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AIR QUALITY INDEX ASSESSMENT BASED ON CROWDSOURCING DATA

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Abstract

Air quality indicators offer qualitative insights into environmental conditions regarding the concentration of air pollutants. Among the most widely utilized indicators globally is the Air Quality Index (AQI), facilitating the evaluation of air pollution levels and its ramifications on health and natural ecosystems. The AQI relies on various calculation methods, which differ from country to country.
This paper introduces a methodology for processing air pollutant concentrations, utilizing data gathered from open-access monitoring platforms via crowdsourced sensor networks in urban areas. Multiple AQI assessment methods are outlined, with a critical review aimed at establishing recommendations for governmental bodies to align with international standards.

Keywords: AQI, indicators, pollution, monitoring

1. CONTEXT

1.1. Air pollution

In most European cities, air quality has become a subject of analysis and debate over the past decades. We can say that air pollution has been reduced in many cities due to local, national and European initiatives [4,5]. However, air quality still affects public health in densely populated areas around the world [3]. Air quality is therefore a common problem to almost all major cities – significant source becomes road traffic [1,4,5].

In many urban areas, air quality is a real issue and it is therefore monitored by the open-access monitoring platforms through crowdsourcing sensor networks in urban locations [9].The main pollutants monitored by these platforms are: particulate matter $PM_{2,5}$, PM_{10}, nitrogen oxides (NO_x), ozone (O_3), sulphur dioxide (SO_2) and carbon monoxide (CO) [4].

1.2. Exposure to air pollution by PM

Air pollution, particularly the presence of fine particulate matter ($PM_{2.5}$ and PM_{10}), poses significant health risks to populations worldwide.

Figure 1 depicts the exposure to air pollution by $PM_{2.5}$ across Europe, highlighting significant variations in pollutant levels across different regions.

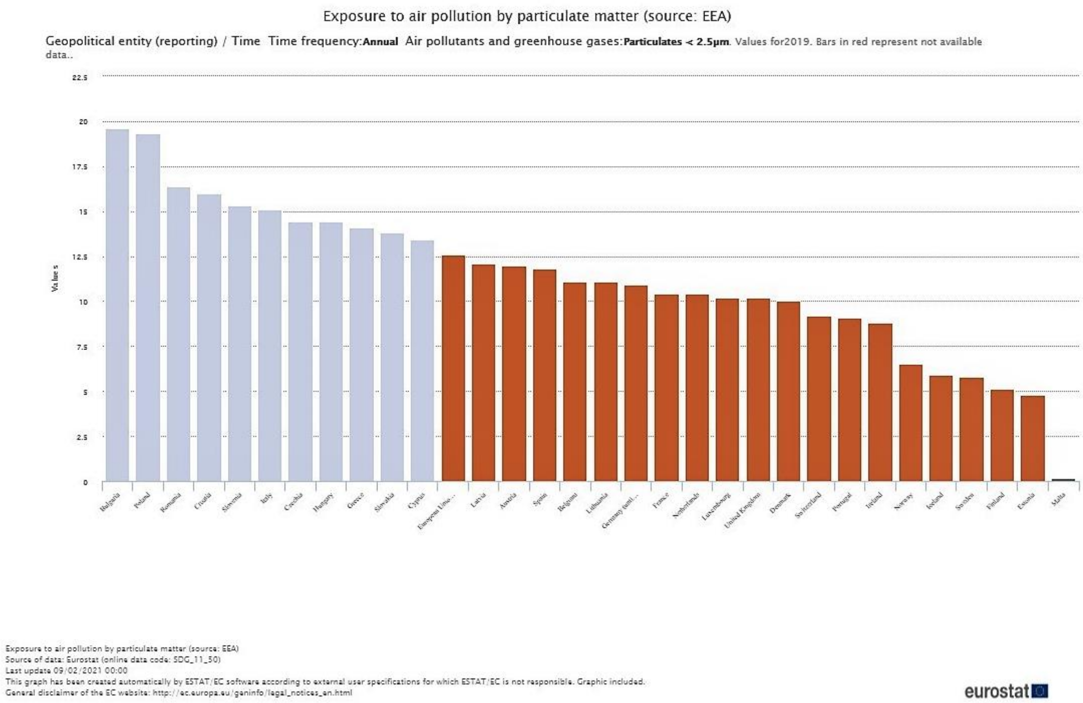

Figure 1. Exposure to air pollution by $PM_{2,5}$ in EU for 2019 [12]

