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Air quality index and its use in management plans

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Abstract

The paper discusses the techniques to evaluate the general trend of air quality within the elaboration of air quality management plans.

The form of representation selected, in order to represent in a synthetic form the air quality data, is the box plot. In such typology of graph is possible to follow at the same time the average trend, the trend of the tail of distribution frequency and the extreme values (maximum and minimum).

The paper presents an Air Quality Index (AQI) derived by modifying and adapting to the national legislation the indicator PSI (Pollutant Standard Index) as defined by US-EPA (United States Environmental Protection Agency).

This index has been introduced to supply an accurate, speed and easily understandable indicator of the pollution level. The trend of the index can be also represented by “box plot” graphs.

In the paper is described as case study, the application of the methodology of data analysis, and particularly of the air quality index, within the realization of Trento (Italy) air quality management plan.

Keywords: Air quality; Air quality index; Air quality management plan.

1. Introduction

Italy Ministry of Environment in 1991 (Decree of May 20, 1991) has introduced prescriptions and rules for elaboration of regional air quality management plans. Some Italian provinces or regions are carrying out the plan (Trento, Bolzano, Toscana, Liguria, and Basilicata). Within the plan of the Autonomous Province of Trento a synthetic index has been elaborated, in order to represent the air quality data, not depending on the single pollutant considered.

2. National legislative regulations relating to air quality.

In Tab. 1 are reported the values of air concentrations of main pollutants, provided by legislation [1, 2, 3].

SO_2	Limit Value	Median of 24 hours average concentration during a year (April 1–March 31)	80 $\mu g/m^3$	(1)
	Limit Value	98^{th} percentile of 24 hours average concentration during (April 1-March 31)	250 $\mu g/m^3$	(1)
	Limit Value	Median of 24 hours average concentration during the winter (October 1-March 31)	130 $\mu g/m^3$	(1)
	Guide Value	Arithmetic average of 24 hours average concentration during a year (April 1-March 31)	40-60 $\mu g/m^3$	(1)
	Guide Value	24 hours average concentration	100-150 $\mu g/m^3$	(1)
	Alert Level	24 hours average concentration	250 $\mu g/m^3$	(2)
	Attention Level	24 hours average concentration	125 $\mu g/m^3$	(2)
CO	Limit Value	1 hour average concentration	40 mg/m^3	(3)
	Limit Value	8 hours average concentration	10 mg/m^3	(3)
	Alert Level	1 hour average concentration	30 mg/m^3	(2)
	Attention Level	1 hour average concentration	15 mg/m^3	(2)
NO_2	Limit Value	98^{th} percentile of 1 hour average concentration during a year (January 1-December 31)	200 $\mu g/m^3$	(1)
	Guide Value	98^{th} percentile of 1 hour average concentration during a year (January 1-December 31)	135 $\mu g/m^3$	(1)
	Guide Value	Median of 1 hour average concentration during a year (January 1-December 31)	50 $\mu g/m^3$	(1)
	Alert Level	1 hour average concentration	400 $\mu g/m^3$	(2)
	Attention Level	1 hour average concentration	200 $\mu g/m^3$	(2)
O_3	Limit Value	1 hour average concentration	200 $\mu g/m^3$	(3)
	Alert Level	1 hour average concentration	360 $\mu g/m^3$	(2)
	Attention Level	1 hour average concentration	180 $\mu g/m^3$	(2)
PM	Limit Value	Arithmetic average of 24 hours average concentration during a year (April 1-March 31)	150 $\mu g/m^3$	(3)
	Guide Value	Arithmetic average of 24 hours average concentration during a year (April 1-March 31)	40-60 $\mu g/m^3$	(1)
	Limit Value	95^{th} percentile of 24 hours average concentration during a year (April 1-March 31)	300 $\mu g/m^3$	(3)
	Guide Value	24 hours average concentration	100-150 $\mu g/m^3$	(1)
	Alert Level	24 hours average concentration	300 $\mu g/m^3$	(2)
	Attention Level	24 hours average concentration	150 $\mu g/m^3$	(2)

