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COMPARATIVE ANALYSIS ON AIR POLLUTION LEVEL OF BUCHAREST URBAN AREA DURING THE COVID-19 PANDEMIC

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Abstract

The pollution level of urban area is often high, mainly due to the traffic conditions that can lead to pollutant emissions such as nitrogen dioxide (NO_2) and particulate matter (PM), negatively affecting inhabitant's health. However, this level of traffic had a strong decrease, given the lockdown of the population imposed by the COVID-19 pandemic. Thus, the present paper is a comparative analysis on air pollution level, before and during the two periods of lockdown. For this, the concentrations of specific traffic pollutants, suspended particles (PM2.5) and nitrogen dioxide (NO_2), were monitored. According to the obtained results, PM2.5 values have been lowering with 37.5% and 54.8 %, in trend with those from San Jose (45%) or Los Angeles (41%). Likewise, NO_2 concentrations decreased with 62.3% in the first month and with 57.0% in the second month of the lockdown, similar with values recorded in London (40%) or Barcelona (70%). The analysis showed that air pollution can be reduced and considering the importance of heath for inhabitants, long-term solutions must be found.

Key words*: air pollution, COVID-19 pandemic, environmental monitoring, health effects.*

INTRODUCTION

According to the United Nations Environment Programme (UNEP), the leading global authority on the environment, "air pollution is the greatest environmental threat to public health globally" (unep.org), and is responsible for around seven million premature deaths, worldwide, every year (Siouti et al., 2024; WHO, 2021; unep.org).

The urban area seems to be the most affected by air pollution, mainly due to human activities, such as industrial activities, energy generation and transportation (Roșu et al., 2023; Feng et al., 2023). Among the most important air pollutants monitored in urban areas are particles with a diameter lower than 2.5 μm (PM2.5) (Siouti et al., 2024; Roșu et al., 2023; Cherecheș et al., 2023; Feng et al., 2023), and nitrogen dioxide (NO_2) (Cherecheș et al., 2023; Roșu et al., 2023; Velayarce et al., 2022; Zoran et al., 2020). All the mentioned studies described the well-known PM2.5 - aerosol particles, with chemical compositions, shapes and different origins, and NO_2, a chemical substance in gaseous state, yellowish-brown, irritating and toxic.

The main ambient sources of NO_2 are fuel burning, especially from means of transport, off-road equipment, housing heating systems, energy sector (power plants), etc. (Velayarce et al., 2022; Cherecheș et al., 2023; Fuller et al., 2020). The reasons for their monitoring are mainly linked to the harmful effects on health of inhabitants, especially respiratory, cardiovascular, and neurological or skin problems, presented extensively in a lot of research papers (Cherecheș et al., 2023; Zoran et al., 2022; Velayarce et al., 2022; Siouti et al., 2024).

Nevertheless, in the first part of 2020, internationally, a severe epidemiological situation occurred, because of the spread of SARS-CoV-2 in more than 150 countries, on March 11, 2020, the World Health Organization declaring the Pandemic State, being infected, at that moment, about 160,000 people and more than 5,800 dead.

In Romania, the first case of infected person appeared on February 26, 2020, and due to rapid evolution of coronavirus, the President of Romania declared throughout the territory, for a period of 30 days, between March 16 to April

15, the health emergency state (HES1), by (Decree no. 195 of March 16, 2020). The ascending evolution of SARS-CoV-2 epidemic, quantified by the number of infected persons and the registered number of deaths, after the entry into force of the mentioned decree, has led to extend by another 30 days, between April 16 to May 15, of the health emergency state (HES2) throughout Romania, by (Decree no. 240 of April 14, 2020).

The measures established by the two decrees had as their main purpose the limitation of the spread of the disease, but they also led to the limitation of people's movement, with the reduction of most economic activities and implicitly also of transports. This resulted in a considerable reduction in traffic and, as a consequence, a commensurate reduction in levels of urban pollution (Tobias et al., 2020).

This article presents a comparative analysis on urban air pollution level of Bucharest in terms of PM2.5 and NO_2 monitored concentrations, in three period of time from the beginning of 2020, namely before the establishment of the state of health emergency, between February 18 and March 15 (bHES), during the first decree (HES1) and during the second decree (HES2), the periods being above-mentioned. Images of Bucharest streets during the first period of health emergency state are presented in Figure 1 (https://visitbucharest.today/coronavirus-lockdown-the-fascinating-deserted-streets-of-bucharest/).