A pressing concern for citizens is the direct correlation between air quality and human health, as emphasized by health experts and policymakers [6]. Notably, urban roads often run alongside residential areas, making transportation a primary contributor to urban air pollution in many instances. [1,6].

The graph presented in Figure 2 illustrates the exposure to air pollution by PM_{10} across various countries in Europe. By understanding the geographical distribution of PM_{10} pollution across Europe, stakeholders can prioritize resources and implement effective measures to improve air quality and promote the well-being of communities across the continent.

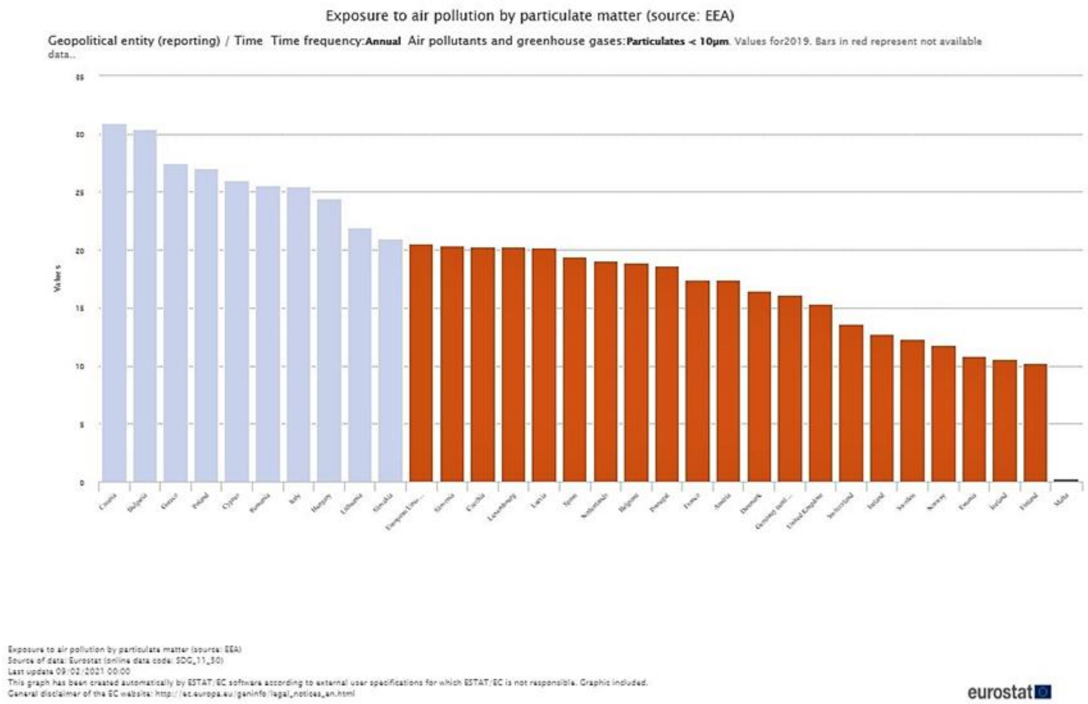

Figure 2. Exposure to air pollution by PM_{10} in EU for 2019 [12]

When trying to deal with local air quality, traffic seems to be the reliable choice for intervention. Solving local problems can be achieved by emission reductions through the deployment of cleaner vehicles and the reduction of traffic flows or by promoting public transport use. Nevertheless, such measures reduce the exposure to air pollution in high concentrations, but do not improve the air quality itself [3,4].

