Heliyon 9 (2023) e18918

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Air quality changes in NE Romania during the first Covid 19 pandemic wave

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A R T I C L E I N F O

Keywords:
Air quality
Covid-19 outbreak
Meteorology
Atmospheric pollution

A B S T R A C T

This study analyzes for the first time uniformly and causally the level of pollution and air quality for the NE-Romania Region, one of the poorest region in the European Union. Knowing the level of pollution and air quality in this region, which can be taken as a benchmark due to its positional and economic-geographical attributes, responds to current scientific and practical needs. The study uses an hourly database (for five pollutants and five climate elements), from 2009 to 2020, from 19 air quality monitoring stations in northeastern Romania. Pollutant levels were statistically and graphically/cartographically modeled for the entire 2009–2020 interval on the distributive-spatial and regime, temporal component. Inter-station differences and similarities were analyzed causally. Taking advantage of the emergency measures between March 16 and May 14, 2020, we observed the impact of the event on the regional air quality in northeastern Romania. During the emergency period, the metropolitan area of Suceava (with over 100,000 inhabitants) was quarantined, which allowed us to analyze the impact of the quarantine period on the local air quality. We found that, in this region, air quality falls into class I (for NO_2, SO_2 and CO), II for O_3 and III for PM_{10}. During the lockdown periods NO_2 and SO_2 decreased for the entire region by 8.6 and 14.3%, respectively, and in Suceava by 13.9 and 40.1%, respectively. The causes of the reduction were anthropogenic in nature.

1. Introduction

Air quality in the North-East Region of Romania (RNER) has not been fully researched, only limited observations are available so far. A few aspects of RNER air chemistry are known from the few published studies [1–6].

Global warming due to air pollution is a major problem in today's world. Scientists have established a long-term relationship between population growth, production, air pollution and global warming [7]. The impact of pollution on the air environment and human health is real and growing [8–10].

The start of the pandemic declared at the beginning of 2020 by the World Health Organization (O.M.S.), due the appearance of the

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https://doi.org/10.1016/j.heliyon.2023.e18918
Received 29 October 2022; Received in revised form 1 August 2023; Accepted 2 August 2023
Available online 9 August 2023

new Sars-Cov-2 virus that spread very quickly and uncontrollably, brought positive consequences on the environment [11]. The suspension of many industrial activities, the limitation of road and air transport around the globe have led to a decrease in the levels of pollutants in the atmosphere. Air quality studies have been conducted in large, densely populated urban areas, but also in rural areas to demonstrate these changes. In most research, the authors' attention was focused on the analysis of NO_2, SO_2, CO, PM_{10}, $PM_{2,5}$, O_3 levels.

In order to reduce the risk of population infection with Sars-Cov-2, measures have been imposed to drastically restrict traffic, with an impact on many economic and social activities, which have had as end effect a reduction of air pollutants in many cities or regions. These reductions have been reported for different periods of the pandemic and for different regions of the world from both satellite observations and in situ measurements [12–23].

Research teams [19,24,25]. noted (based on data from NASA, ESA, Copernicus Sentinel - 5P Tropomi Instrument and CREA) that pollution in many Sars-Cov-2 epicenters (from China, USA, Brazil, but also from European countries such as Italy or Spain), were reduced in the restriction period by more than 30%. With the help of the Tropomi instrument, mounted on the Copernicus Sentinel-5P satellite launched by Russia on October 13, 2017, clear decreases in NO concentrations were observed in all continents, and in megalopolises and metropolises, reductions in NO amounts on the tropospheric air column were between 14% and 63% [26]. During the emergency period, data from satellite and ground-level observations showed large but variable reductions in NO_2 concentrations in different regions of the US, China, South Korea, Europe (Western Europe, northern Italy, the Netherlands) [27–30].

[31,32] showed a 10% decrease in $PM_{2,5}$ air concentrations in the largest cities in the world, synchronous with the increase in ozone concentrations. In the USA, studies have shown an uneven reduction in NO_2 and CO in territorial profile [33,34]. The same studies showed a significant reduction in $PM_{2,5}$ and PM_{10} also in the NE and SW regions (California and Nevada). The general improvement in air quality and the decrease in NO_2 concentration during the Covid 19 pandemic in Atlanta (USA) was due to a decrease of over 50% in human activities shown by the satellite observations and ground observations [35]. In India, after the lockdown between March 24 and April 12, 2020, the rate of improvement in air quality was also high [36]. Also in India, according to data obtained from NASA, a 50% decrease in air pollutants (dust, nitrogen oxides) was observed during the lockdown [37]. During the emergency period, NO_2 levels in China and India fell by about 30% and 70%, respectively, and in Europe, the level of pollution fell by 25% in Spain and by 30% in France and Italy [38].

Across the European continent, there has been a decrease in NO_2 concentrations by between 5 and 55% [39]; Tobias et al., 2020) and an increase in ozone concentrations [40]. Studies conducted by the European Environment Agency [41] show a decrease in NO_2 concentrations in 2020 compared to 2019 in all cities analyzed, PM_{10} concentrations were significantly lower than in 2019, and O_3 concentrations were higher in 2020 compared to 2019 (EEA, 2020). The European Space Agency stated air pollution was reduced as a result of quarantine. In Madrid, Milan and Rome there were decreases in NO_2 concentration of up to 45%, while in Paris this decrease even reached 54% (ESA, 2020). A study conducted in the UK revealed an improvement in air quality during the state of emergency, by decreasing the concentrations of NO, NO_2 and NOx in the atmosphere and an increase in O_3 concentrations [42]. [43] show in their study that, in 2020, the most significant reduction in NO_2 concentrations as a result of the reduction in traffic was highlighted in Portugal [44,45]. sounded the alarm that heavy air pollution is a favorable context for the spread of viruses, a fact observed in northern Italy where continued exposure to pollutants such as PM_{10} and $PM_{2,5}$ was the main cause of the large number of COVID-19 cases [46]. observed that the introduction of restrictive measures in Budapest has resulted in a decrease in road traffic of vehicles up to about 50% during the most severe restrictions, in parallel with the decrease in concentrations of NO, NO_2, CO, N, PM_{10}, $PM_{2.5}$, while O_3 concentrations tended to increase. The intentional decrease in traffic intensity has led to improved urban air quality.

'Telework' and 'online school' put road transport on a longer hiatus, resulting in a significant reduction in NO_2 concentrations (in Central European urban areas there were average reductions of up to two weeks at 55% in the second half of March) [47].

In Romania [48], noticed that in the emergency period the reduction of the circulation led to the improvement of the air quality [49]. showed a slight decrease in PM_{10} concentrations in the capital city Bucharest, during the state of emergency (March 16-May 13, 2020) compared to the same period in 2011–2019. Another case study conducted in Bucharest on NO_2 concentrations shows the same decreasing trend as in other cities in Europe, only some sudden increases could be observed due to fires in landfills [50]. NO_2 concentrations recorded at the in situ stations in the city of Galati (SE Romania), during the state of emergency, decreased between 10 and 40%, at some stations, being best highlighted during the working days [51]. In April 2020, during the state of emergency, the levels of $PM_{2.5}$ and PM_{10} decreased also in Brașov, the most important tourist center in Romania [52].

In this context, we focused our study to the analysis of the situation of pollutant concentrations in the NE Region - Romania (RNER). We propose a unitary causal assessment for the first time of air quality in this region, a comparative regional assessment of the air quality from the emergency period between March 16 - May 14, 2020 imposed by the COVID 19 pandemic (Ep) with the one from the reference period March 16 - May 14, 2009–2019 (Rp) and an assessment for the municipality of Suceava and the neighboring localities of quality air in the time period of the emergency period March 16 - May 14, 2020 (Ep) and quarantine March 30 - May 14, 2020 (Qp) imposed by the COVID 19 pandemic.

The present study started from two premises: that of the comprehensive ignorance of air quality in RNER, a shortcoming that needs to be remedied and the second premise was that a two-month Ep (in the case of AMSv a 2-week Ep followed by a Qp of 6 weeks) should result in improved air quality parameters (reduction of pollutant levels and air quality indices to indicate a cleaner atmosphere). The assumed objectives are: i) unitary causal assessment for the first time of air quality in RNER – this regional study can be taken as a benchmark in comparative analyses of air quality for other regional studies), ii) regional assessment of air quality in EP imposed by COVID 19 pandemic compared to the one in Rp, iii) the assessment for the Suceava Metropolitan Agglomeration (AMSv) - the only one of such a size that was quarantined in Romania - of the air quality in the time window Ep and Qp imposed by the COVID 19 pandemic.

