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ORIGINAL PAPER

PM_{10} and NO_2 Air Pollution and Evolution of COVID-19 Cases in Romania

Irina Mihaela STOIAN[a, b], Simona PARVU[a, b], Andra NEAMTU[b], Violeta CALOTA[b], Angelica VOINOIU[b], Adriana PISTOL[a, b], Radu CUCUIU[b], Dana Galieta MINCA[a, b]

[a]"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

[b]National Institute of Public Health, Bucharest, Romania

ABSTRACT

Objectives: *Based on the correlation between air pollution and COVID-19 incidence/mortality already existing in the literature, we aimed to develop a study to investigate the link between the average level of* PM_{10} *(particulate matter 10 – particulate matter 10 microns in diameter) and* NO_2 *(nitrogen dioxide) concentration over five years and the cumulative incidence of COVID-19 cases* per *1000 people in Romania.*

Methods: *To assess* PM_{10} *and* NO_2 *exposure, we determined the average value of annual* PM_{10} *and* NO_2 *concentration for each city over five years (2015-2019). For this purpose, the average of annual* PM_{10} *and* NO_2 *concentrations collected from monitoring stations in selected cities was calculated. Then, the annual values over five years were averaged to finally obtain the average* PM_{10} *and* NO_2 *concentration for each city. Data on the cumulative number of confirmed cases of COVID-19 up to the 28th of September 2020 were provided by the National Centre for Surveillance and Control of Communicable Diseases (CNSCBT) of the National Institute of Public Health (INSP). The study used the cumulative incidence/hour* per *1000 population on 28.09.2020.*

Results: *According to Law no. 104/2011, the annual permissible limit value of PM10 concentration of 40 µg/m³ was not exceeded in any of the 43 cities in our study. The average for all cities was 24.0±4.8 µg/m³, with a minimum value of average* PM_{10} *concentration of 13.9 µg/m³ measured in Alba Iulia and a maximum value of 39.1 µg/m³ in Iasi. The regression model shows that, in Bucharest, 77.9% of the variation in case incidence is explained by the variation in* PM_{10} *concentration. In order to find the number of new cases that would correspond to a cumulative incidence of 0.166, taking as an example one of the districts with a population of 259,084, the above regression model shows that an increase in the average* PM_{10} *concentration by one unit is associated with 43 new cases.*

Conclusions: *The study demonstrates that an exposure of the population to particulate matter in atmospheric air, at low values, below the permissible limit values but for a long time (the follow-up period in our study was five years, between 2015 and 2019), can have effects on the health status of the population, which becomes much more vulnerable to external agents, in our case pathogenic microorganisms (viruses).*

Keywords: atmospheric air quality, COVID-19, fine particulate matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), the minimum incidence value, the maximum incidence value.

Address for correspondence:
Irina Mihaela Stoian
Postal address: Dr Leonte Anastasievici, No. 1-3, District 5, Bucharest, postal code 050463, Romania
Tel: +0736394311; email: irina.stoian@drd.umfcd.ro

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INTRODUCTION

The quality of atmospheric air and its effect on population's health, especially in urban areas, is a priority at the European level. It is also a point of interest in the current epidemiological context concerning the COVID-19 pandemic. The literature has repeatedly shown that long-term exposure to air pollutants – fine particulate matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) – could both reduce lung function and be a determinant or promoter of certain respiratory diseases (1-3). These pollutants can act by inducing a persistent inflammatory response, even in young people, increasing the risk of respiratory tract infections caused by pathogenic microorganisms (4).

Certain chemicals in ambient air are associated with health effects, particularly on the respiratory tract, increasing susceptibility to the action of pathogenic microorganisms, including COVID-19. This is more evident in at risk individuals with comorbidities such as obesity, respiratory disease, cardiovascular disease and immune-toxicity (5, 6).

Establishing an evident link between chronic past exposure to these pollutants and cases of COVID-19 requires individual-level data, following the personal characteristics of each person (age and health conditions), as well as a broad individualised analysis and a lengthy process. Thus, the best alternative at this stage is considered to be the analysis of as many geographical regions as possible, looking at detailed data on the characteristics of these regions. This allows the researcher to assess whether there is a correlation between atmospheric air quality and the occurrence of COVID-19 cases.

In this context, recent studies suggest that long-term exposure to mixtures of chemicals in ambient air, even in small doses, can lead to low immunity and thus, the human body becomes more exposed to epidemics and pandemics (5).