Exposure to particulate matter air pollution remains a significant concern across Europe, with implications for public health and environmental sustainability. Addressing this issue requires coordinated efforts at the local, national, and international levels to mitigate emissions, enhance air quality monitoring, and promote policies that prioritize human health and environmental protection.

2. MONITORING PLATFORMS THROUGH CROWDSOURCING SENSOR NETWORKS

Air quality monitoring stations utilize advanced particle sensors for real-time pollution measurement. Among the pollutants most frequently monitored by these platforms are PM_{10} and $PM_{2.5}$ particles, known to be some of the most harmful air pollutants. These sensor networks are remarkably simple to set up, requiring only a WIFI access point and a USB power supply. Once connected, air pollution levels are logged in a database and promptly displayed on a map for public access.

In Romania, the National Air Quality Monitoring System (SNMCA) establishes the organizational, institutional, and legal framework for cooperation between public authorities and institutions with expertise in the field. Its primary objectives are to uniformly assess and manage air quality and to inform both the public and European and international institutions about air quality conditions. Notably, SNMCA's official communications outline a project aimed at establishing a national sensor-based monitoring network.

The overarching goal of this project initiative is to enhance public awareness regarding air quality issues and to furnish real-time information on air quality nationwide [10]. Leveraging publicly available information, residents receive recommendations tailored to the measured air pollution levels (e.g., guidance on outdoor physical activities).

In Romania, alongside official efforts, there are public initiatives serving as alternative platforms for air quality and environmental monitoring. These initiatives are driven by organizations active in environmental protection, which have successfully implemented these projects through public participation.

These platforms offer real-time results, graphs, and statistics over extended periods (Figure 3 and Figure 4). Utilizing an open data approach, monitoring platforms transmit data freely, allowing other networks or iOS/Android applications to access and download the information.

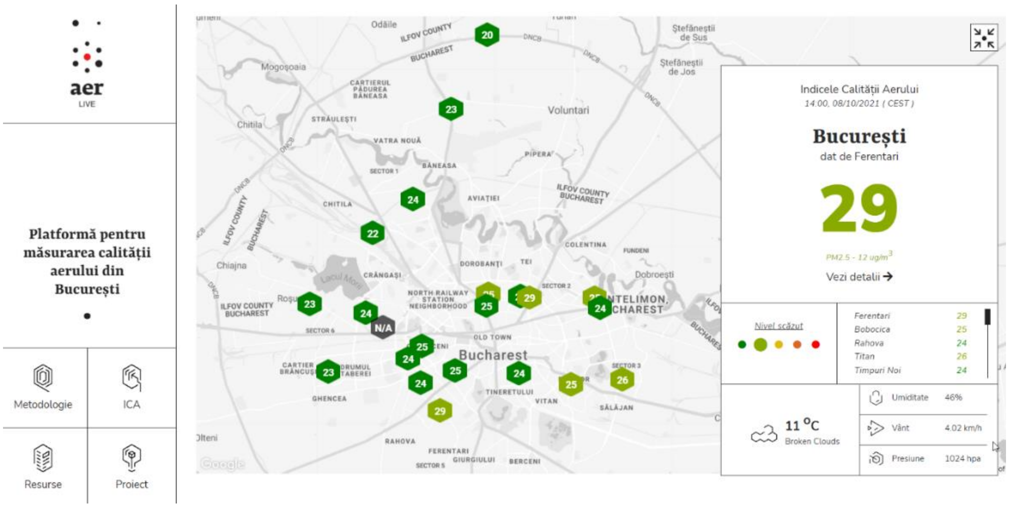

Figure 3. ”AerLive” monitoring platform [11]

