs. This mechanism supports the hypothesis that the wildfire allied pollutants particulate matters (PM-2.5) and carbon monoxide resulted in an increase in the SARS-COV-2 cases and deaths in San Francisco, one of the regions affected by the wildfires in California, USA.

Study Strengths and Limitations

This is the first study added in literature that has investigated the effect of wildfire allied major pollutants, particulate matter (PM-2.5) and carbon monoxide (CO) on the incidence and mortality trends of SARS-COV-2 infection in San Francisco. We selected the main pollutants, PM-2.5 and CO, as both has a sharper decline deep into the lungs. We were unable to consider other pollutants, such as PM-10, ozone, carbon dioxide which may also affect the dynamics of the COVID-19 epidemic and this represents a limitation to our study.

Conclusions

The present study finding shows an increasing trend of wildfire allied environmental pollutants, particulate matters (PM-2.5) and carbon monoxide with the COVID-19 pandemic in San Francisco, one of the regions affected by the wildfires in California, USA. The findings are highlighting the important contribution of PM-2.5 and CO as triggering factors for COVID-19 cases and mortality. Further studies are needed to strengthen scientific evidence and support firm conclusions. The findings have outcomes for policymakers and health officials about the impact of environmental pollution, particulate matter PM2.5 and CO on the epidemiological trends of daily new cases and deaths due to the COVID-19 pandemic. The metrological and health officials must implement the policies to minimize the wildfire occurrences, environmental pollution, and enhance awareness in planning to fight against such environmental and COVID-19 pandemic situations both at regional and international levels.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethical Statement

For this study the data on the daily new cases and deaths due to COVID-19 pandemic, particulate matter PM2.5, and CO related information were obtained from the Worldometer, weather web "BAAQMD" from the publicly available data, hence ethical approval was not required.

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