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Trend analysis of Air Quality Index in Catania from 2010 to 2014.

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Abstract

Information on air quality in urban areas represents an important objective to raise awareness and participation of citizens towards those measures aimed at containing and reducing vehicular traffic. For several years at the international level, evaluation procedures have been adopted by indices. One of the first synthetic indices, adopted by the United States Environmental Protection Agency (US-EPA), was the Pollution Standard Index (PSI). In 1999, the EPA replaced the PSI index with Air Quality Index (AQI), which includes two new sub-indices, the ozone at ground level and fine particulate.

Despite the European Decisions 97/101/EC and 2001/752/EC, have established an exchange of information from networks and individual stations measuring ambient air pollution in Member States, the use of a single index has not yet been defined that allows you to compare different realities.This heterogeneity emerges in Italy as well, where only a few Environmental Protection Agencies disclose indexes to inform citizens.

In this article, the Air Quality Index (AQI) currently used by the United States Environmental Protection Agency has been applied to the metropolitan city of Catania, in order to analyze the level of pollution daily from 2010 to 2014. Through the use of the AQI it was possible to synthesize in a single daily value, concentrations of major pollutants in urban areas (NO_2, O_3, CO, SO_2, PM_{10}) for the entire period. For the calculation procedure of the AQI, the data concentrations were provided by Municipal Ecology and Environment Office. The data relates to three monitoring stations, whose locations have not changed over the years. This also made it possible to evaluate the change in frequency of AQI agglomerations where the monitoring units have been positioned. The value obtained by the AQI for each station has been ranked in six levels of pollution; each level has been associated with a particular coloring allowing this information to be more intuitive. Lastly, it was possible to reach the air quality assessment in urban environment from the frequency variations of each level derived from the year 2010 until 2014.

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Keywords: Air quality; Air pollution; AQI; Urban area; Monitoring network.

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1. Introduction

Air quality is a measure of how the air is free from pollution and harmless if inhaled by humans. The responsibilities for monitoring air quality and air pollution are distributed at different levels: protocols and international agreements, Community legislation, national and regional level.

The air quality monitoring in Italy is regulated by the Legislative Decree no. 155/2010, which transposes the European Directive 2008/50/EC and the latest Legislative Decree 250/2012. In these decrees is enshrined the need to reduce pollution to levels which minimize harmful effects on human health, with particular attention to sensitive populations [1], defining them as limit values, target values, information threshold and alarm, as well as improving the monitoring, air quality assessment, identification of point sources [2], and providing continuous information to the public.Informing the population on the state of air quality is very important not only because it is required by industry regulations but also because it supports the adoption of necessary consolidation measures. For several years at the international level, evaluation procedures have been adopted using indexes.

One of the first synthetic indices adopted by the United States Environmental Protection Agency (US-EPA), was the Pollution Standard Index (PSI) developed by Ott and Hunt [3]. In 1999, the EPA replaced the index PSI with the Air Quality Index (AQI), which includes two new sub-indices, the ozone at ground level and fine particulate [4].

Even in several European countries a system indicator is used to explain to the population, in simple and immediate way, the quality of the air we breathe [5,6]. Despite the European Decisions 97/101/EC and 2001/752/EC, have established an exchange of information (Exchange of Information, EOI) from networks and individual stations measuring ambient air pollution in Member States, the use of a single index has not yet been defined to allow you to compare different realities.Some states are using a modified version of AQI [7], others employ indices of environmental sustainability, where air pollution is the only parameter taken into account, as in the case of Germany, which adopts the index DUX [8].

This inconsistency is also apparent in Italy where only very few environmental protection agencies disclose indices for information and public awareness on the issue of air quality.

In this article the Air Quality Index (AQI) currently adopted by the United States Environmental Protection Agency, was applied to the metropolitan city of Catania in order to analyze the trends in air quality from 2010 to 2014 in the urban setting [9]. The data of pollutant concentrations were provided by the Municipal Ecology and Environment Office. The data relates to three monitoring stations, whose locations have remained unchanged over the years [10]. The most important agglomeration was obtained, among the categories provided by the AQI, where the monitory units are positioned. It was also possible to evaluate the changes in air quality over the considered period.