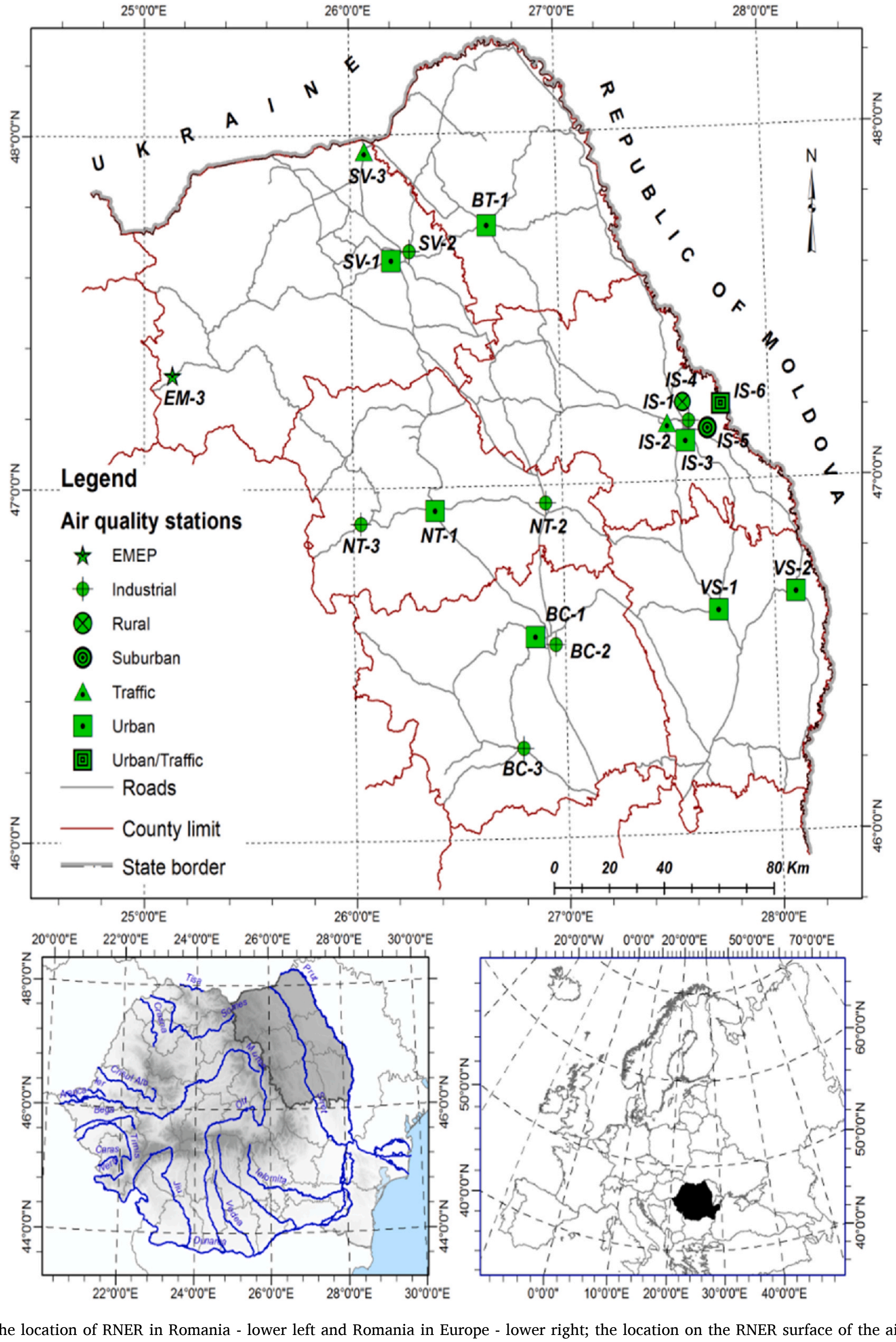

Fig. 1. The location of RNER in Romania - lower left and Romania in Europe - lower right; the location on the RNER surface of the air quality monitoring stations and their typology – top.

1.1. Means, methods and data

The stages of the analysis consisted of: i establishing the average and extreme levels for all determination points and for each pollutant of the five monitored, respectively for the monitored meteorological elements based on their concentrations/diurnal values resulting from hourly data with their statistical, graphical and cartographic modeling, ii) correlation of the diurnal levels of pollutants with the determining environmental factors, with special attention on the meteo - climatic factors, iii) focusing the analysis of the diurnal/hourly levels of the pollutants on Ep/Qp, with their relation to Rp for RNER and as a case study for AMSv (Fig. 1).

The study was based on the analysis of hourly and daily air quality data and hourly values of meteorological elements from January 1, 2009 to December 31, 2020) from 19 air quality monitoring stations located in NE Romania. This data is available free of charge on the site https://www.calitateaer.ro/public/home-page/?locale=ro.

Other similar studies used for different regions ground data (example: [36]; for New Delhi), satellite data (examples [36]: for India [26], for several European cities and extra-European) or a combination of both (for example: [53]; in China).

The means of determining pollutant levels and methods of determination were the standard ones used throughout the EU network (Table 1 - Supplementary material - Sm).

The downloaded time data were validated according to the validation rules. Hourly averages, daily averages and monthly averages were then calculated using Microsoft Office - Excel. Graphical representation of data over different time intervals was performed through the Pycharm and Grapher programs. By boxplot type graphs we represented the basic, multi-annual parameters of the levels of air pollutants and meteorological elements. Boxplot charts were made in the Python programming language (in the Pycharm program), using different libraries (algorithms already implemented by researchers) both for retrieving data from the Excel document and for creating the actual charts. The Grapher program allowed us to represent the average annual regime or time regime sequences of pollutants and meteorological elements focused on the Rp and Ep intervals. The general maps of the location of the researched area and the thematic ones with the levels of pollutants in the atmosphere were made in ArcGIS 10.4, and the cartographic representations with land cover and land use around the pollutant levels were based on satellite images and the Corine Land Cover 2018 classification system. (http://geoportal.ancpi.ro/geoportal/imobile/Harta.html).

All the results obtained were reported to the limit values in Table 2 - Sm. The results were interpreted according to these limit values, which are set by Law no. 104/June 15, 2011 on ambient air quality published in the Official Gazette, Part I no. 452/June 28, 2011, in accordance with European Directives 2008/50/EC and 96/62/EC.

Positive thermal anomalies for RNER were detected by the instruments MODIS (with Aqua and Terra satellites), VIIRS (with Suomi National Polar-orbiting Partnership - Suomi NPP and National Oceanic and Atmospheric Administration-20 - NOAA-20 satellites. The data source was the platform https://firms.modaps.eosdis. nasa.gov/download/(accessed on July 24, 2021), from which the images of MODIS Collection 6.1 (Temporal Coverage: November 11, 2000 - present), VIIRS S-NPP 375 m (Temporal Coverage: January 20, 2012 - present) and VIIRS were taken NOAA-20 375 m (Temporary Coverage: January 1, 2020 - present). MODIS data is extracted from images with a spatial resolution of 1 km, and in the case of VIIRS images the spatial resolution of the data increases to 375 m. Given that we used all three data sources, there were situations when two or more satellites detected the same positive thermal anomaly. To eliminate an overestimation of the number of positive thermal anomalies detected at the level of each 10 km buffer around each station we applied a series of corrections to eliminate identical points.

Thus, we used the geographical coordinates and the temporal moment of the data acquisition to eliminate the identical (overlapping) elements and keep the unique elements. Next, vector geoprocessing techniques were applied, respectively statistical accounting both in bulk (annually) and for the period March 16-May 14, 2009–2020 at the level of each air quality monitoring station. We also identified cases when certain positive thermal anomalies had to be classified in two or more buffers, due to the proximity of the stations (examples: SV1 with SV2; IS1 with IS2, IS3, IS4, IS5, IS6; BC1 with BC2). However, the number of common anomalies has been maintained in order to have a real situation in the diameter of 10 km around each station. And in this case, in order to avoid an overestimation of the number of positive thermal anomalies, we considered only the unique elements on each buffer in chronological order. Regional information on the area burned, the number and size of fires was extracted from the platform https://gwis.jrc.ec.europa. eu/apps/country.profile/overview/ROU accessed on July 24, 2021.

2. Results

2.1. Sources of air pollution for RNER

The atmosphere of the RNER is affected by emissions from a multitude of stationary pollution sources (industrial enterprises and economic agents in the agricultural sector), mobile, transport (car, rail and air) to which are added the diffuse *surface sources* represented by the household combustion plants, temporary waste storage platforms, etc. All these polluting sources are analyzed in detail in Sm.

2.2. Regional or local factors that amplify or reduce RNER pollution

Atmospheric pollution and air quality in the RNER are dependent on the regional specificity of geographical factors such as landforms, presence, typology and area occupied by aquatic or wetland units, typology, characteristics and area occupied by different plant formations, soil cover features, but also of meteorological factors and elements. Extensive information on these regional factors for determining the level of pollutants and air quality is presented in more detail in Sm.