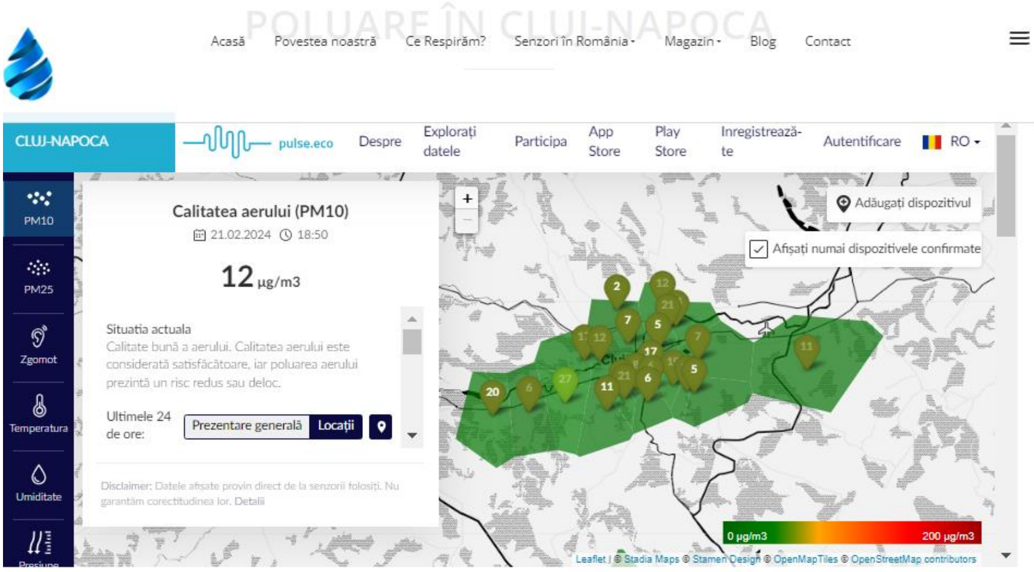

Figure 4.”Strop de aer” monitoring platform [14]

3. METHODOLOGIES

3.1. Indices

The society is constantly working with indicators to simplify reality and report it to a state considered normal or reference [8].

Air quality indicators and indices provide an easy method to communicate environmental information, emphasizing differences from the normal state or expected values [2,6]. Therefor different actions can be taken, such as identifying the evolution of processes, developing forecasts and strategies, evaluating the success of environmental policies and informing the public [7].

The most common method of using air quality indicators and indices involves comparing the values obtained from monitoring with maximum permitted concentrations, or limit values, or thresholds [8]. These values are in fact limit levels set by legislation, based on scientific knowledge, in order to avoid, prevent or reduce harmful effects on human health or the environment [1]. Depending on the timeframe considered, these limit values can be set hourly, daily, weekly, monthly, or annually [5,6,8]. Essentially, they represent the maximum allowable value for the parameter in question during the specified period, without causing detrimental effects to the environment.

There are other complex methods in determining the air quality indicators which involve data processing, calculation of sub-indices and then indices [6]. These methodologies also entail comparing outcomes with maximum permitted concentrations, ultimately presenting the air quality index in a straightforward manner that is easily comprehensible to the public, often utilizing standardized chromatic symbols.

3.2. Air Quality General Index (Romania)

In Romania, the prevailing method for assessing air quality is through the utilization of an air quality index, referred to colloquially as the "specific index." This system entails encoding the concentrations of several key pollutants monitored nationwide, including SO_2, NO_2, O_3, CO, PM_{10} and $PM_{2.5}$. The general index is organized into six distinct categories, as illustrated in Figure 4. This index is determined individually for each monitoring station based on the highest specific index derived from the monitored pollutants. This system allows for a comprehensive assessment of air quality at each monitoring station by considering multiple pollutants and condensing the information into a single value that is easy to understand for the general public.

