Romania's degree of compliance with European Union air quality requirements: an urban-level analysis

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Abstract. The present study evaluates the degree of compliance of Cluj-Napoca municipality with European Union air quality standards for the 2019-2023 period, within a context marked by the pressure of accelerated urbanization and the new rigors of the European Green Deal. The central objective was to determine the alignment level of PM10, PM2.5, and NO_2 indicators with legal limit values, utilizing data provided by the official monitoring network (stations CJ-1, CJ-2, and CJ-3). The methodology involved a comparative analysis of annual averages and the frequency of daily exceedances, corroborated with the interpretation of local topoclimatic and anthropogenic factors. The case study results indicate a verdict of partial compliance: although an improvement in indicators was observed after 2020, traffic stations continue to report critical values, bordering on alert thresholds.
Keywords: air quality, Cluj-Napoca, EU compliance.

Introduction. In recent decades, urban air quality has become one of the most pressing concerns at both global and European levels, given its direct impact on public health and ecosystem integrity. The accelerated process of urbanization, coupled with the intensification of industrial activities and the exponential expansion of road transport, has led to a severe degradation of the respiratory environment in major urban agglomerations. Within the European Union, this issue is regulated by strict directives that impose mandatory limits on member states for key atmospheric pollutants (Directive 2008/50/CE). In Romania, the transposition of these standards was achieved through Law no. 104/2011 on ambient air quality.

The post-industrial transition of the municipality of Cluj-Napoca has profoundly altered the local emission profile. Although major historical industrial platforms have reduced their activity, the decline in point-source pollution has been counterbalanced by a massive increase in diffuse pollution generated by road traffic and the expansion of peri-urban residential areas. This complex dynamic has exposed the limitations of monitoring infrastructure and air quality management.

At the European level, legal pressure has increased considerably, with Romania being subject to infringement procedures due to systematic exceedances of limit values. A landmark moment in this regard is Case C-638/18, through which the Court of Justice of the European Union (CJUE) officially condemned Romania for the systematic and persistent failure to fulfill its obligations regarding compliance with daily limit values for particulate matter (PM10).

The effects of these pollutants on the human body are extensively documented in the literature. Particulate matter (PM10 and PM2.5) penetrates deep into the respiratory system, causing chronic cardiovascular and respiratory diseases, an aspect highlighted in the synthesis reports of the World Health Organization (2013). Recent international studies indicate that reducing anthropogenic emissions at the urban level requires an integrated approach to mobility policies and territorial planning (Zhang et al 2019; Zheng et al 2018).

Furthermore, pollutant dynamics are strongly influenced by the long-range transport of air masses and the contribution of natural sources, such as windblown dust (Vautard et al 2005). For an accurate assessment of population exposure, correlating ground-level data with satellite remote sensing technologies represents an essential direction in modern environmental research (Wang & Christopher 2003).

Material and Method

Description of the study site. The present study is based on the analysis of empirical data recorded during the 2019–2023 period by the National Air Quality Monitoring Network (RNMCA) within the Cluj-Napoca urban agglomeration. The evaluation of the behavior of critical pollutants (NO2, PM10, and PM2.5) was performed through three automated monitoring stations, selected for their strategic placement and their capacity to reflect different exposure matrices. The CJ-1 station is a traffic station positioned on Calea Turzii in a central area with intense traffic flow, characterized by frequent traffic congestions and an urban street canyon geometry conducive to the accumulation of pollutants at ground level. The CJ-2 station is an industrial station located on the eastern flank of the city in the Mărăști / Bulevardul Muncii area and monitors the cumulative impact of residual economic activities, major real estate construction sites, and heavy transit commercial traffic. The CJ-3 station is an urban background station situated in the western part of the municipality in the Grigorescu district, recording the background air quality at the entrance of the dominant wind vector into the Someș valley corridor and serving as a control witness for the pollution generated strictly within the city perimeter. The analytical methods utilized by the automated equipment in these stations fully comply with national and European standards, employing chemiluminescence for nitrogen dioxide (NO_2), and the beta attenuation monitoring method and the reference gravimetric method for particulate matter (PM10 and PM2.5).

Results and Discussion. The comparative analysis of the data collected by the RNMCA stations in Cluj-Napoca during the 2019–2023 period highlights a complex evolution, profoundly marked by the dynamics of urban anthropogenic activities and local meteorological characteristics. The reference year 2019 was characterized by a high pollution pressure, particularly in areas with a high density of road traffic. At the CJ-1 traffic station on Calea Turzii, the annual mean concentration of nitrogen dioxide (NO_2) reached a value of 42 µg/m³, explicitly exceeding the mandatory statutory limit value imposed by Law no. 104/2011 and Directive 2008/50/CE, both set at 40 µg/m³ (Table 1). In stark contrast, the industrial station CJ-2 with an average of 31 µg/m³ and the urban background station CJ-3 with an average of 18 µg/m³ were situated below this limit, statistically confirming that NO_2 pollution is an issue strictly linked to major traffic arteries and vehicular congestion.