MATERIALS AND METHODS

The HAZ-SCANNER EPAS equipment for monitoring air quality parameters of the atmospheric environment is positioned within the platform of INCD - URBAN-INCERC, Bucharest, Romania near two boulevards with intense urban traffic (Figure 2). The mentioned instrument has data logging capabilities, and renders, in real-time, direct readings. The technical characteristics of HAZ SCANNER EPAS, manufacturer SKC, UK, are presented in the Table 1.

The concentrations of the two pollutants were monitored continuously, at 1-minute intervals, and, simultaneously the climate parameters, temperature and relative humidity.

Figure 1. Images from Bucharest streets during the first period of health emergency state (https://visitbucharest.today/coronavirus-lockdown)

Figure 2. HAZ-SCANNER equipment position compared to the two boulevards

Table 1. Details of HAZ-SCANEER EPAS equipment

Pollutant/ Climate parameter	Principle	Values range	Resolution
Particulate matter, PM2.5	Optical	0 - 5000 µg/m^3	1 µg/m^3
Nitrogen Dioxide, NO_2	Electrochemical	0 to 5000 ppb (0 to 5 ppm)	1ppb
Temperature, degree C	NTC thermistor	-4 to 140 F (-20 to 60 C)	1 degree F or C
Relative humidity, %	Thin-film capacitive	0 to 100%	1%

RESULTS AND DISCUSSIONS

The obtained results in the three periods of early 2020 - bHES, HES1 and HES2, were analysed to quantify the influence of lockdown measures on air pollution level of urban area of Bucharest. Regarding the PM2.5 concentration levels, it can be seen that they varied during the bHES period between 20.6 and 225.7 µg/m^3, with an average of 46.9 µg/m^3 and a median value of 39.3 µg/m^3; in the HES1 period, between 10.04 and 54.8 µg/m^3, with an average of 29.3 µg/m^3 and a median value of 29.6 µg/m^3; and in the HES2 period, between 12.01 and 33.8 µg/m^3, with an average of 21.2 µg/m^3, and 20.1 µg/m^3 median value. There is a decrease in PM2.5 concentrations during the two periods HES1 and HES2, both in the minimum values recorded, as well as in the maximum and average values, the average being between 37.5 and 54.8%.

The trend is similar to that recorded in cities like San Jose, with 45%, or Las Vegas and Los Angeles, with 41% (Antony Chen et al., 2020), in Milan between 37.1% and 47.4% (Collivignarelli et al., 2020), Delhi by 20.8%, Mumbai by 20.2%, Wuhan by 21.1%, Bangalore by 33.6%, Lima by 23.79%, London by 21.1% and Moscow by 30.5% (Kumari and Toshniwal, 2020). However, in some cities increases in PM2.5 concentrations were found, namely in United Kingdom of Great Britain (UK) by 28.2% (Ropkins and Tate, 2021), by 47% in Indianapolis and by 44% in Seattle (Chen et al., 2020). The summary of concentration variation for PM2.5 is shown in Table 2.

Nitrogen dioxide (NO_2) concentration values, recorded during the bHES period, varied between 21.8 µg/m^3 and 108.9 µg/m^3, with an average of 67.9 µg/m^3 and 66.7 µg/m^3 median value; in the HES1 period, between 5.6 µg/m^3 and 54.0 µg/m^3, with an average of 25.6 µg/m^3, a median value of 22.0 µg/m^3 and in the HES2 period, between 8.8 µg/m^3 and 78.4 µg/m^3, with an average of 29, 2 µg/m^3 and 28.4 µg/m^3 median value.

The findings are similar to those reported in other studies in large European cities, for example Barcelona or London, with reductions in NO_2 concentrations of 51% (Tobias et al., 2020) and 40% (Brown et al., 2021), Milan, with

64.7% (Zoran et al., 2020), cities in India such as New Delhi or Mumbai, with 60% and 78% respectively (Kumari and Toshniwal, 2020) or in the USA such as Las Vegas, Salt Lake City or New York, with 49%, 43% and 40% respectively (Chen et al., 2020). The values of concentration variation for NO_2 are summarized in Table 3.