A series of clinical studies suggested a possible correlation between exposure to air pollutants and COVID-19 incidence/mortality (6).

In most cases, SARS-CoV-2 produces only mild symptoms. However, in a smaller number of cases, it causes an excessive inflammatory response, which leads to acute respiratory distress syndrome (ARDS) and death.

The relationship between ambient air pollution with different pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3) and the number of COVID-19 infections could be translated into two possibilities: a) air pollution, especially particulate matter, may act as a vehicle for the virus responsible for COVID-19 infection (7); and b) ambient air pollution, being a recognised cause of lung inflammation and damage, which causes conditions that predispose to infection and then further exacerbate the severity of SARS-CoV-2-induced disease (1).

Clinical studies were carried out this year in several European countries, including France, Germany, Italy, Spain, the Netherlands, and the United Kingdom, but also in other parts of the world such as the US, Brazil, Japan, India, China, Iran, New Zealand, suggesting that air pollution may contribute to the increased incidence/mortality of SARS-CoV-2 and thus, to complications and deaths among infected people (4, 6, 9-11, 13, 14).

One contributing factor, which has been explored in several recent clinical studies, is the poor air quality. Some studies have found that significant improvements in air quality resulted in decreased or blocked SARS-CoV-2 transmission in the community (5, 7, 8, 12, 16).

Other studies showed a correlation between hotspots where many cases of COVID-19 have occurred and areas with high levels of air pollutants (6). Some studies have suggested that, in some areas, poor air quality may increase the risk of infection and lead to higher mortality from the disease (6, 9, 12, 16).

Evidence of a correlation between cases of COVID-19 and concentrations of nitrogen oxides (NOx) and ozone (O_3) was found in the UK (6, 8) as well as in 66 regions in Italy, Spain, France, and Germany (7, 9, 14, 15). Studies conducted in Northern Italy correlated the increased pollutant concentrations with high death rates in COVID-19 cases in the explored region (10, 11).

A preliminary analysis in the Netherlands also found evidence of a link between $PM_{2.5}$ levels and COVID-19 cases (13), concluding that a 1 $\mu g/m^3$ increase in $PM_{2.5}$ concentrations was associated with an 8% increase in COVID-19 mortality rates (16).

Based on convincing evidence of a link between air pollutants, $PM_{2.5}$ concentrations, COVID-19 cases in those areas, hospital admissions and deaths, a 1 μ/m³ increase in $PM_{2.5}$ concentrations was associated with 9.4 more COVID-19 cases, 3.0 more hospital admissions and 2.3 more deaths (12, 13). ❑

METHODS

Our study was carried out in Romania and included 43 cities (41 county capital cities and two localities in Ilfov County); each of them has between one and four automatic air quality monitoring stations, except for the city of Bucharest, where six stations are installed.

In order to assess PM_{10} and NO_2 exposure, we determined the average value of annual PM_{10} and NO_2 concentration for each city over five years (2015-2019). For this purpose, the average of annual PM_{10} and NO_2 concentrations collected from monitoring stations in the respective city was calculated. Then, the annual values over five years were averaged to finally obtain the average PM_{10} and NO_2 concentration for each city.

Data on the cumulative number of confirmed cases of COVID-19 up to the 28th of September 2020 were provided by the National Centre for Surveillance and Control of Communicable Diseases (CNSCBT) of the National Institute of Public Health (INSP) (17).

The present study used the cumulative incidence/hour *per* 1000 population on September 28, 2020, and the population size of each city which was known on January 1st, 2020, according to data from the National Institute of Statistics (17).

On September 28, 2020, there were 123,944 confirmed cases of COVID-19 (Figures 1 and 2) (17).

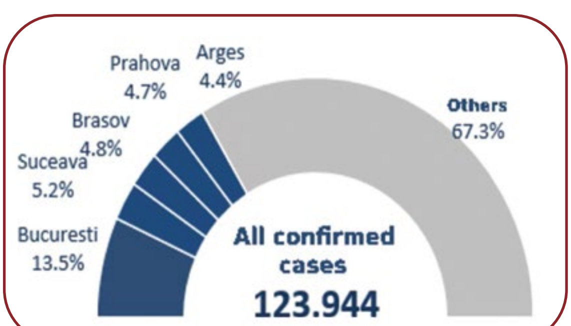

FIGURE 1. During 21-27 September 2020, according to data from INSP, 34.3% of all cases were registered in Bucharest, Iasi, Bacau, Constanta and Brasov