Figure 4. Air quality general index (Romania) [13]

The calculation method for the general index involves two primary steps. Initially, the specific index is computed for each pollutant by comparing the hourly average values to the maximum permitted concentrations or limit values, as stipulated by national legislation (OM no. 1818/2020). Subsequently, the general index is derived by selecting the highest value among the specific indices for each pollutant component.

3.3. Air Quality Index AQI (US EPA)

The air quality index stands as one of the most universally adopted metrics globally for evaluating air pollution levels. Within this index framework, each pollutant is categorized into six distinct quality classes, each defined by specific threshold concentrations and corresponding reference indices (Table 1) [6,7]. This systematic classification not only facilitates a comprehensive understanding of pollutant levels but also provides clear benchmarks for assessing air quality conditions across diverse geographical regions.

Table 1. AQI/ AQI Health message (US EPA) [6]

AQI Value	AQI Category	AQI Color
0 - 50	Good	Green
51 - 100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive Groups	Orange
151 - 200	Unhealthy	Red
201 - 300	Very Unhealthy	Purple
301 - 500	Hazardous	Maroon

Daily Air Quality Standard

AQI Value	Health Message	AQI Color
0 - 50	None	Green
51 - 100	Unusually sensitive people should reduce prolonged or heavy exertion	Yellow
101 - 150	Sensitive groups should reduce prolonged or heavy exertion	Orange
151 - 200	Sensitive groups should avoid prolonged or heavy exertion; general public should reduce prolonged or heavy exertion	Red
201 - 300	Sensitive groups should avoid all physical activity outdoors; general public should avoid prolonged or heavy exertion	Purple
301 - 500	Everyone should avoid all physical activity outdoors	Maroon

The calculation method involves the determination of specific sub-indices from the average hourly values obtained for each monitored pollutant, using Equation (1). The final index, calculated with equation (2), is determined as the maximum value among the subindices for each individual component (pollutant).

$$AQI_n = \frac{(AQI_{high} - AQI_{low})}{(C_{high} - C_{low})} \times (C - C_{low}) + AQI_{low} \qquad \text{(eq.1)}$$

$$AQI = \max(AQI_n) \qquad \text{(eq.2)}$$

C – 1 hour or 24-hour average concentration in $\mu g/m^3$;
C_{low} – class threshold value less than C;
C_{high} – class threshold value higher than C;
AQI_{low} – the value of the index corresponding to the C_{low} threshold;
AQI_{high} – the value of the index corresponding to the C_{high} threshold.

3.4. Common Air Quality Index CAQI (EU)

The air quality index stands as one of the most universally adopted metrics globally for evaluating air pollution levels. Within this index framework, each pollutant is categorized into six distinct quality classes, each defined by specific threshold concentrations and corresponding reference indices (Table 1) [6,7]. This systematic classification not only facilitates a comprehensive understanding of pollutant levels but also provides clear benchmarks for assessing air quality conditions across diverse geographical regions.

Air quality in European cities is presented in an easily understandable way by converting all air quality measurements into a single relative figure: the Common Air Quality Index (or CAQI). [4,5]

The Common Air Quality Index (CAQI) is designed to present and compare air quality in near-real time on an hourly or daily basis. It has five levels, using a scale from 0 (very low) to >100 (very high) and the matching colours range from light green to dark red. The CAQI is computed according to the grid system (shown in Table 2) by linear interpolation between the class borders. The final index is the highest value of the subindices for each component (pollutant).[2,4,5]

Table 2. AQI/ AQI Health message (US EPA) [6]