Nomenclature

AQI	Air quality index [-]
$I_{[\ ]}$	Air Quality sub-index [-]
C	Pollutant concentration [μg/m^3] or [ppm] or [ppb]
C_{low}	Concentration breakpoint that is ≤ C [μg/m^3] or [ppm] or [ppb]
C_{high}	Concentration breakpoint that is ≥ C [μg/m^3] or [ppm] or [ppb]
I_{low}	The index breakpoint corresponding to C_{low} [-]
I_{high}	The index breakpoint corresponding to C_{high} [-]
m.avg*(8 hrs)*	Moving average over eight hours[ppm] or [ppb]

avg*(1 hr)*	Average hourly [ppb]
(24 hrs)	Daily value[µg/m^3]

2. Materials and Methods

2.1. The Air Quality Index (AQI)

The AQI is a dimensionless quantity defined to represent synthetically the overall state of air pollution. The numerical value of the index may fall into 6 classes of judgment of air quality, reported in Table 1, associated with the different colors in order to make this information easily transmitted to the public.

When the AQI values are below 100, the air quality, as a whole, is satisfactory and there is no potential interest to public health. When the AQI has a value almost equal to 100, the measured values of the pollutants overall are in accordance with the law. However, when the values of AQI increase above 100, clean air decreases making it become of interest to the public health.

The AQI considers pollutants that present an acute effect on health (PM_{10}, $PM_{2.5}$, CO, NO_2, O_3, SO_2). The choice of including only pollutants which present acute effects, may be questionable, and stems from the fact that this index is made for the purpose of giving information daily to the population in order to avoid short-term effects (of cardiovascular and respiratory systems).

Table 1. EPA's table of breakpoints

O_3 (ppb)	**O_3 (ppb)**	**$PM_{2.5}$ (µg/m^3)**	**PM_{10}(µg/m^3)**	**CO (ppm)**	**SO_2 (ppb)**	**NO_2 (ppb)**	**AQI**	**AQI Category**
C_{low}-C_{high}*(m.avg 8 hr)*	C_{low}-C_{high} *(avg 1 hr)*	C_{low}-C_{high}*(24 hr)*	C_{low}-C_{high}*(24 hr)*	C_{low}-C_{high} *(m.avg 8 hr)*	C_{low}-C_{high} *(avg 1 hr)*	C_{low}-C_{high} *(avg 1 hr)*	I_{low} - I_{high}	
0 - 59	-	0.0 - 12.0	0 - 54	0.0 - 4.4	0 - 35	0 – 53	0 - 50	Good
60 - 75	-	12.1 - 35.4	55 - 154	4.5 - 9.4	36 - 75	54-100	51 - 100	Moderate
76 - 95	125 - 164	35.5 - 55.4	155 - 254	9.5 - 12.4	76 - 185	101-360	101 - 150	Unhealthy for Sensitive Groups
96 - 115	165 - 204	55.5 - 150.4	255 - 354	12.5 - 15.4	186 - 304	361-649	151 - 200	Unhealthy
116 - 374	205 - 404	150.5 - 250.4	355 - 424	15.5 - 30.4	305 - 604	650-1249	201 - 300	Very Unhealthy
-	405 - 504	250.5 - 350.4	425 - 504	30.5 - 40.4	605 - 804	1250-1649	> 300	Hazardous

2.2. Calculation of AQI

The Air Quality Index is a piecewise linear function of the concentration of pollutant [11]. To convert the concentration of pollutant in the AQI equation (1) is used:.

$$I_{[\ ]} = \frac{I_{high}-I_{low}}{C_{high}-C_{low}}(C - C_{low}) + I_{low} \qquad (1).$$

To calculate the moving average over eight hours (8 hrsavg), average hourly (avg 1hr), daily value (24 hrs), foreseen for some pollutants, we proceeded in accordance with the terms set out by the Legislative Decree 155/2010, Annex XI.Equation (1) must be applied for each pollutant measured at the monitoring site.

