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ASSOCIATIONS OF AIR POLLUTION WITH COVID-19 PANDEMIC IN BUCHAREST CITY

Maria Zoran[1], Roxana Savastru[1], Dan Savastru[1], Marina Tautan[1], Daniel Tenciu[1]

[1]National Institute of R&D for Optoelectronics, 409 Atomistilor Street, Magurele, MG5, mzoran@inoe.ro, Romania,

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Introduction

Coronavirus Disease 2019 (COVID-19) – caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) – killed more than 65,755 people, and infected more than 2, 927,187 people from 26 February 2020 till 6 July 2022 in Romania. Bucharest metropolitan city recorded 16.97% of the total Romanian confirmed COVID-19 cases and 8.83% of Romanian deaths. As future viral waves are likely to occur, with unpredictable height and breadth of the waves is an imperious need to understand the evolution of COVID-19 pandemic risk in relation with air pollution in urban agglomerated area of Bucharest. According to the World Health Organization, poor ambient air quality has long-term cumulative effects on human health, being a potential linkage between the transmission of SARS-CoV-2 virus and air quality parameters, which can be an important indicator of the health status of the individuals. Due to their increased oxidative toxicity the short-term and long-term exposure to high ground levels concentrations of particulate matter PM2.5 and PM10, NO_2, O_3, SO_2, and CO concentrations may exacerbate COVID-19 health outcomes. The lower atmospheric system of urban areas can be a significant transport vector for airborne microbiome (bacterial, fungal, viral) communities and their seasonal shift in both the concentration and biodiversity under the influence of local and regional climate parameters (air temperature, relative humidity, pressure, wind speed intensity, and direction, Planetary Boundary Layer heights -PBL, surface solar irradiance) variability. This paper explores the synergy between the changes in the exposure to the main ambient air pollutants and climate-related factors, which may exacerbate the SARS-CoV-2 viral 'effect on human health and the COVID-19 incidence and lethality in Bucharest. Through applied statistical analyses of daily in-situ and satellite time series data recorded during several seasons and over a long time period (26 February 2020-1 April 2022), during five COVID-19 pandemic waves, this study provides an accurate estimation of the local and regional mutual seasonality of the air quality and epidemiologic conditions impacts of the COVID-19 disease evolution in Bucharest metropolitan city.

Materials and methods

The test site Bucharest city, the Romania' capital centred at (44.43°N, 26.10 °E) area is located in the South-Eastern part of Europe and South-Eastern part of Romania, which, due to extensive traffic-related and industrial pollution is considered the largest urban carbon emitter among all Romanian cities, and one of the most

polluted town in Europe. The time series analysis of air pollution, and meteorological mutual seasonality relationship with COVID-19 incidence and mortality in Bucharest is based on a large global dataset built by collecting information from in-situ air monitoring and various freely available sources. The dependence between pairs of daily time series air pollutants including Aerosol Optical Depth and meteorological variables, as well as COVID-19 incidence and mortality data, were quantified in this study by standard tools of statistical analysis, Pearson, Spearman, and Kendall rank correlation, and rank-correlation non-parametric test coefficients as well as linear regression analysis. The normality of data was evaluated through Kolmogorov-Smirnov Tests of Normality for daily time-series data sets. As the data on daily new COVID-19 cases (DNC) and daily new COVID-19 deaths (DND) showed non-normal distribution, Spearman rank correlation was employed to identify the linear correlation between the following variables: (1) air pollutants PM2.5, PM10, NO_2, SO_2, CO, and O_3 concentrations, Aerosol Optical Depth, meteorological parameters and (2) COVID-19 incidence and mortality rates. All statistical analyses were achieved using ORIGIN 10.0 software, version 2021 for Microsoft windows.

