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✓ *Environmental engineering*

ANNALS OF THE UNIVERSITY OF CRAIOVA

Vol. XXVII (LXIII) - 2022

AIR QUALITY STUDY IN CRAIOVA MUNICIPALITY BASED ON DATA PROVIDED BY URADM INDEPENDENT SENSOR NETWORK

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Keywords*: air, quality, monitoring, sensor, independent.*

ABSTRACT

This paper presents the assessment of the concentration of PM 2.5 particles at the level of the Craiova Municipality, reported over a period of 8 months, comparing it with the established limit value and with the specific quality index for PM 2.5, as well as the quantitative assessment of the data provided by the independent sensors in relation to the local stations in the RNMCA. The PM 2.5 values used are provided by specially chosen sensors, located in the "red" areas of the city, frequently indicated by Craiova residents for poor air quality, evaluated through the lens of discomfort felt.

INTRODUCTION

Air pollution is considered to be the biggest threat to global health, causing approximately 7 million premature deaths worldwide each year, according to data presented by the World Health Organization in the "World Air Quality Report 2021".

Recognizing the severity of the impact of air pollution on global health, as early as 2005, the World Health Assembly adopted a landmark resolution on air quality and health, emphasizing that air pollution is the major risk factor for non-communicable diseases such as ischemic heart disease, stroke, diabetes, asthma, cancer, chronic obstructive pulmonary disease, mental and neurological conditions, etc.

It is estimated that in 2021, the deaths of 40,000 children under the age of 5 were directly linked to PM2.5 air pollution, and in the context of the COVID-19 pandemic, research has shown that exposure to PM2.5 has increased both the risk of to contract the virus, as well as the probability of making much more severe forms, once contacted. At the same time, the economic cost of air pollution has been estimated at 8 billion USD per day, with the annual global cost amounting to more than 2.9 trillion dollars (approx. 3-4% of the gross world product).

An increasing range of adverse health effects has been linked to air pollution, even at lower pollutant concentrations, particularly for PM2.5. Research has shown that no "threshold" concentration of particulate matter or ozone has been identified below which there are no adverse health effects.

Despite the efforts made so far at European level, air pollution still remains a real cause for concern and a major health problem for Europeans. The human toll for poor air quality is worse than for road accidents, making it the leading environmental cause of premature death in the EU, with over 390,000 premature deaths each year. According to Martin et al. 2011, short-term elevations of ambient fine particulate matter are associated with increased risk of ischemic stroke onset among patients with diabetes mellitus and those hospitalized with non-cardioembolic strokes.

The main air pollutants are particulate matter, sulfur oxides (SOx), nitrogen oxides (NOx), ammonia, organic compounds and ozone. Road transport, fuel combustion, agriculture, industry, energy production and distribution, home heating, waste incineration, etc. are the main sectors responsible for atmospheric pollutant emissions (Gavrilescu & Buzatu 2014).

The World Health Organization describes Romania's air quality as moderate-unsafe and fluctuating, worsening significantly in winter, due to the burning of solid fuels and atmospheric conditions favorable to pollution, although air quality does not depend only on pollutant emissions, but also on weather conditions, the chemical transformations, the geographical conditions, the proximity of the source and the altitude at which the pollutants are released into the atmosphere (de Miranda et al. 2012).

According to the European Court of Auditors, Romania has failed to fulfill monitoring and reporting obligations, with poor air quality continuing to be a problem, and points out that there is a risk that air pollution may be underestimated in some cases, as monitoring may not be always carried out in the right places or be carried out without following the procedures established at the level of the union and reduced in quantity.

The frequent exceeding of the annual limit value for NO_2, PM10 and PM2.5 in several cities in the country, brought Romania before the Court of Justice of the European Union in 2018, and in December 2021, for non-compliance with EU rules on combating industrial pollution (Directive 2010/75/EU) and failure to fulfill the obligation to adopt an air pollution control program, pursuant to Directive 2016/2284 on the reduction of national emissions of certain air pollutants ("PNE Directive"). In 2020, Romania was condemned by the EU Court of Justice for its systematic failure to reduce dust pollution (PM10) in Bucharest, with citizens of the capital having been exposed to very unhealthy levels of dust since 2007.

10 other cities in the country have come to the attention of the European institutions, due to the high level of air pollution, the Municipality of Craiova being one of them, along with Cluj, Timișoara, Constanța, Brăila, Turnu Măgurele, Galați, Bacău, Ploiesti and Pitesti.