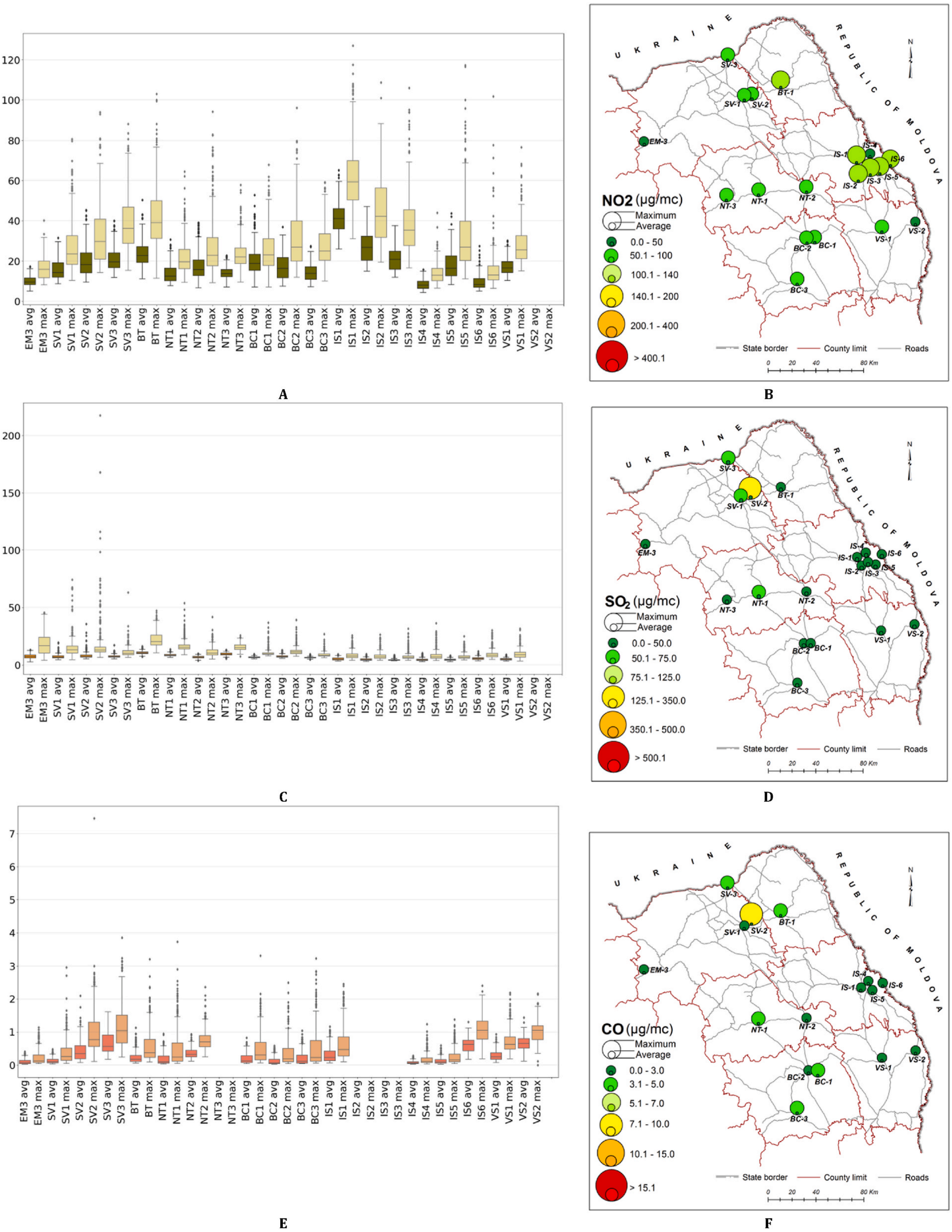

Fig. 2. Average and maximum diurnal NO_2, SO_2 and CO levels (µg m-3) for RNER stations with reference to the interval 2009–2020 (boxplot diagrams A, C, E, maps B, D, F the diameter of the circles is related to the level of the pollutant; the color renders the quality class according to the Qi thresholds).

Detailing on real data the links of statistical interdependence between the level of pollutants and the values of meteorological elements we can observe aspects that generally escape the assessments and deductive logic. An analysis of the main components (PCA) indicates differentiated models in different degrees of the relations between the parameters of the analyzed pollutants (NO_2, SO_2, CO, O_3, PM_{10}) and the elements or a series of parameters of the meteorological elements (GR – global radiation, T – air temperature, RH – air humidity, P – air pressure, W – wind speed). The axes representing factors/dimensions 1 and 2 explain between 77.12 and 83.32% of the variation of the pollutant level in relation to the values of the meteorological variables. These observations suggest that almost all parameters should be kept for inclusion in the analysis, as there are no other parameters that can replace the meteorological parameters considered (Fig. 1 – Sm).

We present more in detail (Sm) the links between the level of pollutants and the values of meteorological elements, because we consider that this two factors could generate differentiations between the level of pollutants during Ep related to Rp, namely: reducing the pace of economic and social activities and differentiating the values and regime of meteorological elements.

The characteristics of the urban network, the size of the cities and the urban factors themselves can favor or prevent self-purification of the air. The territorial distribution of urban localities is a factor with an important role in terms of air quality. The spatial dispersion of urban localities in RNER is not balanced. There are several areas without cities within a radius of 25–30 km (as east of Bacău county - west of Vaslui county), which makes the air pollution lower and the air quality good. As a contrast in the urban regions with high population densities (as Iași and Bacău), the amount of pollutants emitted as a result of human activities is high and air quality is worsening. In addition, the complex architectural profile, the high density of buildings, the extremely varied composite materials from which they are built, the narrow and poorly ventilated streets, the small areas of green space, the small number of artesian wells, hinder the self-purification process and reduce air quality.

In order to have a detailed picture of the location of the air quality monitoring stations in RNER, we extracted 19 buffers assimilated to squares with a side of 1 km and which placed at the intersection of their diagonals the air quality monitoring stations (Fig. 2 - Sm). The analysis of the characteristics and the use of the topographic surface around each station, can give us valuable information about the values of the levels of pollutants and about the specifics of their variability. In order to have a comprehensive and unitary vision on the projection of the geographical and local site factor, respectively technically, we made a rating (by notes from 1 to 5) of the 5 factors that leave their value or other imprint on the data provided by each station in part. We selected 3 location factors (local location of the station related to the elements of the physical-geographical framework, location of the station related to the surrounding anthropogenic elements, the degree of shading or obstruction of the horizon around the station) to which we gave grades from 1 to 5 and which together hold 60% of the share of the final grade. The other two technical factors (the level of equipment with sensors of the stations and the data capture obtained) were given 40% of the weight of the final grade. After calculating the averages from the marks awarded for each factor, a hierarchy of 3 categories of stations resulted: i) those with averages below 3 (IS6, VS2 – where there were problems of location, equipment and continuity of observations), ii) those with averages below the value 4 (SV3, EM3, VS1 – with small problems at the level of some of the considered factors) and iii) those with averages ≤ with 5 (BT1, SV1, SV2, I3, IS4, IS5, NT1, NT2, NT3, BC1, BC2, BC3) where all site and technical requirements have been met.

2.3. Air quality at regional level

Mention should be made that this study is the first to assess the air quality in the RNER, located on the EU's eastern border.

2.3.1. 1 air quality at regional level analyzed on the basis of the levels of specific pollutants

Calculating the average diurnal level of NO_2 on the whole RNER (2009–2020) we obtained the value of 18.3 μgm^{-3}, which shows us that the degree of air pollution with this gas is very low, inscribing the quality indices of the atmosphere of the region as a whole in quality class 1. The lowest mean daily NO_2 levels for the research period were calculated for IS4 (8.4 $\mu g\ m^{-3}$), and the highest for IS1 (41.4 $\mu g\ m^{-3}$) (Fig. 2a). The standard deviation of the daily NO_2 levels from the whole region was 5.2 (2.3 at VS1 and 7.4 at BC1). According to the average diurnal Qi levels of the air, all the monitoring stations were classified in quality class I. The maximum diurnal NO_2 levels rose to values between 40.2 μgm^{-3} at EM3 and 127.0 $\mu g\ m^{-3}$ at IS1. According to the maximum diurnal levels of NO_2, the air quality classes were between I for EM3 respectively IS4 and III for the following stations: BT1, IS1, IS2, IS3, IS5 and IS6 (Fig. 2b).

At a more detailed level, the statistical calculations show that, for the entire RNER, the percentage of hours that were included in quality classes I-III (from excellent to good - Table 1a) was 84.7%, and that of the hours that were classified in quality classes IV-VI (from medium to very bad) was 15.3%.

At some monitoring stations the air quality was better than the region average (example: EM3 with percentage values of 99.2 and 0.8% respectively), and at others it was worse (example: IS1 with percentage values of 36.1 and 63.9 respectively %).