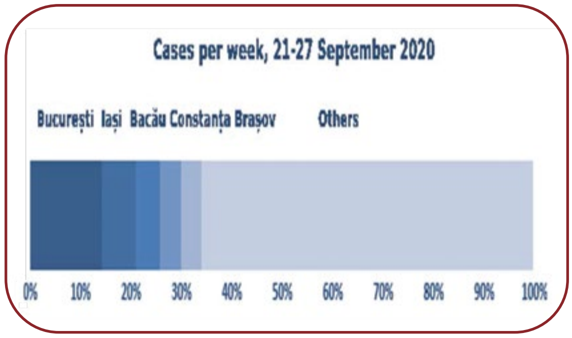

FIGURE 2. Cases *per* week, 21-27 September 2020, according to data from INSP (34.3% of all cases in Bucharest, Iasi, Bacau, Constanta and Brasov)

FIGURE 3. Cumulative incidence *per* 1000 inhabitants (September 28, 2020)

In 15 counties and Bucharest, there was a cumulative incidence rate above 100/1000 population. Data on PM_{10} pollution were provided by the Public Health Directorates and/or were obtained following Law no. 104/2011 on ambient air quality through the National Air Quality Monitoring System – SNMCA (17, 18).

Univariate statistical analysis, correlation and regression analysis were used to explore the collected data. A level of $P < 0.05$ was used to indicate statistical significance. Statistical analysis was performed using STATA MP Version 13.0. ❑

RESULTS

Cumulative incidence of confirmed Covid-19 cases *per* 1000 population, cumulative to September 28, 2020, for the 43 cities included in the present study (17, 18)

The incidence *per* 1000 people had an average value of 7.1±2.4, a minimum value of 2.2

in Satu Mare, and a maximum value of 13.7 in Suceava.

In 75% (32) of the 43 cities, the cumulative incidence was less than 8.8 *per* 1000 population. In 10% of the explored cities (4), the cumulative incidence was between 10.1 and 13.7 *per* 1000 inhabitants (Figures 3 and 4).

Average PM_{10} concentration values over five years (2015-2019) for each of the 43 cities surveyed in the present study (17, 18)

The permissible annual limit value of 40 μg/m^3 for PM_{10}, according to Law no. 104/2011, was not exceeded in any of the 43 cities in our study.

The average for all cities was 24.0±4.8 μg/m^3, with a minimum value of average PM_{10} concentration of 13.9 μg/m^3 measured in Alba Iulia and a maximum value of 39.1 μg/m^3 in Iasi.

The five-year average PM_{10} level remained below 26.7 μg/m^3 in 75% (32) of the 43 cities and varied between 29.8 μg/m^3–39.1 μg/m^3 in 10% (4) of the 43 cities.

Average NO_2 concentrations over five years (2015-2019) for each of the 43 cities surveyed in the present study (17, 18)

The annual limit value of 40 μg/m^3 for NO_2 concentration, according to Law no. 104/2011, was exceeded only in the city of Brasov, where the average concentration over five years was 41 μg/m^3.

The average for all cities in the study was 20.6±7.0 μg/m^3, with a minimum average NO_2 concentration of 11.3 μg/m^3 measured in the city of Balotesti, Ilfov County.

The average NO_2 level over five years has remained below 24.1 μg/m^3 in 75% (32) of the 43 cities and varied between 31.6–41.0 μg/m^3 in 10% (4) of the 43 cities (Figure 5).

PM_{10} and NO_2 exposure in the 43 cities included in the study and cases of SARS-CoV-2 infection (17, 18)

In order to investigate whether there is a link (a linear association) between PM_{10} and NO_2