The particulate matter (PM), especially those with an aerodynamic equivalent diameter smaller than 2.5 µm are seldom studied due to the restricted availability of $PM_{2.5}$ related data (Bodor et al. 2022).

MATERIAL AND METHODS

Air quality monitoring is a subject that has enjoyed increased interest in recent years in Romania, as a result of the increased awareness of the consequences of air pollution on health, but also the availability and accessibility of technologies with the help of which these measurements can be made simply, efficiently and at low cost. Advances in sensor technology have changed the approach to monitoring a wide range of air pollutants, enabling rapid online measurements in denser networks. At the moment there are several private networks dedicated to measuring air quality, providing additional data on the state of air quality that complements that provided by public networks. Such networks also exist within the municipality of Craiova, developing exclusively as citizens' initiatives for independent air quality measurement, following frequent episodes of alarming pollution in areas of the city not covered by the RNMCA monitoring stations.

The paper analyzes the independent local network formed by uRADMonitor devices and aims to highlight its importance at the local level, both through the lens of the data provided and easy access to them, as well as by expanding the monitored areas and increasing the awareness of the impact of air pollution on the health of the entire local community. The uRADMonitor project belongs to Magnasci, a Romanian company. It is an ambitious project started in Timișoara, which has developed a system to detect and warn of harmful chemical and physical factors around us. The more than 6,000 sensors around the world now form the global network of interconnected air quality measuring devices that collect real-time measurements of air pollution levels. The data on air quality at the level of Craiova Municipality, analyzed in this study, were extracted from the uRADMonitor platform (https://www.uradmonitor.com/tools/users/craiova/). The chosen sensors are located in different areas of the city, in order to analyze the evolution of PM 2.5 particle values over a larger area of the city.

To achieve these objectives, the research was carried out in the following directions:

• analyzing the latest studies and reports published by the highest international and European forums in the field of environment and public health, in order to accurately know the current trends regarding the global state of the surrounding air, but also the latest regulations or recommendations related to health environment and population;

• assessment of the state of air quality in Craiova with the help of the data extracted from the uRADMonitor platform and the quantitative assessment of the data provided by the independent sensors in relation to the local stations in the RNMCA.

RESULTS AND DISCUSSIONS

The analyzed data comes from the 6 sensors (Fig. 1) located on Vasile Alecsandri Street (S1), General Nicolae Magereanu Street (S2), Aleea Păltiniș (S3), Alexandru Ioan Cuza str. (S4), Doctor Ion Cantacuzino str. (S5) and Voineasa str. (S6).

Sensor S1 located on Vasile Alecsandri Street, with identification number in the uRADM network 1600020C, between 01.09.2021 - 30.04.2022 recorded the following data:

- in the period 01.09.2021 - 31.10.2021, the S1 sensor recorded an average of PM 2.5 of 14.45 µg/m³, the maximum of 184 µg/m³, with 155 µg/m³ average in real time on 25.10.2021, time 12:21:27 AM.

- in the period 01.11.2021 - 31.12.2021, the S1 sensor recorded an average of PM 2.5 of 72.10 µg/m³, the maximum of 2267 µg/m³, recorded on 01.12.2021, time 11:55:57 PM, average displayed in real time being 2233 µg/m³.

- in the period 01.01.2022 - 28.02.2022, the average PM 2.5 recorded by the S1 sensor was 27.42 µg/m³, and the maximum of 243 µg/m³, on 01.01.2022, at 12:00:14 AM, the average value displayed in real time reaching 221 µg/m³.