Table 1 - Values of air concentrations of pollutants provided for legislation

The legislative regulations relating to air quality are represented by:

- limit values of air quality (LV) – maximum limits of acceptability of concentration and maximum limits of exposure relating to pollutants in ambient air;
- guide values of air quality (GV) – limits values of concentration and limits of exposure relating to pollutants in ambient air devoted:
  - to long-term prevention relating to the protection of human health and environment,
  - to constitute parameters of reference for specific areas of environmental protection for which it's necessary a particular attention to air quality;
- alert level (ALL) – the concentration which determine a situation of air pollution susceptible to determinate an environmental and sanitary risk (alert state);
- attention level (ATL) – the concentration of pollutants which determine a situation of air pollution (attention state) that, if persistent, determine the risk of alert state.

3. Air Quality Index

In order to evaluate the different pollutants the index PSI (Pollutants Standard Index) developed by US-EPA (United States – Environmental Protection Agency) [4] is adapted to the national normative in order to supply accurate, speedy and comprehensible indicator of the pollution level.

The AQI (Air Quality Index) is built in the following way. At first a specific index for every pollutant is calculated:

$$I_i = \frac{C_i^*}{S_i} \times 100 \qquad (1)$$

where:

i, is the pollutant,

C^*_i is the measured hourly concentration (C_i) for nitrogen dioxide, carbon monoxide and ozone, while it is the 24 hours carried mobile average for sulphur dioxide and particulate matter; particularly in this second case:

$$C_i^* = \sum_{j=i,i+24} C_i / 24 \qquad (2)$$

S_i is the concentration value for the attention state.

The index I_i, so built, is equal to 100 when the concentration measured (or the mobile mean over 24 hours) is equal to the attention state; an index lower than 100 means that the pollutant has a value lower than the attention state.

After the different indexes I_i have been calculate for every pollutant, we select the maximum index I between different indexes:

$I = \max_i I_i$ (3)

In this way a characterization of the pollutant level a part from the pollutant taken into account is obtained. For example, in winter the more critical pollutants are CO and NO_x, depending on road traffic and domestic heating. In summer it's possible that for O_3 is registered a higher index depending on temperature.

4. Case study: the Autonomous Province of Trento

Within the realization of air quality management plan of the Autonomous Province of Trento, a study of air quality data coming from air quality management network was carried out.

4.1. Description of the air quality management network.

The six fixed stations of air quality management network of Autonomous Province of Trento are localized as:

- *Trento Center*: in the center of the city;
- *Trento Nord – Gardolo*: near the Brennero extra urban road with the aim to measure the pollution in a peripheric area involved in traffic;
- *Grumo – San Michele all'Adige*: near an industrial zone with consistent fluxes of traffic for the presence of the Brennero highway and the road to Val di Non area;
- *Rovereto*: in the historical center, indicative of the emissions from traffic;
- *Borgo Valsugana*: in a small center with consistent traffic, especially in periods characterized by tourism; the data are indicative of many small areas of *Trentino*;
- *Riva del Garda*: in an area in which a remarkable industrial activity and high tourist presence exist.