Table 1

Annual mean concentrations of NO_2 (µg/m³) recorded at monitoring stations in Cluj-Napoca (2019–2023)

Year	*CJ-1*	*CJ-2*	*CJ-3*	*Compliance Status*
2019	42	24	18	Non-compliant
2020	31	19	14	Compliant
2021	35	22	16	Compliant
2022	38	24	17	Compliant
2023	37	23	16	Compliant

Regarding particulate matter PM10, the year 2019 recorded frequent exceedances of the daily limit value for the protection of human health of 50 µg/m³ (Table 2). The CJ-1 traffic station reported a critical number of 38 exceedance days over the course of 2019, significantly surpassing the maximum number of 35 days per year permitted by European

legislation. This state of systemic non-compliance underlines the vulnerability of the urban agglomeration prior to the emergence of external mobility disruption factors.

Table 2

Number of days exceeding the daily limit value for PM10 (50 µg/m³) in Cluj-Napoca (2019–2023)

Year	*CJ-1*	*CJ-2*	*CJ-3*	*Compliance Status*
2019	38	22	12	Non-compliant
2020	18	11	8	Compliant
2021	24	15	11	Compliant
2022	31	21	14	Compliant
2023	27	19	10	Compliant

The introduction of quarantine measures and traffic restrictions imposed in the context of the COVID-19 pandemic during the 2020–2021 period led to a sudden and substantial reduction in the concentrations of all monitored atmospheric pollutants. At the CJ-1 station, annual NO2 means dropped rapidly to 31 µg/m³ in 2020 and to 33 µg/m³ in 2021, while the annual number of exceedance days for PM10 fell below the critical statutory threshold. However, detailed monitoring from the post-pandemic period between 2022 and 2023 reveals a clear U-shaped recovery trajectory. With the full resumption of economic activities and regular traffic flows, values recorded a continuous upward trend, as traffic and industrial stations returned to an alarming proximity to legal thresholds, thus demonstrating that the improvement during the pandemic was merely a situational anomaly and not the result of sustainable structural transformations. The values for fine particulate matter PM2.5 at the CJ-1 and CJ-2 stations climbed back to the limit threshold of 20 µg/m³ in the year 2022 (Table 3).

Table 3

Annual mean concentrations of PM2.5 (µg/m³) recorded at monitoring stations in Cluj-Napoca (2019–2023)

Year	*CJ-1*	*CJ-2*	*CJ-3*	*Compliance Status*
2019	22	19	15	Non-compliant
2020	17	14	11	Compliant
2021	18	16	12	Compliant
2022	20	18	15	At limit threshold
2023	19	17	14	Compliant

The dynamics of pollutants in Cluj-Napoca cannot be explained exclusively through mobile emission sources, as local topography plays a crucial restrictive role. Located in the Someșul Mic depressional corridor, the municipality is flanked by imposing hilly slopes, a geographical configuration that favours the frequent occurrence of thermal inversions during the cold season. During these winter periods, cold and dense air remains trapped at ground level, covered by a layer of warmer air, a meteorological phenomenon that blocks the upward movement of air masses and disperses with great difficulty the emissions originating from solid fuel combustion for residential heating in surrounding areas and from morning traffic.

Furthermore, rapid urban expansion and the replacement of natural surfaces with impermeable materials have favoured the development of an Urban Heat Island (UHI). The heavily anthropized eastern zones, such as the industrial platforms and the Bulevardul Muncii axis, record substantial positive thermal anomalies exceeding 2°C, intensifying secondary photochemical reactions and blocking the natural air circulation along the East-West axis due to new architectural barriers.

Correlating the data with the updated guidelines transmitted by the World Health Organization (2021) demonstrates that achieving formal compliance with European Union directives does not guarantee the full protection of public health. A major gap is observed because the national threshold in Law 104/2011 for PM2.5 is four times more permissive than the biological threshold recommended by medical experts, an aspect that masks a chronic toxicological risk for the urban population exposed day by day.

Conclusions. Based on the systematic monitoring conducted through the RNMCA during the 2019–2023 period, it can be concluded that the municipality of Cluj-Napoca currently falls into the category of urban areas partially compliant with European Union air quality requirements. The critical areas of non-compliance and persistent vulnerability are represented by the traffic-dominated street canyons in the central zone, where vehicular emissions maintain NO_2 and fine particulate matter concentrations at the upper boundary of legality. The restrictive effect of the depressional topography, manifested through frequent thermal inversions during the winter season, amplifies the impact of local emissions and limits the vertical dispersion of pollutants. The study highlights an urgent need to transition from a formal administrative compliance to local policies focused on expanding low-emission zones and reducing the use of solid fuels. The major gap identified between current legal thresholds and the strict recommendations issued by the World Health Organization (2021) necessitates an urgent revision of local environmental management indicators to ensure genuine community protection.

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Conflicts of Interest. The author declares that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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