The recorded values for climate parameters, temperature and relative humidity are represented in graphic form in Figures 3 and 4, and the summary of them in Table 4. From the data presented in Table 4, it can be observed that the temperature values varied in the analysed periods between 5.6^{0}C and 15.0^{0}C in bHES, between 2.8^{0}C and 17.5^{0}C in HES1 and between 9.7^{0}C and 24.1^{0}C in HES2, and the relative humidity had values between 32.8% and 98.6% in bHES, between 15.4% and 88.4% in HES1 and between 20.5% and 90.7% in HES2

Also, it was carried out a comparative analysis of the results obtained by monitoring the ambient air quality, with the levels provided by specific documents (Table 5), in force at European and international level, namely:

- Directive 2008/50 / EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.
- World Health Organization (WHO) (2021). WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

Table 2. Variation of PM2.5 levels in different cities of the world

Pollutant level Decrease (-)/ Increase (+) %	City/ Reference	Pollutant level Decrease (-)/ Increase (+) %	City/ Reference
-45	San Jose/ Chen et al., 2020	-23.79	Lima/Kumari and Toshniwal, 2020
-41	Las Vegas/ Chen et al., 2020	+28.2	Londra/Ropkins and Tate, 2021
-41	Los Angeles/Chen et al., 2020	+47	Indianapolis /Chen et al., 2020
-47.4	Milano/ Collivignarelli et al., 2020	+44	Seattle/Chen et al., 2020
-21.1	Wuhan/Kumari and Toshniwal, 2020	-18.84	Cluj-Napoca/Cherecheș et al., 2023
-33.6	Bengalore/Kumari and Toshniwal, 2020	-37.5; -54.8	Bucharest/Current study

Table 3. Summary of values levels for NO_2 around the world

Pollutant level Decrease (-)/ Increase (+) %	City/ Reference	Pollutant level Decrease (-)/ Increase (+) %	City/ Reference
-51	Barcelona/ Tobias et al., 2020	-43	Salt Lake City/Chen et al., 2020
-40	London/ Brown et al., 2020	-40	New York/Chen et al., 2020
-64.7	Milan/Zoran et al., 2020	-15	Atlanta/Chen et al., 2020
-78	Mumbai/Kumari and Toshniwal, 2020	-13; -23.4	Cities from Ecuador/Pacheco et al., 2020
-60	New Delhi/Kumari and Toshniwal, 2020	-60: -40	Lima/Velayarce et al., 2022
-20.1	Vienna/Brancher, 2020	-33.45	Cluj-Napoca/Cherecheș et al., 2023
-49	Las Vegas/Chen et al., 2020	-57; -62.3	Bucharest/Current study

Table 4. Values levels of climate parameters in the three periods of 2020

Period	Climate parameters Average (min/max/median) Temperature, ^{0}C	 Relative humidity, %
bHES	10.0 (5.6/15.0/9.5)	67.9 (32.8/98.6/67.9)
HES1	11.1 (2.8/17.5/11.2)	35.3 (15.4/88.4/32.6)
Variation, %	+11.0	-48.0
HES2	16.5 (9.7/24.1/16.5)	44.5 (20.5/90.7/42.9)
Variation, %	+65.0	-34.5

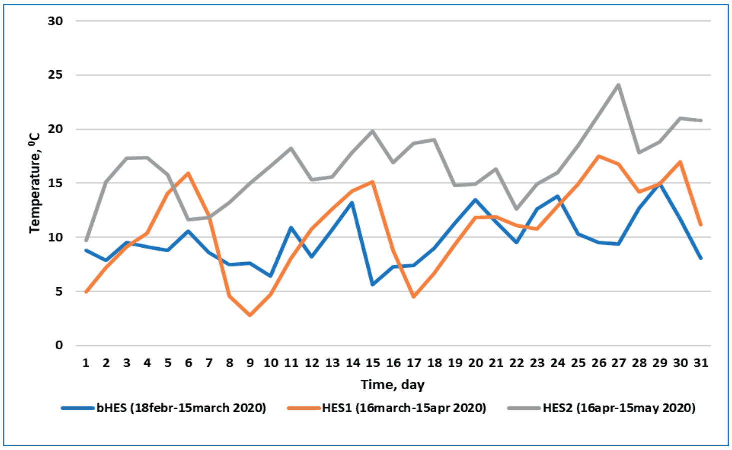

Figure 3. Variation of one of climate parameters – temperature in the analysed periods