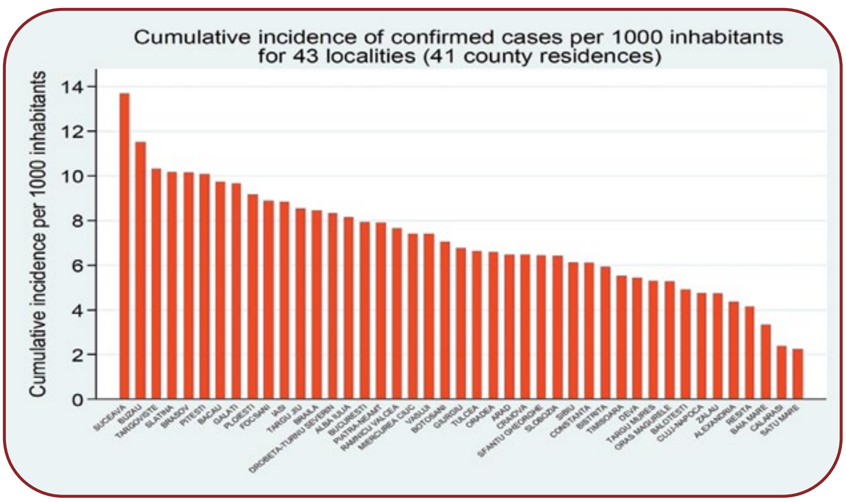

FIGURE 4. Cumulative incidence of confirmed Covid-19 cases *per* 1000 population, cumulated up to September 28, 2020, for the 43 cities included in the present study

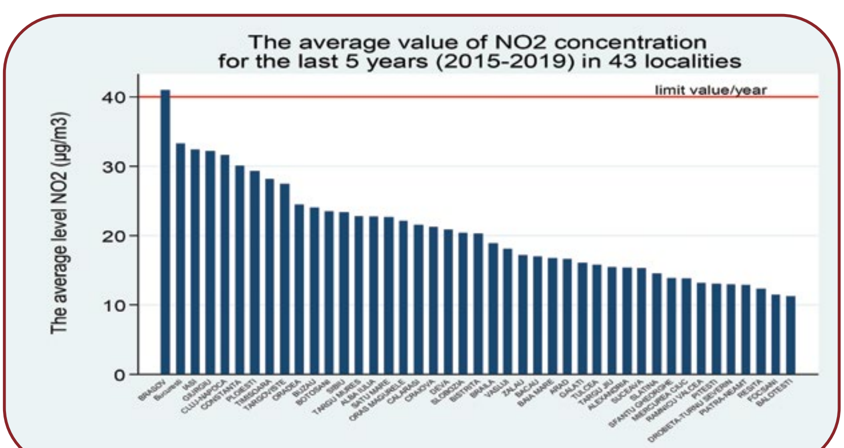

FIGURE 5. Average NO_2 concentrations over five years (2015-2019) for each of the 43 cities included in the present study

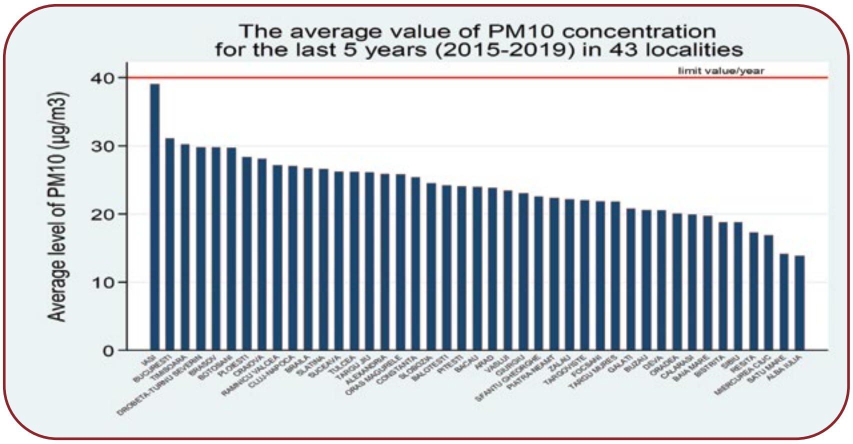

FIGURE 6. Average PM_{10} concentrations over five years (2015-2019) for each of the 43 cities included in the present study