Calculating the average diurnal level of SO_2 on the whole RNER we obtained the value of 6.6 $\mu g\ m^{-3}$, which shows us that the degree of air pollution with this gas is very low, inscribing Qi of the region's atmosphere on its whole in quality class I. The lowest mean diurnal SO_2 values for the research period were calculated for IS3 (4.4 $\mu g\ m^{-3}$), and the highest for BT1 (10.5 $\mu g\ m^{-3}$). The standard deviation of the daily values of SO_2 levels was for the whole region of 1.2 (0.6 for BC3 and 3 for SV2). The mean diurnal levels of Qi of the air included all monitoring stations in quality class I. The maximum diurnal levels of SO_2 rose to values between 24.9 $\mu g\ m^{-3}$ at IS5 and 217.7 $\mu g\ m^{-3}$ at SV2. According to the maximum diurnal levels of SO_2, at 15 monitoring stations the air quality classes had the value I, at 3 stations the value II, and at SV2 the value III (Fig. 2c).

The highest level for this compound was recorded at SV2 in the vicinity of which (less than 1 km) is the AMBRO company, which constantly pollutes its surroundings with this gas (Fig. 2c). At this station, the variability of the meteorological factor induced the highest value fluctuation of this pollutant (Fig. 2d).

Based on the hourly levels, the statistical calculations for SO_2 show that, for the whole region, the percentage of hours that were included in quality classes I-III (from excellent to good - Table 1b) was 99.98%, and that of the hours that were classified in quality grades IV-VI (from medium to very bad) was only 0.02%. At most monitoring stations (13 stations) the air quality according to the hourly level of SO_2 was excellent throughout the period 2009–2020. At SV1, SV2, SV3, BT and NT1 there were a reduced number of hours with very good air quality, at SV1, SV2 and BC2 hours with good air quality, and at SV2, SV3 and BT hours with average quality of the air (Table 1b).

The mean diurnal CO level for the entire RNER in the period 2009–2020 was 0.3 μgm-3 (between the minimum of 0.1 μgm-3 at five monitoring stations and the maximum of 0.7 μgm-3 at SV3 and VS2). Based on the average diurnal values, from all stations, over the whole period 2009–2020, we can appreciate that the specific indices for CO indicated an excellent air quality. The standard deviation of the daily values of CO levels was at the regional level of 0.2 (between 0.1 at 7 monitoring stations and 0.3 at SV2 and SV3). The diurnal maxima were between 1.1 μgm and 3 at EM3 and 7.5 μgm-3 at SV2 (Fig. 2e).

Taking as a benchmark the maximum diurnal values of CO levels, at most stations the air quality was excellent (10 stations out of 16 for which we had data). At five stations the air quality was very good and only at SV2 it was average (Fig. 2f).

The hourly levels of CO show for the whole region that the percentage of hours that were in grades I-III (from excellent to good - Table 1c) was 99.998%, and that of the hours that were in quality grades IV-VI (medium to very bad) was 0.002%.

At most monitoring stations, the air quality, depending on the hourly CO level, was predominantly excellent throughout the period 2009–2020. At most stations there were also hours with very good air quality, at six stations there were hours with good air quality and only at SV2 there were also hours with average air quality, but their percentage was extremely low (0.002%).

The mean daily O_3 level for the entire RNER and the 2009–2020 range was 45.6 μg m^{-3}. The multiannual diurnal averages ranged

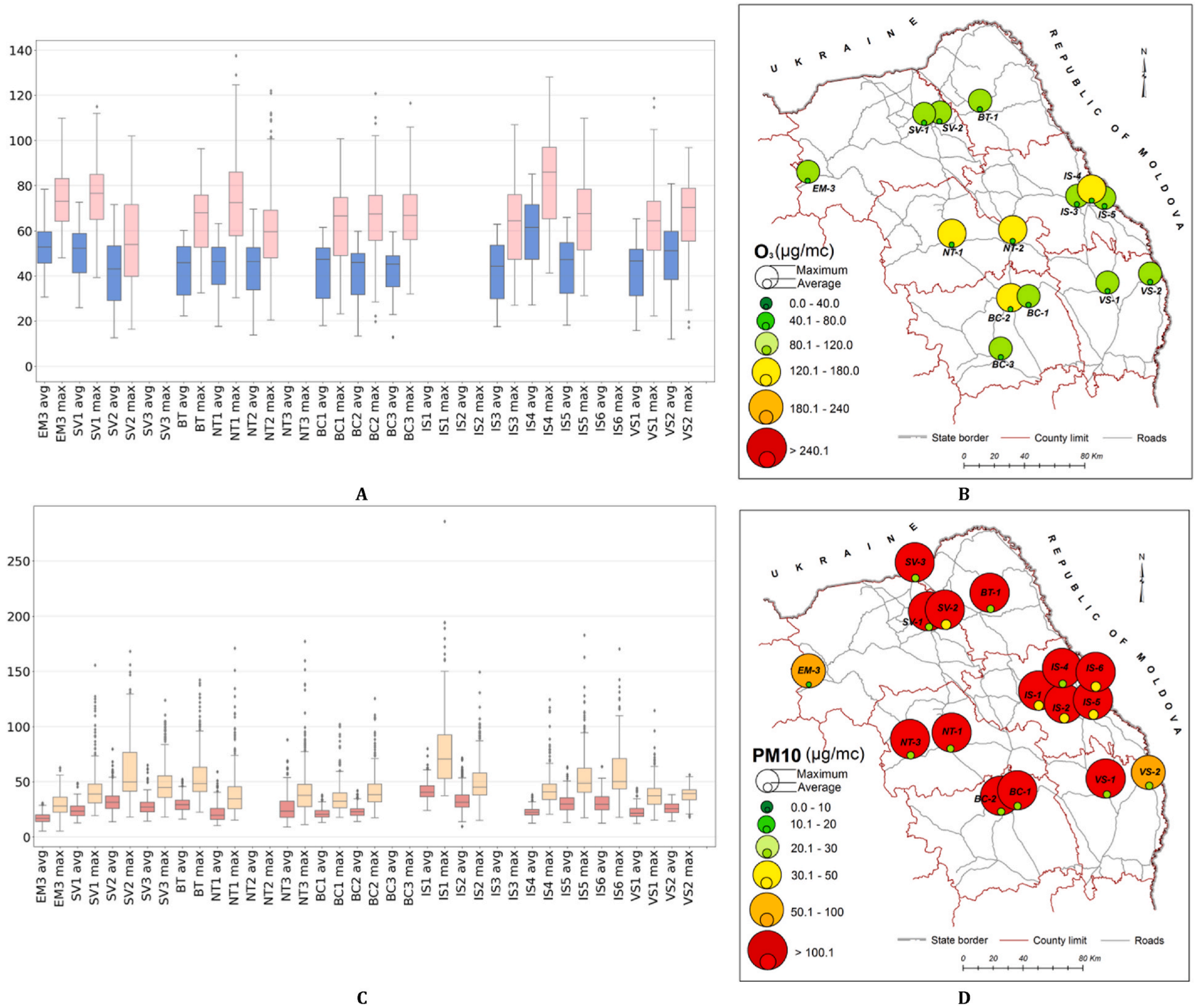

Fig. 3. Average and maximum diurnal O_3, PM_{10} levels (μg m-3) for RNER stations with reference to the interval 2009–2020 (boxplot diagrams A, C, maps B, D, the diameter of the circles is related to the level of the pollutant; the color renders the quality class according to the Qi thresholds).

from 41.1 μg m^{-3} at SV1 and 59.4 μg m^{-3} at IS4. According to them and the scale for assessing the quality indices (Table 2 - Sm and Fig. 3a and b), the air quality at all stations was very good.

The standard deviation of the daily averages was for the whole region and the period of 11.7 (8.8 at BC3 and 14.5 la IS4). Daytime highs ranged from 96.3 μg m^{-3} at BT1 and 137.5 μg m^{-3} at NT1. According to the air quality indices related to the O_3 maxima at 11 of the 15 stations from which we had data, the air quality was good, and at four it was average (NT1, NT2, BC2 și IS4). At EM3 (cross-border station) there are signs of cross-border pollution.

The average hourly frequency for all RNER and the researched period of O_3 levels and related quality indices show that in 99.61% of cases the air quality was in grades I-III (excellent - good) and only in 0.39% of cases in grades quality IV and V (medium and bad - only at NT1 and NT2 stations). The prospect of global warming correlated with the strong links between T and O_3 may lead to a worsening of regional statistics on O_3 levels shown in Fig. 3a and b and Table 1d.

The mean daily level of PM_{10} in RNER in the period 2009–2020 was 27 μg m^{-3}. It is RNER grade III (good). The mean daytime level of PM_{10} ranged from 17.1 μg m^{-3} at EM3 and 41.9 μg m^{-3} at IS1 (Fig. 3c). Of the 16 stations from which we had enough data, at one station the air quality was very good, at 10 good and at 5 stations average. The mean standard deviation of mean diurnal PM_{10} levels was 7 (ranging from 4.4 at IS4 to 11.7 at NT3). PM_{10} diurnal maxima ranged from 56.4 μg m^{-3} at VS2 and 285.7 μg m^{-3} at IS1. According to the diurnal maxima, the quality indices of PM_{10} went up at two stations (EM3 and VS2) to the value V (bad air quality), and at other 14 stations to the value VI (very bad air quality) (Fig. 3d). The maximum diurnal PM_{10} levels at EM3 are worrying.