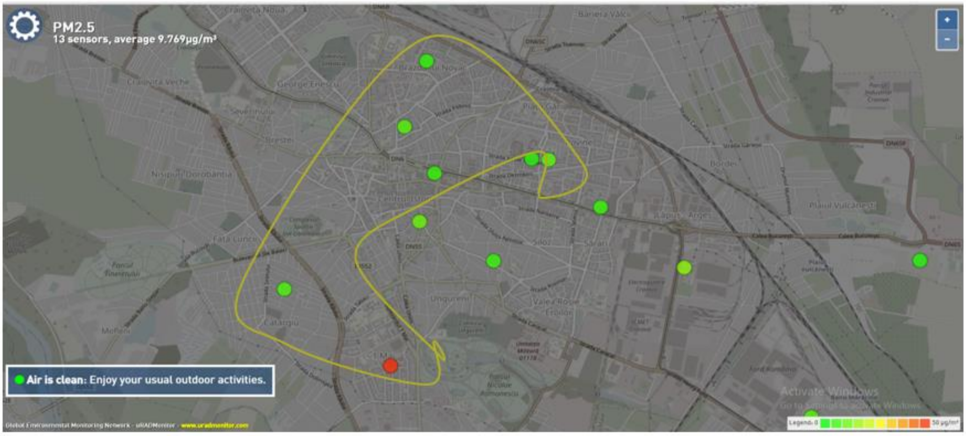

Figure 1. Locations of the analyzed sensors

- in the period 01.03.2022 - 30.04.2022, the average PM 2.5 recorded by the S1 sensor was 19.50 µg/m³, the maximum of 174 µg/m³, on 07.03.2021, at 2:22:21 PM, resulting in a average value displayed in real time of 32 µg/m³.

The S2 sensor located on General Nicolae Măgereanu Street, with identification number in the uRADM network 160001FF, between 01.09.2021 and 30.04.2022 recorded the following data:

- in the period 01.09.2021 - 31.10.2021 (there are data only for the period 05.10.2021 - 12.10.2021), the average PM 2.5 recorded by the S2 sensor was 7.2 µg/m³, the maximum of 52 µg/m³ (07.10 .2021) the value transmitted in real time being 47 µg/m³.
- in the period 01.11.2021 - 31.12.2021, the average value recorded by the S2 sensor for PM 2.5 was 19.99 µg/m³, the maximum of 2365 µg/m³, recorded on 30.12.2021.
- in the period 01.01.2022 - 28.02.2022, the average recorded for PM2.5 by the S2 sensor was 19.25 µg/m³, the maximum of 656 µg/m³, and the average value displayed in real time of 204 µg/m³, on 01.01. 2022, 12.00.25 AM.
- during the period 01.03.2022 - 30.04.2022, the S2 sensor recorded an average of PM 2.5 of 13.34 µg/m³, the maximum of 230 µg/m³, 72 µg/m³ being the average value displayed in real time for the date of 09.03. 2022, time 6.52.46 AM.

The sensor S3 located on Aleea Păltiniș, with identification number in the uRADM network 16000200, during the period 01.09.2021-30.04.2022 recorded the following data:

- in the period 01.09.2021 - 31.10.2021, the S3 sensor recorded an average of PM2.5 of 17.09 µg/m³, and the maximum of 5353 µg/m³ (short-term), on 21.09.2021, at 5:11 :39 PM, the real-time average displayed was 65 µg/m³.
- in the period 01.11.2021 - 31.12.2021 the S3 sensor recorded an average PM2.5 of 29.35 µg/m³, the maximum of 374 µg/m³ (short-term) on 12.11.2021, at 7:35:36 PM , the real-time average value being 70 µg/m³.

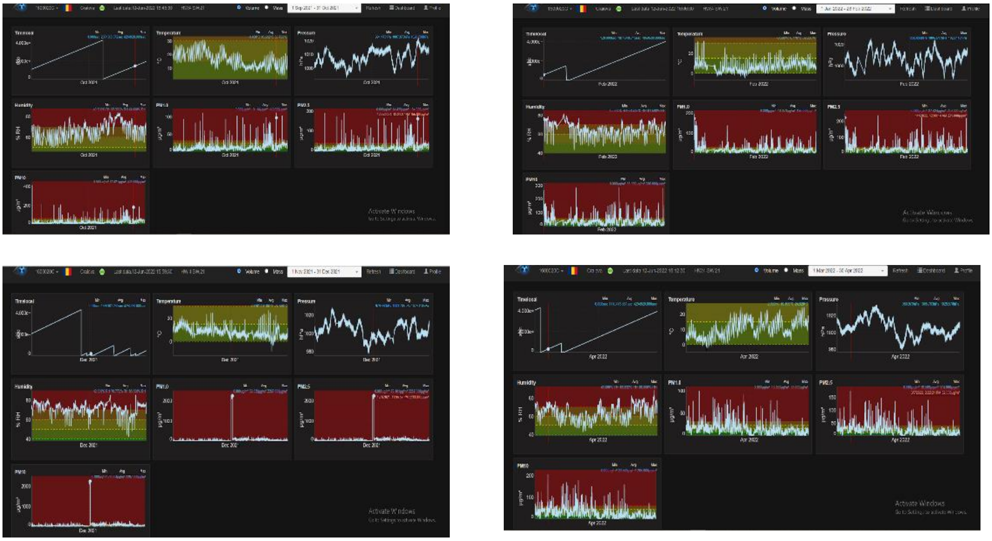

Figure 2. Data recorded by the sensors during the analyzed period

- during the period 01.01.2022 - 28.02.2022, the S3 sensor recorded an average of PM2.5 of 24.93 µg/m³ and a maximum of 532 µg/m³, on 19.01.2022, at 9:48:45 AM, average in real time being 64 µg/m³.
- in the period 01.03.2022 - 30.04.2022, the S3 sensor recorded an average of PM2.5 of 22.51 µg/m³, the maximum of 3518 µg/m³, on 14.04.2022, at 9:20:35 AM, the average in real time being 35 µg/m³.