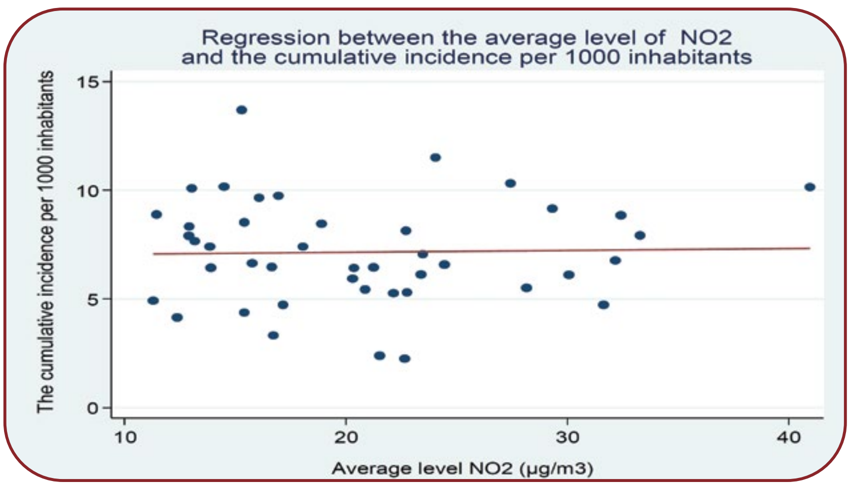

FIGURE 7. Regression equation between the average NO_2 concentration and the cumulative incidence of cases *per* 1000 population

exposure in the 43 cities and SARS-CoV-2 infections, a correlation analysis between the two pollution factors and the cumulative incidence of confirmed cases *per* 1000 population was performed.

Between the five-year average PM_{10} concentration and the cumulative incidence of cases *per* 1000 people, a Pearson correlation coefficient of 0.31, p=0.044, was found, meaning that there was a weak but statistically significant relationship between the two variables. In order to find out the relationship between the two variables, a regression analysis was carried out, which showed that for a one unit increase in the average PM_{10} concentration, the cumulative incidence of cases *per* 1000 people increased by 0.155 [p=0.044; confidence interval (CI) 95%: 0.004-0.31] (Figure 6).

The regression model shows that 9.55% of the variation in the cumulative incidence of cases is explained by the variation in PM_{10} concentration, which means that there are other determinant factors in the cumulative incidence of COVID-19 cases (Figure 7).

To find out the number of new cases that correspond to a cumulative incidence of 0.155, we took as an example a city with a population of 74,885 inhabitants among the 43 cities included in our study. From the above regression model, it follows that an increase in the average PM_{10} concentration by one unit was associated with 11.6 new cases.

From the correlation analysis between the average NO_2 concentration over five years and the cumulative incidence of cases *per* 1000 population, a Pearson correlation coefficient of 0.025, p=0.872, was found, which meant that the relationship between the two variables was negligible.

Average PM_{10} concentration over five years and cumulative incidence of cases *per* 1000 populationin Bucharest (17, 18).

The statistically significant association between the average PM_{10} concentration over five

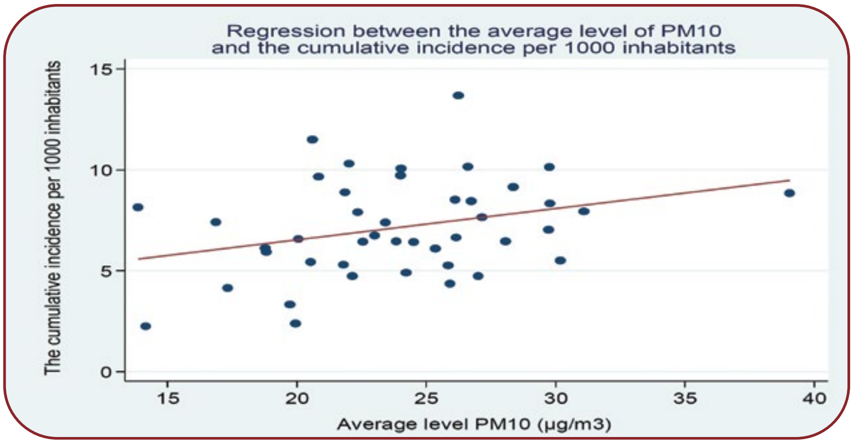

FIGURE 8. Regression between the average level of PM_{10} and the cumulative incidence of cases *per* 1000 inhabitants