PM_{10} sediment dust pollution is a real environmental problem in RNER. Across the region in 33.5% of the days monitored, air quality was average, bad and very bad. A more unfavorable air quality situation than the regional average is specific to IS1 stations (with 72.6% of days with average to very bad air quality), IS2, IS6, IS5, SV2 and BT1, and a more favorable one for EM3 (with only 10.7% of days with average, bad and very bad air quality), BC1 and NT1 (Table 1e).

2.3.2. *Air quality - at RNER level focused on Ep from 2020*

Ep declared in Romania between March 16 and May 14, 2020 imposed a forced decrease in the pace of activity on all levels of economic and social life. This allowed us to assess the consequences of the slowdown in economic activity in terms of regional air quality. In order to have a more pertinent picture of the real impact generated by the pandemic situation on the air quality, we first evaluated the differences between the meteorological conditions of the period March 16-May 14, 2000 (called emergency period - Ep) with the interval March 16-May 14, 2009–2019 (referred to as reference period - Rp).

Overall, the atmosphere above RNER during Ep was dominated by 63% of anticyclonic weather conditions, was calmer, drier and more transparent to solar radiation, but slightly colder and more thermally variable than during Rp. Meteorological differences between the two ranges Ep and Rp did exist, but do not consider them substantial. Details on the similarities and differences between the meteorological characteristics of Ep and the climatic characteristics of Rp are provided in Sm.

In contrast to the meteorological background, during Ep, beyond the differentiations between the stations the NO_2 levels were lower on average, on the whole region by 1.4 μg m^{-3} (by 8.6%) compared to Rp (Fig. 11 Sm). The mean SO_2 levels were also during Ep, on the whole RNER by 0.95 μg m^{-3} (by 14.3%) lower than Rp (Table 2) and the maximum and minimum levels of SO_2 were also on average lower during Ep than in Rp (Fig. 12 Sm). The more significant reduction in NO_2 and SO_2 levels in Ep compared to Rp (synchronous with maintaining about the same weather conditions) was a clear consequence of the slowdown in industrial and transport

Table 1

Hourly frequency (%) of NO_2 (A), SO_2 (B), CO (C), O_3 (D) and PM_{10} (E) levels classified on Qi and specific thresholds for this pollutant (2009–2020).

Qi	Intervals	EM3	SV1	SV2	SV3	BT	NT1	NT2	NT3	BC1	BC2	BC3	IS1	IS2	IS3	IS4	IS5	IS6	VS1	VS2
A																				
1	0-50	61.8	35.2	26.2	22.2	18.1	48	33.9	43.3	17.6	38.4	45.5	3.2	10	24	74	32.1	70.4	27.3	47.5
2	50-100	31	41	39.1	40.6	39.3	34.1	33.8	36.1	44.5	33.1	32.8	13.6	34.5	38.1	21.8	36.6	24.3	43.3	38
3	100-140	6.4	14.3	17.3	19.2	19.9	9.9	17.3	12.3	20.8	14.7	12.4	19.2	23.5	18.3	3.1	15.6	3.9	17.4	10.1
4	140-200	0.8	7.5	12.3	13.2	14.5	6.1	11.4	6.9	13.1	10.4	7.1	33.8	21.3	13.6	1	10.6	1.1	9.7	3.9
5	200-400	0	1.9	5	4.5	7.1	1.8	3.3	1.4	3.9	3.3	2.1	27.5	10	5.7	0.1	4.7	0.3	2.4	0.5
6	>400	0	0.1	0.2	0.3	1	0.1	0.3	0	0	0.1	0.1	2.6	0.7	0.4	0	0.5	0.1	0.1	0
B																				
1	0-50	100	99.7	99.4	99.7	99.8	99.9	100	100	100	99.9	100	100	100	100	100	100	100	100	100
2	50-75	0	0.2	0.3	0.25	0.25	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	75-125	0	0.1	0.1	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0
4	125-350	0	0	0.2	0.05	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	350-500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	>500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C																				
1	0 - 3	99.99	99.97	98.86	99.34	99.8	99.67	99.92	No	99.89	99.96	99.68	99.8	No	No	100	100	99.92	99.97	99.98
2	3 - 5	0.01	0.02	0.99	0.64	0.17	0.31	0.07	No	0.11	0.04	0.31	0.2	No	No	0	0	0.08	0.03	0.02
3	5 − 7	0	0	0.11	0.01	0.02	0.01	0.01	No	0	0	0	0.01	No	No	0	0	0	0	0
4	7 - 10	0	0	0.03	0	0	0	0	No	0	0	0	0	No	No	0	0	0	0	0
5	10 - 15	0	0	0	0	0	0	0	No	0	0	0	0	No	No	0	0	0	0	0
6	>15	0	0	0	0	0	0	0	No	0	0	0	0	No	No	0	0	0	0	0
D																				
1	0-40	33.9	36.4	51	No	48.4	48.6	51.2	50.1	50.9	51.6	No	No	56.2	51.1	21.8	48.5	No	49	41.7
2	40-80	50.1	51.6	38.6	No	44.2	42.7	38.6	42.1	41.6	39.7	No	No	35.8	40.1	58	42.9	No	42.4	45.1
3	80-120	15.2	11.6	10.1	No	7.3	7.9	9.3	7.6	7.2	8.4	No	No	7.9	8.5	19.4	8.3	No	8.5	13.1
4	120-180	0.8	0.3	0.3	No	0.2	0.7	0.8	0.2	0.3	0.3	No	No	0	0.3	0.7	0.4	No	0.1	0.2
5	180-240	0	0	0	No	0	0.1	0.1	0	0	0	No	No	0	0	0	0	No	0	0
6	>240	0	0	0	No	0	0	0	0	0	0	No	No	0	0	0	0	No	0	0
E																				
1	0 - 10	24.3	6.6	4.1	5.8	5	16.6	No	11.7	8.4	6.7	No	1.1	4.2	No	11.8	5.1	9.8	9.8	4.4
2	10 - 20	44.9	36.7	23.9	27.4	22.8	39.5	No	32.5	45.7	40.8	No	7.9	16.5	No	35.9	21.6	23.3	39.4	29.1
3	20 - 30	20.2	32.9	28	31.1	30.2	23.8	No	25.2	29.9	30.7	No	18.4	28.3	No	29.6	30.2	22.5	29.3	31.7
4	30 - 50	10.4	21.3	33.9	30.6	34.6	17.6	No	24.6	15	19.1	No	52.3	37.4	No	20.9	33	32.4	19.5	34.6
5	50 - 100	0.3	2.3	8.8	4.8	6.9	2.2	No	5.6	1	2.4	No	18.1	13.1	No	1.7	9.5	11.3	2.1	0.2
6	> 100	0	0.3	1.2	0.4	0.5	0.3	No	0.4	0.1	0.2	No	2.2	0.5	No	0.1	0.7	0.8	0	0

Table 2
Absolute and percentage differences between RNER/AMSv air pollutant levels during Ep versus Rp.

Pollutant	RNER Ep - Rp		Direction of the difference	AMSv Ep - Rp		Direction of difference
	μg m^{-3}	%		μg m^{-3}	%	
NO_2	**−1.4**	**−8.6**	↓	**−2.1**	**−13.9**	↓
SO_2	**−0.95**	**−14.3**	↓	**−3.2**	**−40.1**	↓
CO	*0.02*	*11.8*	↑	*0.1*	*55.6*	↑
O_3	*5.3*	*9.5*	↑	*7*	*12.2*	↑
PM_{10}	*1.8*	*6.9*	↑	*2.9*	*11.5*	↑

activity. The mean CO levels during Ep were on the whole RNER 0.02 μg m^{-3} (by 11.8%) higher than Rp. The maximum and minimum levels of CO were on average during Ep higher than in Rp (Fig. 13 Sm). CO levels rose as fossil fuel homes continued to heat up in the region for most of the emergency period. Lockdown heating of many homes over a longer period of time (as many residents became technically unemployed or continued working from home) contributed to the increase in CO levels compared to those of Rp and from here to the differences between the evolution of CO levels compared to the involution of NO_2 and SO_2 levels. The mean levels of O_3 during Ep were on the whole RNER 5.3 μg m^{-3} (by 9.5%) higher than Rp (Table 2). Maximum O_3 levels were significantly higher during Ep (by 43 μg m^{-3} in the case of IS6 station) than in Rp (Fig. 14 Sm). Under anticyclonic conditions, with lower dynamics and atmospheric humidity, increased atmospheric transparency contributed to this situation. In the case of PM_{10} the mean levels during Ep were on the whole RNER by 1.8 μg m^{-3} (by 6.9%) higher than Rp (Fig. 15 Sm). Maximum PM_{10} levels were significantly higher during Ep (with 19.54 μg m^{-3}) than Rp. This was also due to an activity of burning vegetable waste and dry vegetation around the houses built on the land and on the lands with agricultural destination nearby (vegetable gardens, meadows). In this way the time window of the lockdown (Ep) in which we would have expected to register much lower levels for all pollutants and therefore a much cleaner air, against the background of the remanence of atmospheric pollutants and the maintenance of activities generating pollutants so-called domestic (home heating, food preparation, cleaning of houses/apartments and gardens - with the free burning of combustible waste), proved to have a better air quality, but not for all pollutants (but only for NO_2 and SO_2) and not at the expected level.