The value of AQI dominant for the monitoring site considered, will be represented by the highest value between the present sub-indices considered; from report (2) the value of the AQI dominant is obtained:

$$AQI = \max(I_{O_3}, I_{PM_{2.5}}, I_{PM_{10}}, I_{CO}, I_{SO_2}, I_{NO_2}) \qquad (2).$$

In this work the values of the concentrations used in the calculation of the AQI were converted in [ppm] or [ppb] in order to properly implement the EPA's table of breakpoints.

In the calculation of the AQI the $PM_{2.5}$ is not considered because the monitoring stations do not acquire concentration values for that pollutant. In reference to the EPA's table of breakpoints, the O_3 is considered the maximum moving average of 8 hours.

Table 2 shows the pollutants considered in the calculation of the AQI, through equations (1) and (2), the type of media adopted for each pollutant and limit values expressed in Decree 155/2010, Annex XI.

Table 2. Pollutants considered in calculating of AQI .

POLLUNTANT	**TYPE OF MEDIA** *D. Lgs 155/2010*	**LIMIT VALUE** *D. Lgs 155/2010*
NO_2	*(avg 1 hr)*	200 µg/m³ not to be exceeded more than 18 times per calendar year
O_3	*(m.avg 8 hrs)*	120 µg/m³ not to be exceeded more than 25 days per calendar year averaged over three years
PM_{10}	*(24 hrs)*	50 µg/m³ not to be exceeded more than 35 times per calendar year
SO_2	*(avg 1 hr)*	350 µg/m³ not to be exceeded more than 24 times per calendar year .
CO	*(m.avg 8 hrs)*	10 mg/m³

2.3. Data source

The data of the concentrations of pollutants come from the monitoring network of the city of Catania, managed by the Ecology and Environment - Pollution Prevention Center. It consists of three monitoring stations identified as Librino (LBR), Viale V. Veneto (VVT), Piazza A. Moro (PZM). In Figure 1 it shows the location of the monitoring stations.

Each station is equipped with a series of analyzers independent from each other, capable of dosing a pollutant (SO2, PM10, CO, O3) or a family of them (NO2, NO, NOx, BTX). The analyzers undergo systematic automated calibration and periodically with a calibration gas mixtures certificates. The data acquired by the equipment are elaborated from the processor station and stored as an average hourly. Subsequently, the data of each station are retrieved from the central computer and then validated and stored.

3. Results and discussion

Equations (1) and (2) were applied to the data pollutant concentrations, measured at the three monitoring stations, in order to determine the AQI daily for the agglomerations. The location of the three monitoring stations was left unchanged from 2010 to 2014; this made it possible to assess the trend of AQI during that period.

Fig. 1. Air quality monitoring network of Catania.

As shown in the graph, in Figure 2 panel (a), from the agglomeration where the monitoring station (LBR) is located, the trend of AQI shows a slight increase during the summer, followed by a decline during the winter period. This seasonality is mainly due to high concentrations of O3, secondary pollutant, which is highly sensitive to solar radiation [12]. The greatest contribution to the accumulation of O3 is given also by the low concentrations of nitric oxide (NO) detected in the agglomeration where the monitoring station (LBR) is located. The low concentrations of (NO) reduces the possibility that the typical reactions of the Ozone Cycle take place, causing its accumulation.

The graph panel b) shows the frequencies of the categories that make up the AQI, calculated for each year. It shows that over the years the conditions of air quality have not undergone any particular changes, except for the year 2014 where technical problems prevented the acquisition of data.

The annual rate of the category "Good" on the average is between 85% and 95%, while the annual rate of the category "Moderate" varies between 3% and 6%. For the category "Unhealthy for Sensitive Groups" frequencies likely to raise concern werenot found. There is no presence of the remaining categories. This result identifies the category "Good" as "dominant" for the agglomeration where the monitoring station is located (LBR).