Results and conclusions

To evaluate the impact of air pollutants and associated climate variables on COVID-19 incidence and mortality during the recorded five-waves with one total and other partial lockdowns and relaxation periods between 26 February 2020-1 April 2022, daily time series patterns of the main air pollutants including radon have been analysed. In good accordance with existing literature, this study found direct correlations between ambient exposure to daily average air pollutants PM2.5, PM10, NO_2, SO_2, CO concentrations, and daily new COVID-19 confirmed (DNC) and deaths (DND) cases. Opposite to PM2.5 and PM10, during the entire analysed period, ground levels of O_3 concentrations presented an inverse seasonal variation, with lower values during fall-winter seasons and higher values during spring - summer periods (Table 1 and Figure 1). For the entire analysed pandemic period in Bucharest our analysis found a decreased value of the daily average PM2.5 concentrations of (24.63 ± 12.05) $\mu g/m^3$ in comparison with the daily average PM2.5 concentration recorded for pre-pandemic period 2015-2019 of (32.61 ± 13.21) $\mu g/m^3$. A similar result was found for PM10 concentrations for the same reported periods, namely (61.92 ± 24.50) $\mu g/m^3$ during the entire pandemic period and (76.32 ± 26.18) $\mu g/m^3$ for pre-pandemic period 2015-2019. These registered reduced values of PM2.5 and PM10 concentrations may be attributed to total or partial lockdown restrictions adopted to limit the SARS-CoV-2 spreading in Bucharest metropolitan city. However, improvement of urban air quality may have a high impact on human health and environment, results confirmed by several other studies. Also, considering contribution of seasonal variability of ground levels of air pollutants concentrations, this analysis underlines the critical role of increased concentrations of daily average particulate matter PM2.5 and PM10 during the second, the fourth and the fifth COVID-19 waves in Bucharest and recorded high numbers of total daily new COVID-19 new cases. Due to complex interaction between air pollutants and humans, this finding is consistent with the results of previous studies, and support the hypothesis that particulate matter, especially PM2.5 in cities can be considered as an anthropogenic environmental mutagen of

SARS-CoV-2 genome with diminishing pulmonary function, and emergence of new variants.

Table 1. Spearman rank correlation coefficients and p values between COVID-19-incidence cases, and daily average of the main air pollutants concentrations for investigated metropolitan Bucharest region during the entire analysed pandemic period, 26 February 2020- 1 April 2022.

Bucharest	**Daily average of ground air pollutant concentration**					
COVID-19 incidence	PM2.5 ($\mu g/m^3$)	PM10 ($\mu g/m^3$)	O_3 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	CO ($\mu g/m^3$)
Daily New cases (DNC)	0.36*	0.35*	-0.49*	0.28*	0.40*	0.49*
Daily New Deaths (DND)	0.38*	0.41*	-0.53*	0.30*	0.42*	0.50*

Note: PM2.5 (Particulate Matter of 2.5µm size), PM10 (Particulate Matter of 10µm size), O_3 (ozone), NO_2 (nitrogen dioxide), SO_2 (sulphur dioxide), CO (carbon monoxide),

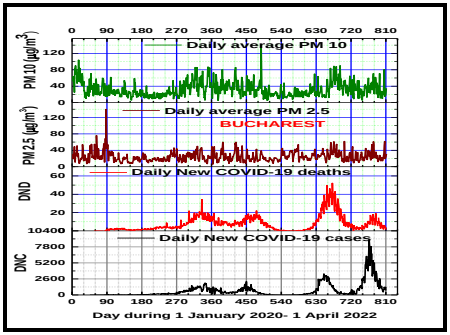

Fig. 1. Temporal distributions of daily average ground levels of PM2.5, PM10 concentrations and daily new COVID-19 cases (DNC) and deaths (DND) during the entire analysed COVID-19 pandemic period in Bucharest city.

Our results underline a significant reduction of the AOD levels over Bucharest metropolitan city (~28 %) during the spring total lockdown period (15 March-15 May 2020) associated with the first COVID-19 wave, and (~16%) during the third COVID-19 wave with few some restrictions, as compared to the long-term average AOD level (2015–2019) for the same periods of the year, finding that is in a good agreement with other studies which reported the reduction in surface level of particulate matter PM2.5 and PM10, and also increase/decrease in trace gases ozone/nitrogen dioxide during the lockdown periods.

Regarding meteorological variables, air low temperatures and surface solar irradiance are inversely correlated with a higher COVID-19 daily new cases and deaths ($r = -0.49$, $p < 0.01$; and $r = -0.59$; $p < 0.01$), and respectively ($r= -0.65$, $p < 0.01$; $r = -0.63$, $p < 0.01$). Also, Planetary Boundary Layer height is inversely correlated with COVID-19 daily new cases and deaths ($r= -0.69$; $p < 0.01$) and respectively ($r= -0.71$; $p < 0.01$). Due to its location in large depression-like structure, Romanian Plain surrounded by Carpathians Mountain barriers, especially during late fall and winter seasons, this study identified existence of strong tropospheric anomalous synoptic anticyclonic conditions over Bucharest metropolitan city, with downwards airflows and positive values on Omega surface charts at 850 mb, that suggests proper conditions for air pollutants and SARS-CoV-2 viral pathogens accumulation near the ground, with associated severity of COVID-19 incidence and mortality. The findings of this paper cannot be interpreted as causal effects but may be considered as additional factors for

COVID-19 pandemic viral infection transmission in large urban metropolitan areas. Also, this paper confirms that COVID-19 transmission surveillance under seasonal variability of environmental conditions, especially in large agglomerated urban areas, and the new variants of concerns such as Omicron and other descendants, will remain important as the pandemic continues. Such studies are essential for policymakers to formulate environmental health prevention and control strategies during pandemic events.

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