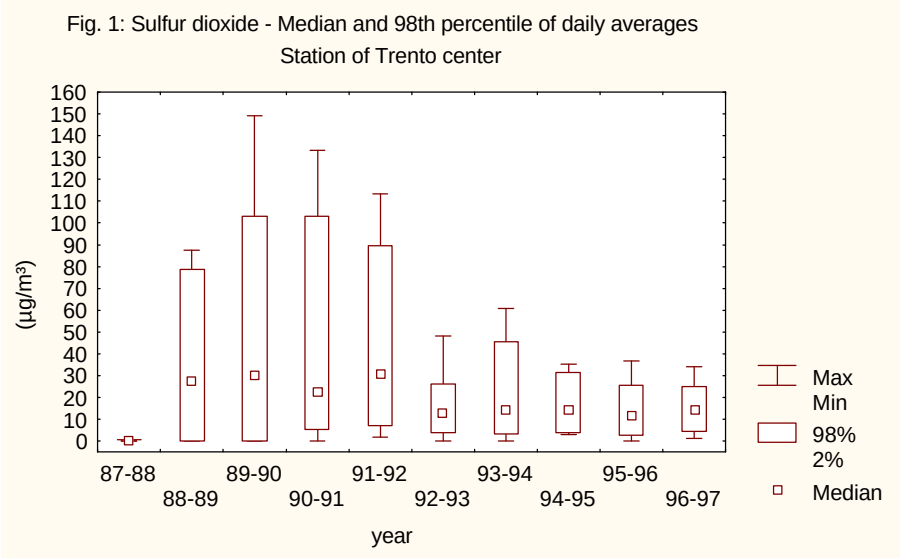
All the stations measure the following pollutants: carbon oxide (CO), sulphur dioxide (SO_2), particulate matter (PM), nitrogen dioxide (NO_x), and ozone (O_3).

4.2. Analysis of data coming from Trento Center station

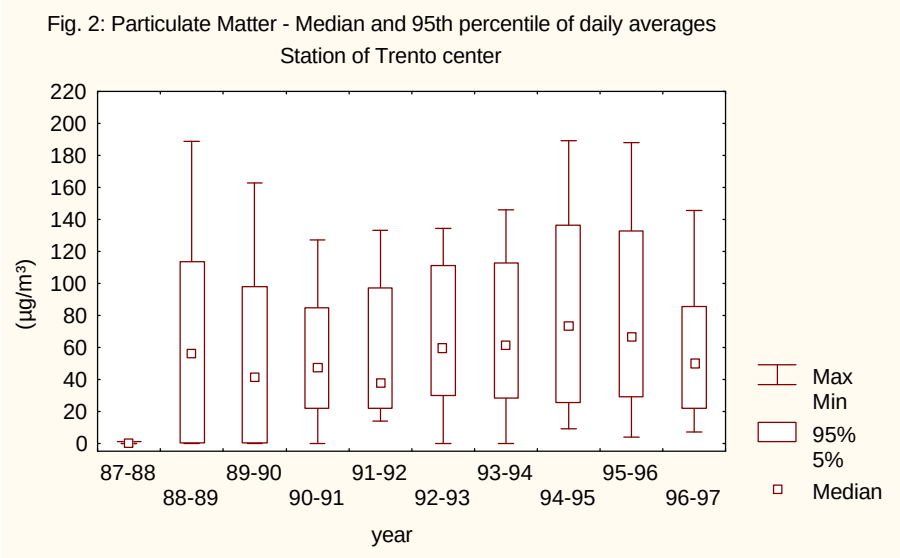
The results of the data analysis coming from monitoring network, devoted to evaluate the general trend of the different pollutants relating to the station of Trento Center, are reported on graphs.

In Fig. 1 the statistical analysis of daily average concentrations of sulphur dioxide is reported. All the measured concentrations are largely lower than limit values while in the years '89 -'92 there are some daily values greater than the inferior value of the

guideline interval and some overcoming of the attention level (125 µg/m^3, not in force at that time). The trend measured is of strong reduction relating to the median and, in a more remarked way, to 98th percentile, depending on penetration of natural gas for domestic heating and industry.