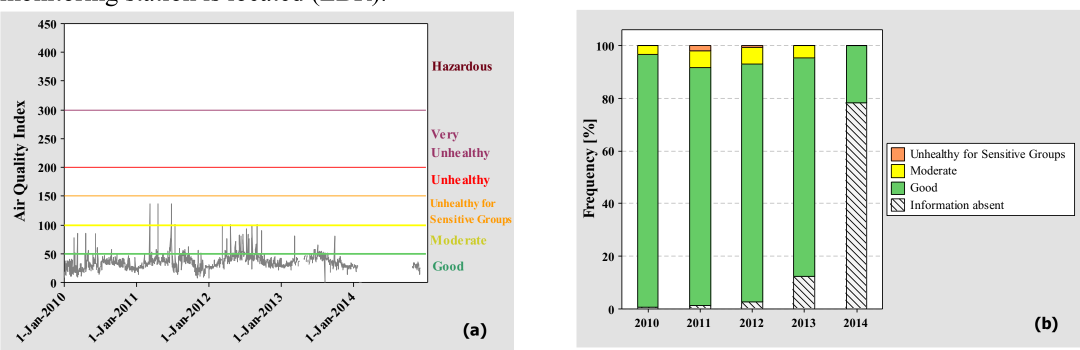

Fig. 2. (a) Trend of AQI from 2010 to 2014 in (LBR); (b) Annual frequencies of AQI categories related to (LBR)

The graph in Figure 3 panel (a) shows the trend of AQI related to the agglomeration where the monitoring station (VVT) is located. In this context we do not observe the seasonality found in (LBR) attributable to the high concentrations of O_3. The monitoring station (VVT) is placed in an agglomeration where high vehicular traffic is present; in this context high concentrations of NO_2 are detected while the O_3 concentrations tend to assume low values [13].

Most likely, the high NO concentrations, typical of areas with high traffic, trigger the reactions cycle characteristics of O_3, greatly reducing their concentrations; conversely high concentrations of NO_2 are found, being one of the final products of the ozone cycle.

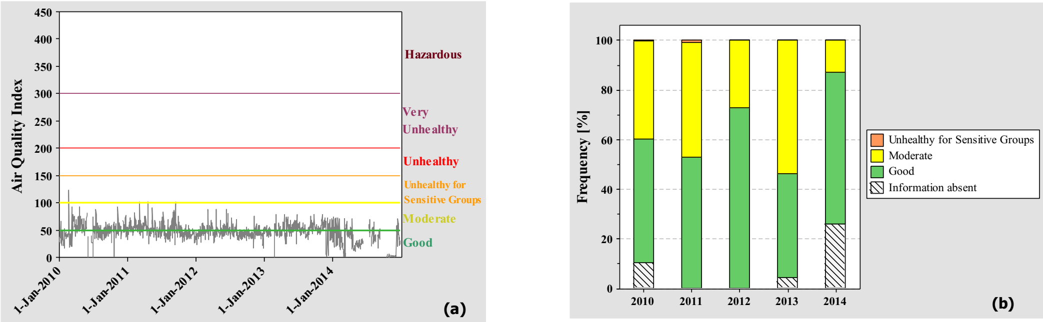

Fig. 3. (a) Trend of AQI from 2010 to 2014 in (VVT); (b) Annual frequencies of AQI categories related to (VVT).

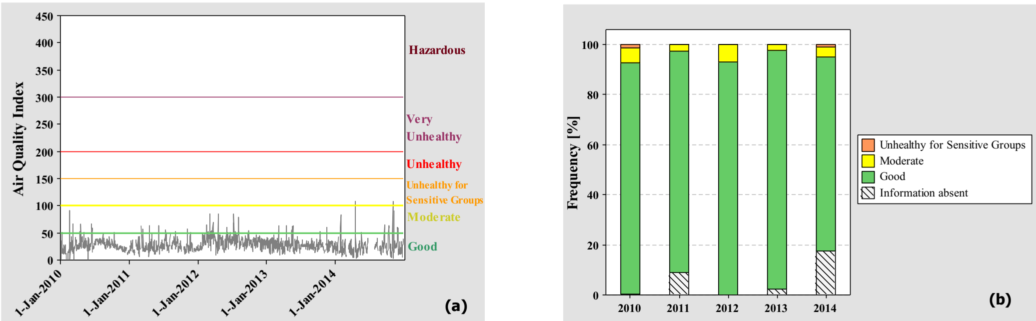

Fig. 4. (a) Trend of AQI from 2010 to 2014 in (PZM); (b) Annual frequencies of AQI categories related to (PZM).