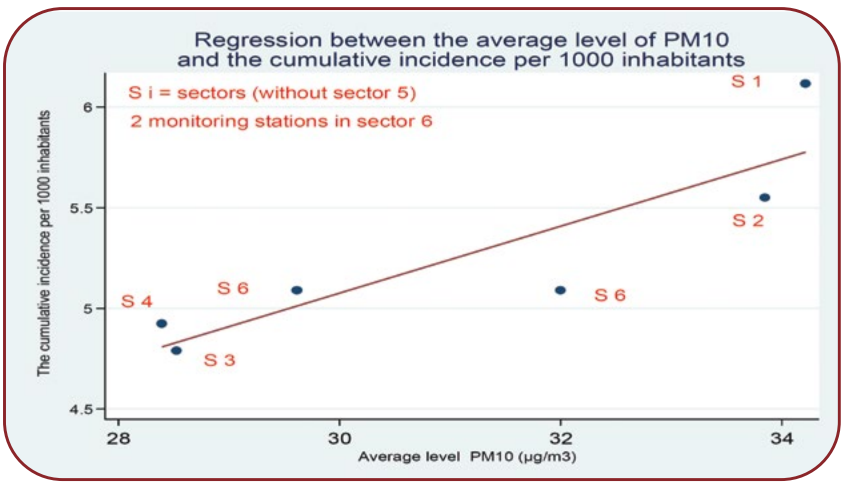

FIGURE 9. Regression equation between the average PM_{10} concentration and the cumulative incidence of cases *per* 1000 inhabitants in Bucharest

years and the cumulative incidence of confirmed COVID-19 cases *per* 1000 people for the 43 cities included in our study encouraged us to investigate whether the use of more detailed exposure and cumulative incidence data would lead to a stronger correlation between the two variables.

Next, a correlation and regression analysis for the city of Bucharest, with six installed automatic air quality monitoring stations (one in each of its first four districts and two in district 6), was performed. For each district we used the cumulative incidence of confirmed COVID-19 cases *per* 1000 population.

The relationship between the average PM_{10} concentration over five years and the cumulative incidence of cases *per* 1000 people was investigated.

The resulting Pearson correlation coefficient has a value of 0.88, p=0.019, which means a strong and statistically significant relationship between the two variables. In order to find out the relationship between the two variables, a regression analysis was carried out, which showed that for a one unit increase in the average PM_{10} concentration, the cumulative incidence of cases *per* 1000 inhabitants increased by 0.166 (p=0.02; CI 95%: 0.04-0.29) (Figure 8).

The regression model shows that in Bucharest, 77.9% of the variation in case incidence is explained by the variation in PM_{10} concentration (Figure 9).

In order to find the corresponding number of new cases for a cumulative incidence of 0.166, taking as an example one of the districts with a population of 259,084, the above regression model shows that an increase in the average PM_{10} concentration by one unit is associated with 43 new cases. ❑

CONCLUSIONS

Deterioration of air quality can have repercussions on our health, especially for persons at risk (children, elderly or people with comorbidities) – the more polluted the atmospheric air, the greater its effect on the human body, especially on the respiratory system, increasing vulnerability to pathogenic microorganisms (viruses and bacteria).

Data processed by us showed no correlation between the five-year average level of NO_2 in ambient air and the cumulative incidence of SARS-CoV-2 cases *per* 1000 people.

Our study found a positive correlation between the five-year average ambient PM_{10} level and the cumulative incidence of SARS-CoV-2 cases *per* 1000 population in 43 Romanian cities. The positive correlation is even more evident for the city of Bucharest.

Our study clearly shows the importance of air pollution with particulate matter (PM_{10}) and its impact on population health. Clinical studies have not yet confirmed the viability and virulence of SARS-CoV-2 trapped on the particle surface.

The present study demonstrates that population exposure to low levels of particulate matter in atmospheric air, below the permissible limit values but for a long time (the follow-up period in our study was five years, between 2015–2019), can have effects on the health status of the population, which becomes much more vulnerable to external agents (in our case, pathogenic microorganisms – viruses).

The reporting of specific respiratory infections (*i.e.*, COVID-19 cases) was accurate and in real time during the five-year follow-up period compared to the commonly used annual reporting of other acute respiratory infections, which helped us to make a correlation between air pollution and the cumulative incidence of COVID-19 cases as well as to establish a link between the average concentration of PM_{10} over five years and the cumulative incidence of COVID-19 cases *per* 1000 inhabitants.

It should be emphasized that our study has not analysed important factors which sometimes influence the cumulative incidence of SARS-CoV-2 cases, including – among the most widely known ones so far – age distribution, lifestyle (diet, smoking) and existing comorbidities (respiratory or cardiovascular disease, diabetes). Also, we did not consider for analysis the percentage of either the tested population or positive tests out of the total number of tests.

Another essential factor that was not taken into account in the present study was the population migration, which was variable from city to city.

During the study period, many Romanians who were unemployed abroad returned home from Italy, Spain, France, Germany, the UK and other countries where, initially, the number of cases was much higher than that recorded in Romania. ❑

Conflicts of interest: none declared.

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