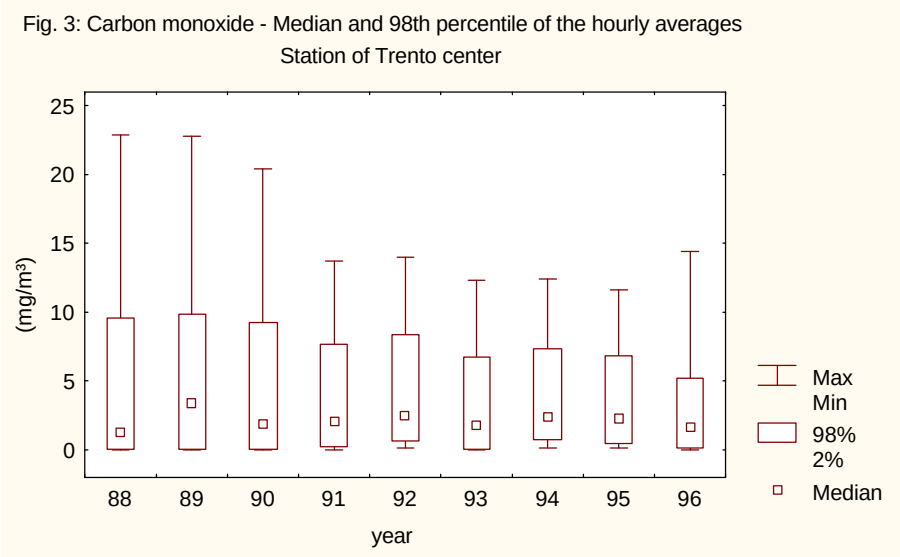


In Fig. 2 the statistical analysis of daily average concentrations of particulate matter is reported. The concentrations measured are all lower than the limit values provided by legislation. Relating to guideline value on the average value of 24 hours (100-150 µg/m^3) and the attention level (150 µg/m^3), a lot of concentrations greater than the guideline value and sometimes greater than the attention level are monitored.

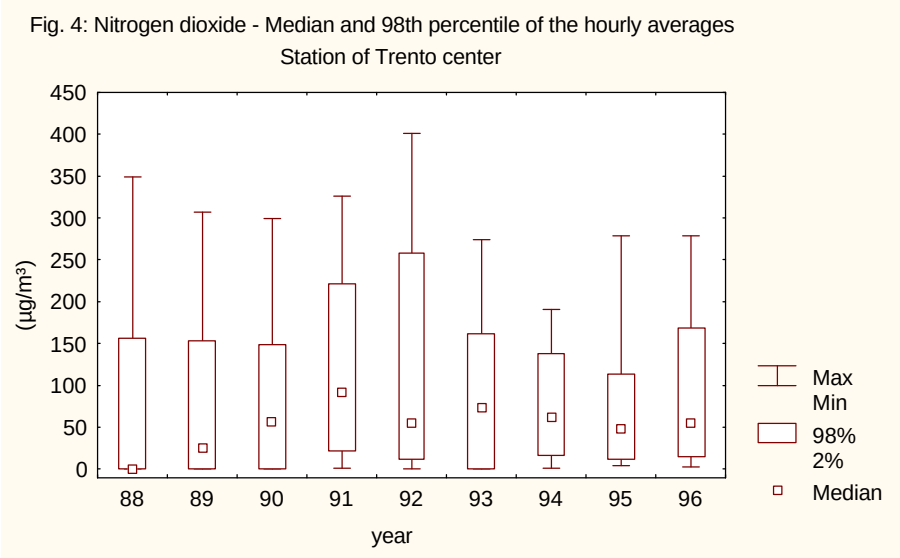


In Fig. 3 the statistical analysis of hourly average concentrations of carbon monoxide is reported. The concentrations measured by the network are, relating to hourly averages, all below the limit provided by the legislation (40 mg/m^3), of the alert

level (30 mg/m^3), and (with some exception in the years ‘88-‘90) of the attention level (15 mg/m^3).