Tab. 3 – Annual frequencies of nelel categories from three monitoring stations

STATION	YEARS	FREQUENCY CATEGORY [%]				
		Good	*Moderate*	*Unhealthy for Sensitive Groups*	*Other*	*Information Absent*
(LBR)	*2010*	95.89	3.29	0.00	0.00	0.82
	2011	90.14	6.58	1.92	0.00	1.37
	2012	90.16	6.28	0.82	0.00	2.73
	2013	83.01	4.66	0.00	0.00	12.33
	2014	21.92	0.00	0.00	0.00	78.08
(VVT)	*2010*	49.86	39.73	0.27	0.00	10.14
	2011	52.88	46.03	1.10	0.00	0.00
	2012	72.68	27.32	0.00	0.00	0.00
	2013	41.64	53.97	0.00	0.00	4.38
	2014	61.10	12.88	0.00	0.00	26.03
(PZM)	*2010*	92.33	5.84	1.34	0.00	0.49
	2011	88.22	2.74	0.00	0.00	9.04
	2012	93.17	6.83	0.00	0.00	0.00
	2013	95.62	2.19	0.00	0.00	2.19
	2014	77.53	4.11	0.82	0.00	17.53

The graph in panel b) instead shows a change of state of the quality of air over the years. The annual frequencies of categories of AQI show that in 2013 the category "Moderate" prevailed with respect to the category "Good", respectively 54% against 42%. As for the other years the category "Good" has prevailed, although with a reduced margin, the category "Moderate". Regardless of the small margin between the frequencies of the two categories, for the agglomeration where the monitoring station is located (VVT), the category "Good" results as "dominant".
The graph in Figure 4 panel(a) shows the trend of AQI related to the agglomeration where the monitoring station is located (PZM).
It shows a first part with a partial seasonal period and a second part where the frequency is most likely covered by an increase in emission of the primary pollutants. Also in this context, it is evident that over the years the conditions of air quality have not undergone significant changes. The annual frequencies of categories of AQI in the graph panel (b), show category "Good" as "dominant", reaching an annual rate between 77% and 95%. Regarding the annual frequencies of the category "Moderate", the percentages are between 2% and 7%.
The values of the annual frequencies of the related categories of the period are summarized in Table 3.

4. Conclusion and future works

In this article we have applied the Air Quality Index (AQI), adopted by the United States Environmental Protection Agency, to the metropolitan city of Catania. The trends of air quality were analyzed from 2010 to 2014 using the data of pollutant concentrations provided by the Municipal Ecology and Environment Office.

From the analysis of the data related to the three monitoring stations in the municipal area, it was possible to calculate the trend of AQI during the considered period. From the analysis of the annual frequencies of the categories provided by the AQI, conducted on the three monitoring stations, we identified the dominant category and the air quality present in agglomerations where the monitoring stations are located. In detail, in the agglomerations represented by the monitoring stations (LBR) and (PZM) there was a clear predominance of category "Good", the category "Moderate" was found very few times, while the category "Unhealthy for Sensitive Groups" was present only for sporadic events. With regards to the agglomeration represented by (VVT) there was a slight predominance of the category "Good" with respect to the category "Moderate".

The scenario that emerged from this analysis showed that the agglomeration represented by the monitoring station (VVT) is more susceptible to a possible worsening of the air quality unless we resort to measures aimed at the prevention and mitigation of urban traffic.

Knowing in advance the value of the AQI, can be a useful support for the government, for the system of preventive health care, or to prevent the exposure of population groups at particular risk.

Future developments aim therefore to the creation of a short-term forecasting model of the AQI, in collaboration with the Municipal Ecology and Environment Office. The forecasting model will be implemented taking into account the meteorological parameters and conditions of the traffic.

Forecasts of the AQI will be visible on the City of Catania’s website, and will complete the alreadypresent section, relating to air quality.

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Biography

Saverio Strano graduate in Materials Physics, collaborator at the University of Catania in the project PON SNIFF " Sensor Network Infrastructure For Factors" in the identification of sources of pollution by implementing source reverse . Interest in research in the field of propagation of air pollution and air quality control.