The relatively small difference between the air quality in Ep and Rp was also favored by the background of relatively low levels of pollutants during Rp, which were not able to generate a major quality contrast between Rp and Ep, especially since Ep was not a period of total lockdown for the inhabitants of the region, who live mostly in houses and who continued their activity in various ways. Added to this was a lower level of social compliance with the rules imposed by the authorities, which were frequently neglected or violated.

The comparative analysis for RNER of the frequency of the diurnal values of the air quality indices corresponding to the levels of the five pollutants analyzed allows us to appreciate, in a relative way, that during Ep, when the state of emergency was declared, the air quality indicators changed the frequency parameters (Table 3). By analyzing these frequencies, changes with positive connotations for air quality can be observed in NO_2 and SO_2 and even CO. We also notice the slight slippage of O_3 frequencies from lower quality classes to higher quality ones during Ep: on some quality classes (I and III) the changes were significant. The increase in ozone levels during Ep compared to Rp was mainly influenced by natural causes (increased transparency of the atmosphere, increased value of global radiation, decreased value of relative humidity) and would probably have been more pronounced if the NO_2 concentration from the atmosphere had not decreased and would not have slightly increased the level of PM_{10}. The habit of the population of RNER to burn with spring cleaning waste of any kind and especially vegetable waste around homes and agricultural fields was manifested with greater intensity in the spring of 2020 amid the record at home of the majority of the population. Cleaning (including fire) and construction (outdoor) activities increased PM_{10} levels in the atmosphere.

In Fig. 4a it can be observed that during Ep on the area of 19 km^2 around the 19 air monitoring points in RNER a total number of 229 fires were registered. Compared to Rp, the number of fires in Ep was triple (Fig. 4b), this being an argument for explaining the relatively high level of PM_{10} (but also that of CO) in an interval in which we would have expected that the levels these two gases would have been lower.

Table 3
Frequency (%), at different intervals of diurnal values of quality indices for RNER during Rp and Ep.

Quality indices	Value limits μg mc^{-1} NO_2	NO_2 Rp	NO_2 Ep	Value limits μg mc^{-1} SO_2	SO_2 Rp	SO_2 Ep	Value limits μg mc^{-1} CO	CO Rp	CO Ep	Value limits μg mc^{-1} O_3	O_3 Rp	O_3 Ep	Value limits μg mc^{-1} PM_{10}	PM_{10} Rp	PM_{10} Ep
1	0-50	96.631	97.835	0-50	99.952	100	0 - 3	99.954	99.98	0-40	30.511	20.754	0 - 10	9.0	7.8
2	50-100	3.205	2.006	50-75	0.035		3 - 5	0.043	0.02	40-80	51.324	54.695	10 - 20	31.2	26.8
3	100-140	0.138	0.136	75-125	0.002		5 - 7	0.002		80-120	17.123	23.956	20 - 30	26.5	24.2
4	140-200	0.024	0.024	125-350	0.011		7 - 10			120-180	1.038	0.597	30 - 50	24.7	27.0
5	200-400	0.001		350-500			10 - 15	0.001		180-240	0.003	0.000	50 - 100	8.4	12.4
6	>400			>500	0.001		>15			>240	0.000	0.000	> 100	0.3	1.9

** no daily value of the respective pollutant was recorded for the value thresholds of which the boxes remained vacant; ** for the value thresholds in whose boxes the value of 0.000 appears, at least one diurnal value of the respective pollutant has been registered, but the value of the average is very small - with more than 3 decimals*

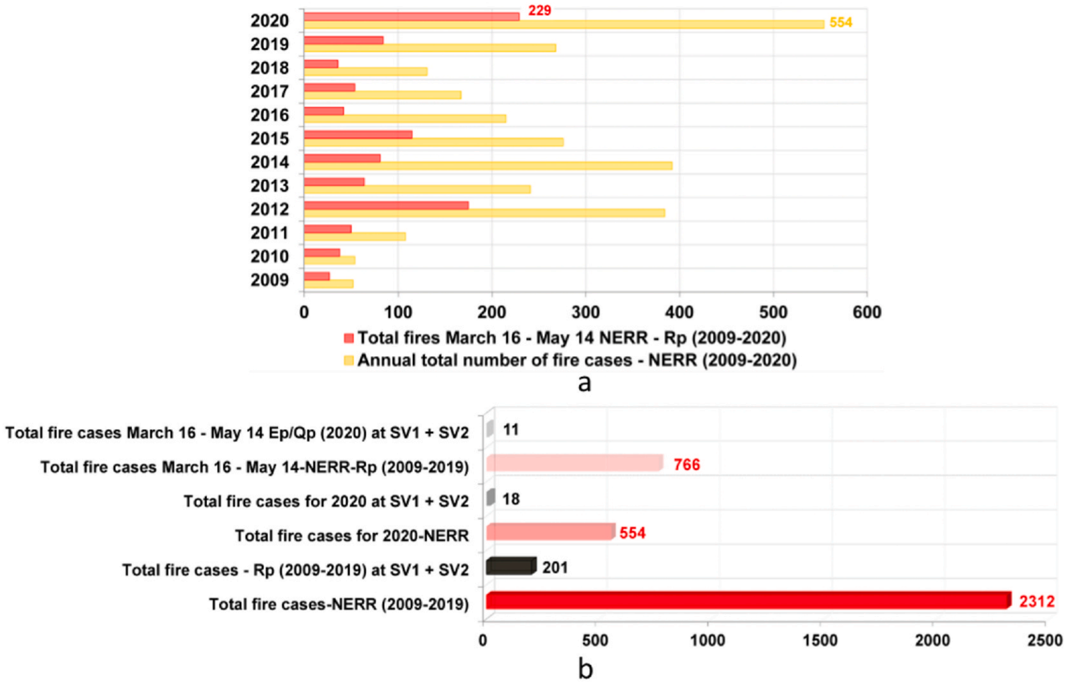

Fig. 4. The total annual number of fires occurring over a distance of 500 m around the air quality monitoring points in the period 2009–2020, respectively only during Rp in the same buffers –a. The total number of fires in the 19 squares considered in the period 2009–2019, in 2020 and during the Ep of the 19 squares of 1 km^2 each around the stations represented for RNER and SV1 and SV2 respectively during Rp and during Ep/Qp - b.

2.4. Case study. Air quality for the Suceava metropolitan area (AMSv) focused on Ep and Qp from 2020

The whole of Romania and AMSv entered Ep on March 16, 2020, and AMSv entered Qp on March 30, 2020. The quarantine of the AMSv population in Qp was a unique event that a population group of over 100,000 inhabitants went through during the pandemic in Romania. The quarantine measures were particularly harsh, so that the more than 100.000 inhabitants were practically physically isolated from the surrounding inhabitants. There were very few people who were hardly allowed (based on verified written documents) to enter and leave the quarantined area. The supply of food and medicine was allowed through large retailers and pharmacies. Suceava became a militarized and almost deserted city. Travel for the supply of food, medicine and goods for immediate use of the population was restricted and was possible only after completing on the basis of their own responsibility some standardized statements, verified by police crews, gendarmes or military police. In the surrounding suburbs, residents were able to carry out some restricted commercial, agricultural and construction activities.

This unique interval, during which economic and social activities were greatly diminished, gave climatologists and air quality specialists a good opportunity to investigate what would happen if man diminished his contribution as a polluting factor of the Earth's atmosphere in a small area, even for a short time. Of course, the AMSv atmosphere was not isolated during Rp, Ep and Qp from the atmosphere of the surrounding territories and dynamically suffered from non-native influences. In the surrounding territories, located at a greater or lesser distance, economic and social activities took place slowly, but were not completely stopped.

And yet, beyond these shortcomings caused by taking into account the levels of pollutants in the uninsulated outdoor atmosphere of a small territory and for a limited period, the consequences in terms of air quality AMSv were visible and quantifiable.

The mirror representation of the interdiurnal regime of pollutants and climatic elements for the entire RNER compared to SV1 and SV2 for Rp and Ep (Fig. 5 a) shows us the annual maximum or minimum intervals of the considered parameters, the direct or inverse correlative links between the chemistry parameters of air and climate, the variability of these parameters and often its synchronism - which argues the impact of the parameters transposed from regional to local scale, but also the differences that existed in the specific meteorological and air quality for Ep compared to Rp. This last fact highlights a certain degree of autonomy of the evolution with local specificity of the elements of the air chemistry and of the meteorological parameters in relation to the regional ones.