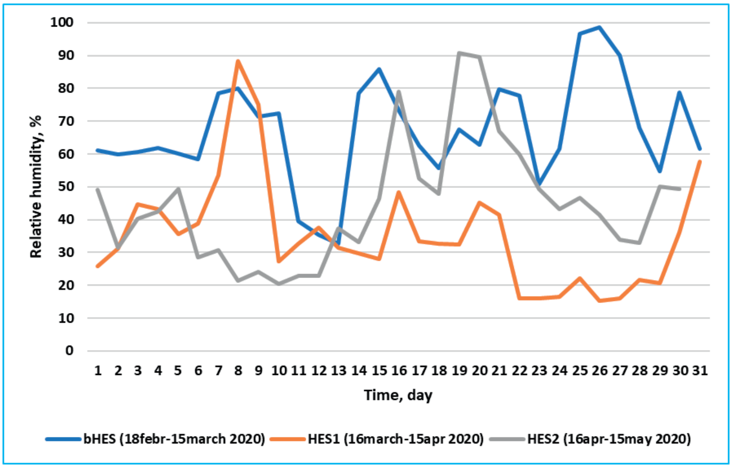

Figure 4. Graphical form of recorded values for relative humidity during the three periods

Table 5. The levels of PM2.5 and NO_2 concentrations, from two specific documents

Pollutant	Averaging time	Admissible level
WHO global air quality guidelines 2021		
PM2.5, $\mu g/m^3$	Annual	5
	24-hour	15
NO_2, $\mu g/m^3$	Annual	10
	24-hour	25
Directive 2008/50/EC		
PM2.5, $\mu g/m^3$	Annual	20
NO_2, $\mu g/m^3$	Annual	40

Figures 5 and 6 represent in graphic form the comparative analysis of the monitored values of the two pollutants, PM2.5 and NO_2, with the limits provided by the two specific documents mentioned, during the three periods studied.
Thus, from the analysis of the recorded levels for PM2.5, it is found that they exceeded the limit value of 20 $\mu g/m^3$, provided by Directive 2008/50/EC, for a period of one year, on all days of the bHES period, in a proportion of 80% of the days of the HES1 period and in 55% of the days of the HES2 period.

The limit of 5 $\mu g/m^3$, for one year, provided by the WHO Guideline 2021, was exceeded in all three studied periods, and the limit of 15 $\mu g/m^3$, provided by the same document for 24 hours was exceeded in a proportion of 100% on the days of bHES period, on 95% of the days of the HES1 period and 95% of the days of the HES2 period.
The comparative analysis of NO_2 levels with the annual limit of 40 $\mu g/m^3$, provided by Directive 2008/50/EC, reveals that in the period February-March 2020 (bHES) most of the average values were above the specified limit, while during the two periods, HES1 and HES2, the average values of NO_2 levels exceeded this limit in only a few days.
Comparing the recorded values of NO_2 concentrations with limit of 10 $\mu g/m^3$ for one year period from WHO Guideline 2021 it can be observed that the obtained results are over this limit in all three studied periods, and comparing with the limit of 25 $\mu g/m^3$ for averaging time of 24-h, in the bHES period all values are over the mentioned limit, and in HES1 and HES2 periods, a proportion of about 50% of monitored values are over the limit.

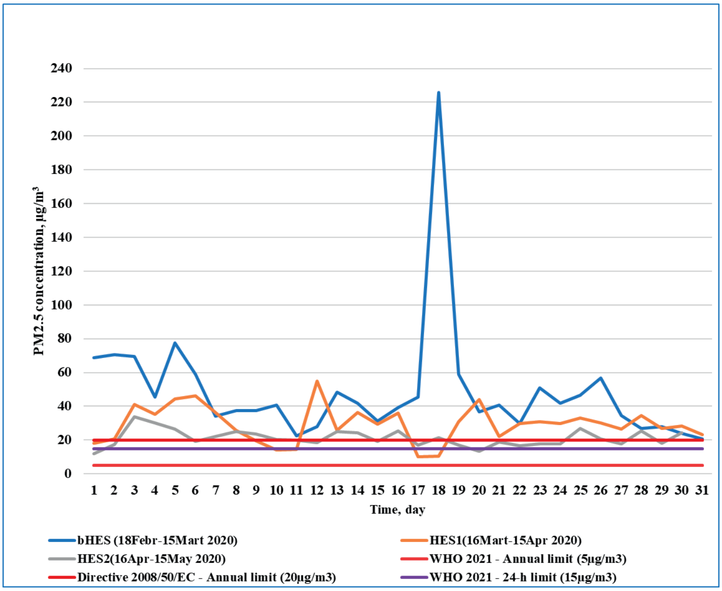

Figure 5. Comparative analysis of PM2.5 concentrations with the limits given in the specific documents