Index Class	Grid	ROADSIDE INDEX: Mandatory pollutant NO2	ROADSIDE INDEX: Mandatory pollutant PM10 1 hour	ROADSIDE INDEX: Mandatory pollutant PM10 24 hours	ROADSIDE INDEX: Auxiliary pollutant PM2.5 1 hour	ROADSIDE INDEX: Auxiliary pollutant PM2.5 24 hours	ROADSIDE INDEX: Auxiliary pollutant CO	BACKGROUND INDEX: Mandatory pollutant NO2	BACKGROUND INDEX: Mandatory pollutant PM10 1 hour	BACKGROUND INDEX: Mandatory pollutant PM10 24 hours	BACKGROUND INDEX: Mandatory pollutant O3	BACKGROUND INDEX: Auxiliary pollutant PM2.5 1 hour	BACKGROUND INDEX: Auxiliary pollutant PM2.5 24 hours	BACKGROUND INDEX: Auxiliary pollutant CO	BACKGROUND INDEX: Auxiliary pollutant SO2
Very High	>100	>400	>180	>100	>110	>60	>20000	>400	>180	>100	>240	>110	>60	>20000	>500
High	100	400	180	100	110	60	20000	400	180	100	240	110	60	20000	500
	75	200	90	50	55	30	10000	200	90	50	180	55	30	10000	350
Medium	75	200	90	50	55	30	10000	200	90	50	180	55	30	10000	350
	50	100	50	30	30	20	7500	100	50	30	120	30	20	7500	100
Low	50	100	50	30	30	20	7500	100	50	30	120	30	20	7500	100
	25	50	25	15	15	10	5000	50	25	15	60	15	10	5000	50
Very Low	25	50	25	15	15	10	5000	50	25	15	60	15	10	5000	50
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.5. Example of comparative calculation for air quality index

By applying the average 24-hour values of two key pollutants (Table 3), $PM_{2.5}$ and PM_{10}, we can initiate a comparative analysis using both the national method outlined in subchapter 3.2 and the European method detailed in subchapter 3.4. This approach allows for a comprehensive examination of air quality standards, considering both domestic regulatory frameworks and broader European guidelines. Through this dual assessment, we can gain valuable insights into the efficacy and stringency of air quality management practices at both national and international levels.

Table 3. Data entry for comparative calculation

Pollutant	24 hours average [µg/m^3]	Specific index (Romanian legislation)					
		1	2	3	4	5	6
$PM_{2,5}$	21	0-10	10-20	20-25	25-50	50-75	75-800
PM_{10}	24	0-20	20-40	40-50	50-100	100-150	150-1200

The comparative analysis of the results presented in Table 4 underscores notable discrepancies in the expression of indices. These discrepancies underscore the varying methodologies or calculation formulas utilized by different countries within the European Union.

Table 4. Comparative results using National Method and EU Method

Air Quality General Index (Romania)	Common Air Quality Index CAQI (EU)
Specific index$_{PM2,5}$ = 2 Specific index$_{PM10}$= 3 General index = Max (Specific index$_n$) General index = Specific index$_{PM10}$= 3 **Index value: 3** Index class: yellow	$\boldsymbol{AQI_{PM2,5} = \frac{(75-50)}{(30-20)} \times (21-20) + 50}$ = 52,5 $\boldsymbol{AQI_{PM10} = \frac{(50-25)}{(30-15)} \times (24-15) + 25}$ = 40 $\boldsymbol{AQI = \max(AQI_n)} \rightarrow$ AQI = $\boldsymbol{AQI_{PM2,5} = 52}$ **Index value: 52** Index class: yellow

3. CONCLUSIONS

There are many ways of providing an air quality index and one way is not necessarily better than the others [6]. The index is a pragmatic process of providing information for the citizens, even if from a scientific point of view this is a gross generalization and a tremendous loss of information.

The comparison of results in Table 5 highlights discrepancies in how the indices are presented. Based on this critical analysis and the insights gained from the case study, we strongly propose the harmonization of AQI calculation methods and information systems across both the national air quality monitoring system and the informal, crowdsourced sensors found in numerous Romanian cities. This alignment would facilitate a more comprehensive understanding of air pollution and potentially foster greater engagement from civil society in environmental protection efforts. Ultimately, such initiatives could pave the way for a bottom-up approach to policy planning in urban areas, thereby promoting more effective and inclusive strategies for addressing environmental challenges.

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