Analyzing the GR values during Ep we noticed that they were higher in RNER on average by 16.9 $Wmp^{-1}\ h^{-1}$, than in Rp, and in the case of AMSv during Ep/Qp it was higher by 10.1 $Wmp^{-1}\ h^{-1}$ compared to Rp. During Ep/Qp, GR values were lower above AMSv than above RNER by 6.8 $Wmp^{-1}\ h^{-1}$ (Fig. 5g). The mean values of T during Ep were lower in RNER by 1.2 °C than in Rp, and in the case of AMSv during Ep/Qp they were lower by 1.4 °C compared to Rp. During Ep/Qp the thermal field above AMSv did not differ from the average thermal field above RNER (Fig. 5h). RH averages during Ep were 13.1% lower in RNER than in Rp, and in the case of AMSv during Ep/Qp they were 8.7% lower than in Rp. During Ep/Qp the hygric field above AMSv had values 0.8% higher than the average

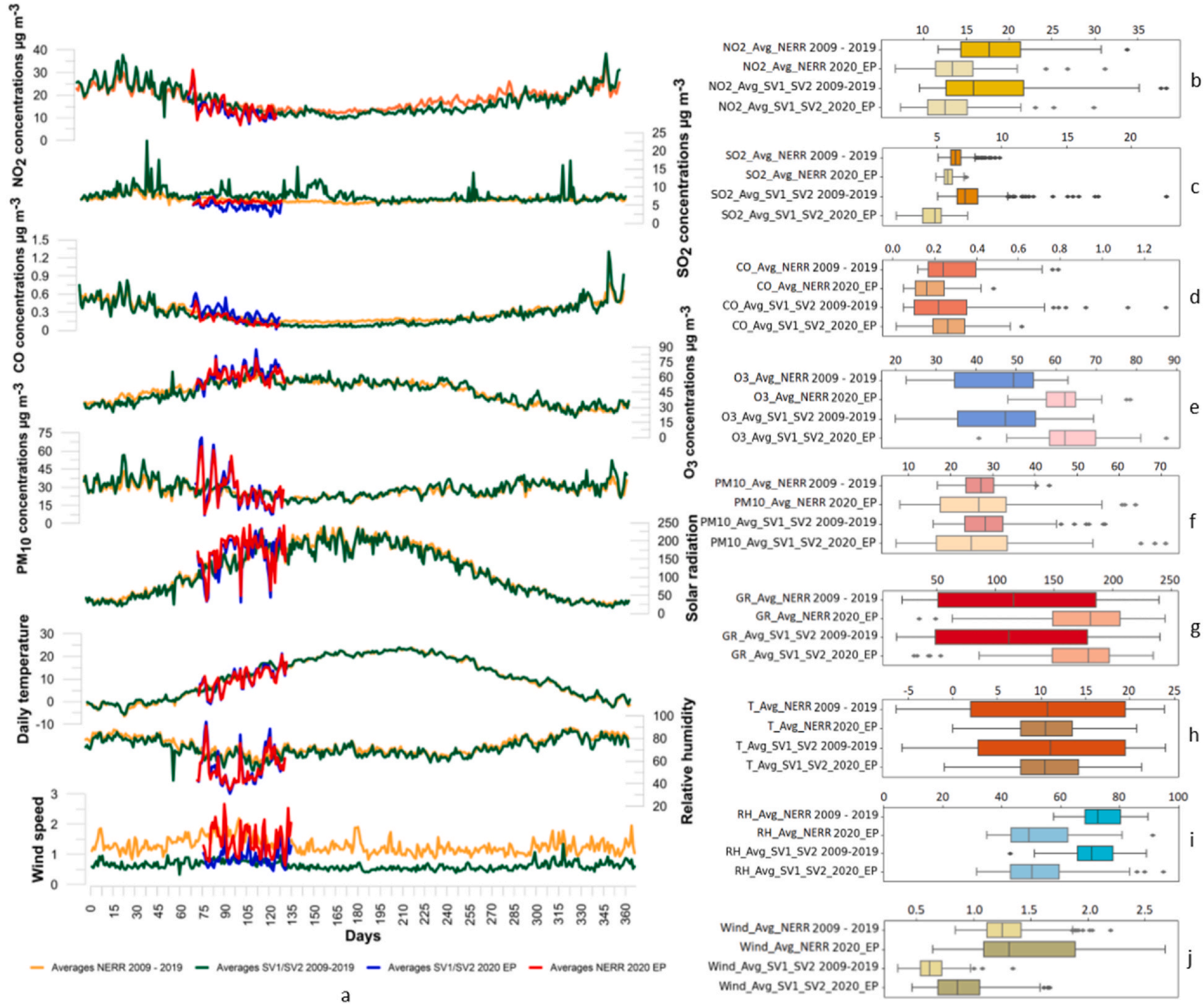

Fig. 5. Interdiurnal regime of levels of air pollutants (NO_2, SO_2, CO, O_3, PM_{10} – în µg m^{-3}) and meteorological elements (GR – în Wmp^{-1} h^{-1}; T – în °C, RH în % și Wind – în ms^{-1}) for RNER and AMSv in the period 2009–2019 and in 2020 - left a); boxplot diagrams of air pollutant levels and meteorological elements for RNER (Rp/Ep) and AMSv (Rp/Ep) - right from b to j.

hygric field above RNER (Fig. 5i). The means of wind speed during Ep were 0.2 ms^{-1} lower in RNER than in Rp, and in the case of AMSv during Ep/Qp they were 0.1 ms^{-1} higher than Rp. During Ep/Qp the dynamic field above AMSv had values 0.5 ms^{-1} lower than the average of the dynamic field above RNER (Fig. 5j).

Compared to Rp in Ep/Qp, the AMSv atmosphere received 10.2 Wmp^{-1} h^{-1} more energy, was 1.5 °C colder, by 8.7% wetter and 0.1 ms^{-1} more dynamic.

During Ep, which also included Qp, the AMSv atmosphere did not differ much from the meteorological point of view compared to the RNER atmosphere: it received a smaller amount of solar energy than the regional level (by 6.5 Wmp^{-1} h^{-1}), it was just as warm, 0.8% wetter, and the wind speed was 0.5 ms^{-1} slower than the regional. There were minor meteorological warnings, which can be explained by local meteorological determinants.

Analyzing the NO_2 level during Ep/Qp in the case of AMSv we found that it was lower by 2.1 µg m^{-3} (by 13.9%) compared to Rp (Table 2). During Ep/Qp the NO_2 level was lower above AMSv than above RNER by 0.7 µg m^{-3}(Fig. 5b). The SO_2 level during Ep/Qp was lower by 3.2 µg m^{-3} (by 40.1%) compared to Rp. During Ep/Qp the SO_2 level was lower above AMSv than above RNER by 2.25 µg m^{-3}. It is the most significant difference. The lower levels of the two noxious substances are attributed to the strong slowdown in industrial activity (on the AMBRO industrial platform) and transport (Fig. 5c). The mean CO level during Ep/Qp was 0.1 µg m^{-3} (by 55.6%) higher than Rp in the case of AMSv. During Ep/Qp the CO level was higher above AMSv than above RNER by 0.08 µg m^{-3}. Home heating and suburban fires imposed this seemingly abnormal reality (Fig. 5d). Regarding the O_3 level during Ep/Qp was in the case of AMSv during Ep/Qp by 7.0 µg m^{-3} (by 12.2%) higher than Rp. During Ep/Qp the O_3 level was higher above AMSv than above RNER by 2.3 µg m^{-3}. We can attribute this difference to the higher transparency of the atmosphere during the day, in conditions of lower humidity and high transparency (Fig. 5e). The mean PM_{10} level during Ep/Qp was 2.9 μg m^{-3} (by 11.5%) higher than Rp for AMSv (Table 2). During Ep/Qp the PM_{10} level was higher above AMSv than above RNER by 1.1 μg m^{-3} (Fig. 5f). Interestingly, the medians of the RNER and AMSv data strings for EP and Ep/Qp respectively show lower levels of PM_{10} pollution for both EP and Qp for both territories than the averages. We therefore deduce that the number of days with lower PM_{10} values was predominant, but certain episodes of increased pollution (due to more fires in 2020) tipped the balance towards higher averages during Ep/Qp than during Rp. The higher number of fires that released into the atmosphere in 2020 particles of ash, carbon black, etc. was able to reduce the influence of the lockdown time window in terms of increasing air quality. The large number of fires in 2020 and during the EP/Qp that released into the atmosphere also other chemical compounds in addition to PM_{10} dust (CO and not only) seems to have largely blurred the positive effects on air quality induced by the slowdown economic and social activities. However, these effects were visible even in the RNER, a region with a much lower level of economic and social activity than in other regions of Europe.