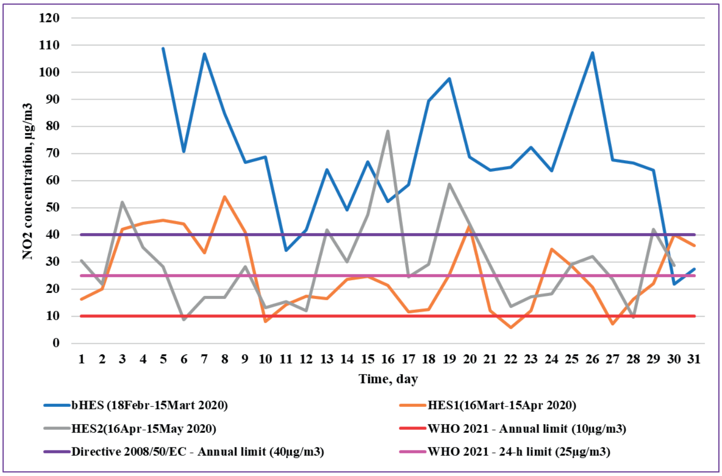

Figure 6. NO_2 concentrations analysis compared to the thresholds from the specific documents

CONCLUSIONS

The industrial development of human societies has brought a lot of advantages to ease daily life, but some activities have become generators of problems for the health of people and the environment. The COVID-19 pandemic proved to be the hard way for humanity to learn that pollution problems can be mitigated through various short-term measures. Thus, our paper carried out a comparative analysis of the levels of PM2.5 and NO_2, two pollutants with sources from different types of human activities, levels recorded both before the establishment of the state of health emergency (bHES) due to the upward evolution of the COVID-19 pandemic, and during the two periods of lockdown (HES1 and HES2). Moreover, the obtained results were compared with the levels provided by specific documents, in force at European and international level, namely: Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, and World Health Organization (WHO) global air quality guidelines, updated in 2021.
Regarding the levels of PM2.5 it was observed that there was a significantly decrease in PM2.5 concentrations during the two periods HES1 and HES2, both in the minimum values recorded, as well as in the maximum and average values, the average being between 37.5 and 54.8%, the findings being similar to those reported in other studies carried out in European or international cities. For NO_2 concentrations, there was a decrease of 62.3% in the first month and of 57.0% in the second month of the lockdown, also similar with values recorded worldwide.
From the comparison of the PM2.5 recorded values with the limit value of 20 µg/m^3, provided by Directive 2008/50/EC, for a period of one year, an overshoot of this limit can be seen on all days of the bHES period, in a proportion of 80% of the days of the HES1 period and in 55% of the days of the HES2 period. Also, the limit of 5 µg/m^3, for one year, provided by the WHO Guideline 2021, was exceeded in all three studied periods, and the limit of 15 µg/m3, provided by the same document for 24 hours was exceeded in a large proportion in all studied periods.
The annual limit of 40 µg/m^3, provided by Directive 2008/50/EC, NO_2 levels was exceeded in the period February-March 2020 (bHES), while during the HES1 and HES2 periods, the average values of NO_2 levels exceeded this limit in only a few days. Comparison of the recorded values of NO_2 concentrations with limit of 10 µg/m^3 for one year period from WHO Guideline 2021 lead to the conclusion that obtained results are over this limit in all three studied periods, and comparing with the limit of 25 µg/m^3 for averaging time of 24-h, in the bHES period all values are over the mentioned limit, and in HES1 and HES2 periods, a proportion of about 50% of monitored values are over the limit.
The conclusions of this analysis showed that air pollution can be reduced, one of the lessons of

COVID-19 pandemic being the possibility to implement, for health reasons, major measures in human societies, changes that seemed impossible having become reality in a few days. We can only hope that mankind will have learnt from this sad experience, and keeping of urban pollution at a low level, will become an essential concern of inhabitants.

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