Sensor S4 located on Alexandru Ioan Cuza Street, near the DJ02 station of RNMCA, identified with the number 820002C3 in the uRADM network, is model A3. The A3 model monitors, in addition to PM1, PM2.5, PM10, temperature, humidity and atmospheric pressure, and volatile organic compound, noise, carbon dioxide, formaldehydes and ozone. In the period 01.09.2021 - 30.04.2022 this sensor recorded the following data:

- in the period 01.09.2021 - 31.10.2021, S4 recorded an average of PM2.5 of 15.14 µg/m³, the maximum of 331 µg/m³, recorded on 25.10.2021, time 1:51:20 AM, average in real time displayed being 55 µg/m³.
- in the period 01.11.2021 - 31.12.2021, S4 sensor recorded an average of PM2.5 of 30.90 µg/m³ and a maximum of 338 µg/m³, on 23.12.2021, time 11:40:41 PM, average displayed in real time reaching the value of 168 µg/m³.
- in the period 01.01.2022 - 28.02.2022, the S4 sensor recorded an average of PM2.5 of 28.21 µg/m³, the maximum of 376 µg/m³, on 01.01.2022, time 12:01:21, average in real time being 195 µg/m³. Regarding the variation of PM2.5 in the time interval 12:00 AM - 11.59 PM from 01.01.2022,the maximum value was recorded at 12:11:19 AM, at 331 µg/m³, decreasing until 6:51:20 AM at the value of 49 µg/m³.
- in the period 01.03.2022 - 30.04.2022, S4 sensor recorded an average of PM2.5 of 19.58 µg/m³, the maximum of 209 µg/m³, on 15.03.2022, time 12:37:13, average over time real being 85 µg/m³.

Sensor S5 located on Doctor Ion Cantacuzino Street (Doctor Nicolae Ionescu-Sisești Street), with identification number 160001FE in the uRADM network, model SMOGGIE, between 01.09.2021 - 30.04.2022 recorded the following data:

- between 01.09.2021 and 31.10.2021, the S5 sensor recorded an average of PM2.5 of 22.80 µg/m³ and a maximum of 44.52 µg/m³, on 10/19/2021, time 10:49:28, average transmitted in real time being 88 µg/m³.
- in the period 01.11.2021 - 31.12.2021, the S5 sensor recorded an average of PM2.5 of 34.89 µg/m³ and a maximum of 38.15 µg/m³ on 05.11.2021, at 6:10:23 PM, the PM 2.5 value in real time being 135 µg/m³.
- between 01.01.2022 and 28.02.2022, the S5 sensor recorded an average PM2.5 of 28.92 µg/m³ and a maximum of 309 µg/m³, on 01.01.2022, at 12:00:51 AM, the PM2.5 value in real time being 145 µg/m³.
- in the period 01.03.2022 – 30.04.2022, the S5 sensor recorded an average of PM2.5 of 23.30 µg/m³ and a maximum of 869 µg/m³, on 08.04.2022, at 8:45:33 PM, the PM2.5 average value in real time being 65 µg/m³.

Sensor S6 located on Voineasa Street (Catargiu), with identification number 1600020D in the uRADM network, model SMOGGIE, between 01.09.2021 - 30.04.2022 recorded the following data:

- between 01.09.2021 and 31.10.2021, the S6 sensor recorded an average of PM2.5 of 21.85 µg/m³ and a maximum of 2101 µg/m³, on 02.10.2021, time 10:02:26 PM, PM2 .5 average value transmitted in real time being 65 µg/m³.
- in the period 01.11.2021 - 31.12.2021 the S6 sensor recorded an average PM2.5 of 43.05 µg/m³ and a maximum of 385 µg/m³, on 27.11.2021, at 8:29:43 PM, PM2 .5 average value transmitted in real time being 359 µg/m³. During this period, there were numerous exceedings of the allowed limit for the concentration of PM2.5 in the air, reaching a maximum value of 365 µg/m³, value transmitted in real time on 23.12.2021. In 11 days, values between 154 µg/m³ and 365 µg/m³ were recorded.
- between 01.01.2022 and 28.02.2022 the S6 sensor recorded an average value of PM2.5 of 41.92 µg/m³ and a maximum of 462 µg/m³ on 01.01.2022 at 12:00:35 AM, PM2.5 average value transmitted in real time being 439 µg/m³. Also during this period, values of PM2.5 extremely dangerous for health were recorded, in 15 days were recorded values between 139 µg/m³ and 439 µg/m³.
- in the period 01.03.2022 – 30.04.2022 the S6 sensor recorded an average value of 27.26 µg/m³ and a maximum of 287 µg/m³ on 15.03.2022 at 9:14:38 PM. PM 2.5 average value transmitted in real time being 219 µg/m³.

To determine whether the values of PM2.5 particles, recorded by the studied sensors, fall within the established limits, they are compared with the established limit value and the specific quality index for PM2.5.

Table 1

Average/maximum PM2.5 values recorded during the analyzed period

Sensor / Period	01.09.2021 31.10.2021	01.11.2021 31.12.2021	01.01.2022 28.02.2022	01.03.2022 30.04.2022	ICA/**LMA**
S1	14.45/184 µg/m³	72.10/2267 µg/m³	27.42/243 µg/m³	19.50/174 µg/m³	2, 6, 4, 2 **33.37**
S2	7.2 /52 µg/m³	19.99/2365 µg/m³	19.25/656 µg/m³	13.34/230 µg/m³	1, 2, 2, 2 **14.94**
S3	17.09/5353 µg/m³	29.35/374 µg/m³	24.93/532 µg/m³	22.51/3518 µg/m³	2, 4, 3, 3 **23.47**

S4	15.14/331 µg/m³	30.90/338 µg/m³	28.21/376 µg/m³	19.58/209 µg/m³	2, 4, 4, 2 **23.46**
S5	22.80/44.52 µg/m³	34.89/38.15 µg/m³	28.92/309 µg/m³	23.30/869 µg/m³	3, 4, 4, 3 **27.48**
S6	21.85/2101 µg/m³	43.05/385 µg/m³	41.92/462 µg/m³	27.26/287 µg/m³	3, 4, 4, 4 **33.525**

By framing the average values recorded by the 6 analyzed sensors into one of the six concentration ranges, the specific air quality index corresponding to suspended particles PM2.5 is obtained, for the period 01.09.2021 - 30.04.2022, as observed from table 1:

- there are no periods when the specific index of PM2.5 indicates very good air quality in the studied area (ICA=1), 5 out of the 6 sensors studied signaling that the level of PM2.5 particle concentrations is quite high.

- in colder months, the ICA has higher values (3, 4 and 6), confirming that residential heating has a significant influence on air quality.

-sensors S5 and S6, located in the 1 Mai and Catargiu neighborhoods, areas frequently indicated by residents for illegal burning of waste, recorded very high values, ICA indicating poor air quality in these areas (3 and 4).

-the sensor located near the DJ2 station in the national network, the only one that monitors PM2.5 particles at the level of Craiova Municipality, the data obtained from the uRADM network are comparable to those presented in the monthly reports of APM Dolj.

- on 01.01.2022, fireworks had a very high influence on the air quality index, as shown by the variation of PM2.5 recorded by S4 sensor.

All these results show that, as found by previous studies on the importance of data provided by independent sensor networks, the uRADM local network has a particularly important role, providing additional information on local air quality.

CONCLUSIONS

The fact that public networks are usually sparsely distributed and inadequate to fully capture the variability of air pollution in an urban agglomeration has led to the increasing importance of a generation of devices that are often generically described as "low-cost sensors" (LCS). These devices create a bridge between the limited spatial coverage of public networks and the desires of individuals to know the quality of the surrounding air.

These aspects also contributed to the creation of the current independent air quality monitoring network in the municipality of Craiova, the data provided by the 6 analyzed sensors contributing to the formation of an overall picture of air quality at the local level. The collected data helps us to better understand pollution factors and possible solutions to limit them, for a cleaner environment and a better quality of life.

The accessibility of sensors offers new opportunities in air monitoring, can support new services and facilitate the growth of the number of users in order to increase the spatial density of measurements. Sensors have brought a change in air pollution monitoring, traffic management, personal exposure and health assessment, citizen information and air quality assessment especially in developing countries.

The low-cost sensors are not a direct substitute for the monitoring stations in the RNMCA, but they are a complementary source of air quality information.

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