3. Discussion

The perception of the urban population in the RNER is that the air they breathe is polluted. Our study shows that pollution is a problem that requires action to reduce primarily levels of PM_{10} and ozone, compounds for which both average and maximum levels are becoming more common and longer lasting, raised. The average levels of the other compounds (NO_2, SO_2 and CO) remain low, and in the most representative pollution episodes, they generate for a short time (a few hours to at most a few days) population discomfort and environmental problems.

In this study, we established the causal links of the average and extreme coordinates of pollutant levels for the entire RNER and for a longer period (12 years), which allow us a real and comprehensive assessment of regional air quality in its dynamics. Resolving this shortcoming was necessary, due to the limited previous studies for the region [2,3,5,6] and addressed only partially the issue of pollution and air quality with their implications. We were able to answer the question: How polluted is the air breathed by the nearly four million inhabitants of the RNER? We can state on a statistical basis that over 58% of the inhabitants of the region (who live in rural areas) breathe good quality air, and the other 42% who live in urban areas breathe in proportion of over 70% of the time good quality air. This 70% is due to the relatively high levels of PM_{10} in the atmosphere of cities and man-made areas.

The extent to which geographical and anthropogenic factors determine pollutant levels has been analyzed in many profile studies [54–56]. In our study, given its objectives, we insisted a little more on the role of the meteorological factor, which could amplify or diminish the effects of the lockdown event transposed in the air chemistry of the researched region. Other authors have sought to quantify in their studies the level of determination of meteorological factors on air quality during lockdown [35,47,57]. We have observed, like other authors [58]; Ordonez et al., 2020; [59–61], that the meteorological factor imposed itself with more power by an array of elements (higher pressure field, lower relative humidity etc.) on the higher level of O_3 in Ep compared to Rp.

In the case of NO_2 and SO_2, above RNER and AMSv, in Ep compared to Rp the decrease of the levels of the two compounds was maintained, but in different measures compared to other geographical entities. The atmosphere above RNER/AMSv received the influences around them, but at the same time, their active surface, imposed a certain degree of autonomy to the composition of the air above, transposed in different percentages of level decreases in the case of NO_2 and SO_2. During the emergency period and especially during the quarantine of Suceava, industry and transport reduced their activity to a minimum, imposing lower levels for NO_2 și SO_2 [62]. highlight that NO_2 recorded the most significant reduction with 54%, 83%, 33% and 19% in BTH (Beijing-Tianjin-Hebei), Wuhan, Seul and Tokyo, while SO_2 concentrations increased in Seoul and Tokyo due to the transport of polluted air in 2020 [63]. show that there has been a 25.5% decrease in NO_2 concentrations in U.S. during the COVID-19 pandemic compared to the reference period. Similar results, with reductions of up to 54.3% in NO_2 concentrations, were reported in Sao Paulo, Brazil [19]. Significant decreases in NO_2 (15–71% were also observed in the case of Portugal. Suspension of industrial activity has also led to a 35% decrease in SO_2 concentrations (Slezakova et al., 2021). Ordonez et al. (2020) noted a significant decrease in the maximum daily NO_2 value across the European continent. A significant reduction in SO_2 was observed in Milan, while in the surrounding areas the concentrations remained unchanged [64].

In the case of CO and PM_{10} in RNER the levels increased in Ep compared to Rp. This is a seemingly illogical situation. And yet the specifics of the economic and social activities in the region and the studied urban agglomeration give answers to the higher levels of these pollutants during the lockdown. Our explanation for the higher levels of CO and PM_{10} during the Ep comes from three sectors of economic and social life that were dynamized and amplified spatially and temporally: the construction sector which gained momentum, decentralized heating of the population by burning fossil fuels and spring 2020 clean-up, which was more intense than usual, as evidenced by the increasing number of out-of-town and in-town fires of dry vegetation waste [19]. observed a 64.8% decrease in CO concentrations in downtown Sao Paulo. Significant reductions in concentrations of this pollutant 35% lower concentrations) were also observed in Almaty, Kazakhstan [65]. In Italy, the reduction in traffic led to a 57.6% decrease in CO concentrations [64]. Similar results were obtained for the Chennai station in India [66], but also for the atmosphere of Great Britain [42]. CO and PM_{10} concentrations increased in some cities in Spain or did not show significant changes compared to the reference period [59]. The city Sale in Morocco recorded a dramatic drop in PM_{10}, by 75% [67]. [68], noted a decrease in air pollution through PM_{10} in China, but noted that the results obtained may be uncertain due to the lack of data that did not take into account the factors that may influence PM_{10} (vegetation fires, atmospheric stability etc.). At European level, there was a general decline in PM concentrations as a result of the implementation of restrictive measures (Athens, Milan, Madrid), but recorded increases in PM concentrations by 20% and 45%, respectively [41].

Therefore, our results for RNER are in agreement with the results of most research conducted for other geographical entities in the case of NO_2, SO_2 and O_3, but have peculiarities derived from the specificity of RNER in the case of CO and PM_{10}.

4. Conclusions

Following the analysis of pollutant levels and air quality in the RNER, located at the extremity of the EU SEE, we can draw a first conclusion: the multiannual average daily levels of NO_2, SO_2 and CO are low (18.3; 6.6 and 0.3 μg m^{-3} respectively), values that allow the air quality of the region to be classified in quality class I. The average levels of O_3 (45.6 μg m^{-3}) classify the air above the region in quality class II. Areas of concern may occur locally. Regional problems are related to the relatively high average diurnal levels of PM_{10} (27 μg m^{-3}) which classify the region in quality class III. On a local scale, there may be days and groups of days with serious pollution problems related to this pollutant. Maximum levels of pollutants reached the range of pollution classes III for NO_2 and SO_2, IV for CO and O_3 and VI for PM_{10}. O_3 pollution can become a real problem in the current climate context, and PM_{10} pollution is already a real problem in the cities of this region. For these two pollutants (O_3 and PM_{10}) cross-border pollution problems (EM3) are statistically outlined.

The period from 16 March to May 14, 2020 opened up an opportunity to investigate the level of pollution and air quality for the RNER, given that a sufficiently long period is not in sight in the near future at global and regional level during which economic and social activities are almost interrupted. The deductive premises from which the study started were correct and well-founded, but in order to get results on this component, one had to first determine the decadal median value of air quality in the region and the factors on which it depends. After resolving this, we were able to analyze the effects of the lockdown in different pollutant levels.

The analysis of RNER pollution in the period 2009–2020 show in general a low level of air pollution. This low level had the role of attenuating the contrast derived from the different levels of pollutants in Ep and Rp. For NO_2 and SO_2 the results of our research indicate (like many other studies) a decrease for RNER by 8.6 and 14.3% respectively of the levels of these pollutants during Ep compared to Rp. The drastic reduction in industry and transport activities contributed to this decline. However, the other three pollutants analyzed (CO, O_3 and PM_{10}) had increases of 11.8, 9.5 and 6.9% respectively during Rp compared to Rp. We attributed these increases (in the case of CO and PM_{10}) to the fact that in the urban environment, where the apartment heating is dominant, the heating of the houses continued throughout the EP, being multiplied temporally and spatially. Moreover, in the suburban area, the heating of wooden houses and especially the increase above the average number of fires with the cleaning in spring 2020, generated in EP levels CO and PM_{10} above the average Rp. We attributed the higher level of O_3 to the anticyclonic weather conditions (in 63% of the days Ep above the RNER dominated the anticyclonic baric formations and anticyclonic ridges) with clear weather, lower RH values (by 13.1% in Ep compared to Rp) and higher atmospheric transparency.

AMSv was the only quarantine urban agglomeration of over 100,000 inhabitants in Romania. The lockdown was a tough one. The inhabitants of the urban area could be better controlled, this was not the case in the suburban and rural environment in the vicinity. The drastic decrease of the activities in industry and transport led to the decrease of NO_2 and SO_2 levels in Ep/Qp by 13.9 and 40.1% respectively compared to those in Rp. Heating homes with fossil fuel, cleaning gardens, burning of vegetable and non-vegetable waste during spring cleaning, but also the continuation of the construction activity caused CO and PM_{10} levels to increase in Ep/Qp by 55.6 and respectively 1.5% compared to Rp. Weather conditions similar to those at the regional level, but marked by an 8.7% decrease in air humidity, imposed higher O_3 levels during Ep/Qp than during Rp.

Author contribution statement

Mihăilă Dumitru: conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Lazurca Liliana–Gina: conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Bistricean Ionel-Petruț: conceived and designed the experiments; Contributed reagents, materials, analysis tools or data. Horodnic Vasilică-Dănuț: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Mihăilă Emilian: conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Emandi Marina: Performed the experiments; Analyzed and interpreted the data; Wrote the paper. Prisacariu Alin: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Nistor Alina: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Nistor Bogdan: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Roșu Constantin: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank the specialists from the County Environmental Protection Agencies from RNER (from Suceava, Botoșani, Neamț, Iași, Bacău and Vaslui counties), who through their effort ensured the time series of air pollutants and meteorological elements, processed in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e18918.

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