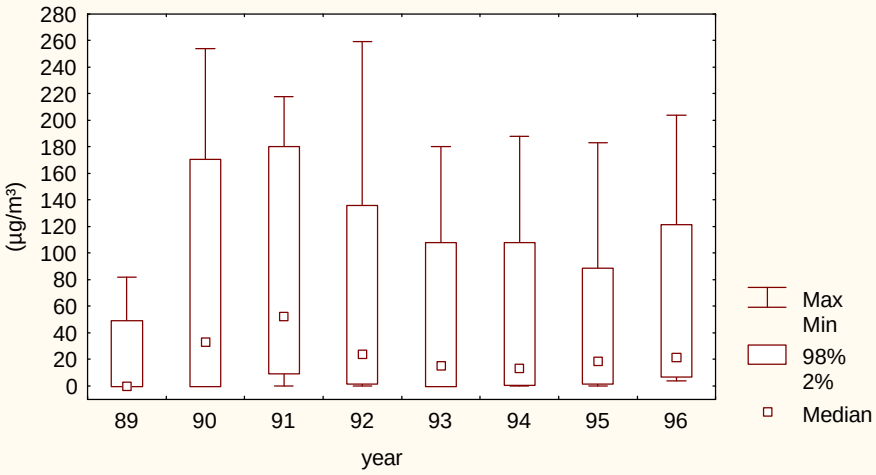
In Fig. 4 the statistical analysis of hourly average concentrations of nitrogen dioxide is reported. The values measured by the network, relating to 98th percentile of the hourly averages, are lower than the limit provided by the legislation (200 µg/m^3) with some exception in the years ‘91 and ‘92. Relating to alert level (400 µg/m^3), the value has been sometimes attained in ’92 when the limits were not in force. On the contrary, relating to guideline values of 98th percentile (135 µg/m^3) and of the median (50 µg/m^3) of the hourly averages, there is an overcoming almost constant. The general trend of this pollutant seems almost stationary in the years.



In Fig. 5 the statistical analysis of hourly average concentrations of ozone is reported. The comparison with the values of the legislation shows that, relating to alert

level (360 µg/m^3) the value has not been never attained, while the attention level (180 µg/m^3) and the limit value (200 µg/m^3) has been sometimes attained.

Fig. 5: Ozone - Median and 98th percentile of the hourly averages
Station of Trento center

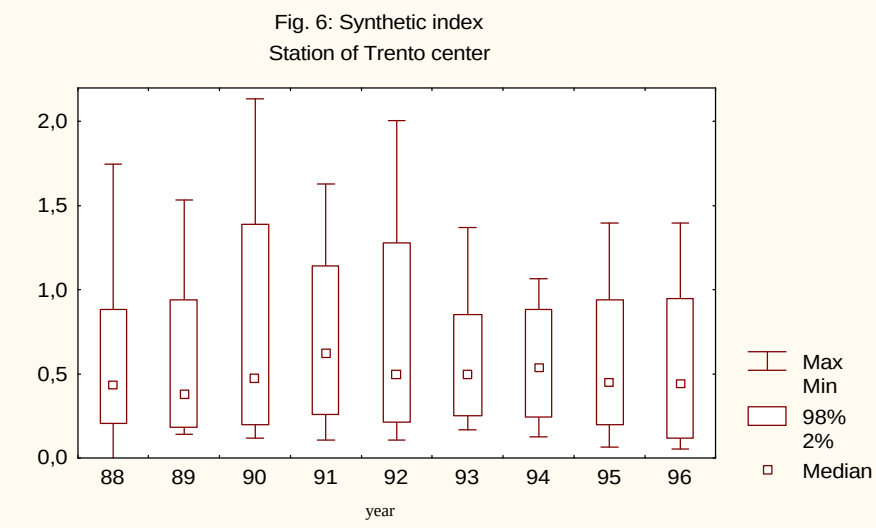


As a final consideration the trends of minimum values don't seem to follow the general reduction trend. These trends show, in a form not very significant but common to all pollutants, a deterioration of the situation in that to number of situations with very low pollution level.

4.3. Calculation of the Air Quality Index for Trento Center station

The Air Quality Index has been calculated for every year and reported on graph (Fig. 6).

Fig. 6: Synthetic index
Station of Trento center



It is possible to note that, in spite of presence of some critical events (with values over the unit), the 98th percentile in the larger part of cases is below of the unit.

The worse situation exists in correspondence of the year 1991 and that depend on the winter particularly rigid. A consideration can be carried out on 1996 data, when it's possible to note a widening of the interval 2-98% of values which evidences an increase of more extreme situations to verify in the next years.

In the Figs. 7 ÷ 9 the number of times in which every pollutant presents the maximum value for the Air Quality Index is reported on graph.

Fig. 7: Synthetic index
Hourly distribution of absolute frequencies
Station of Trento center

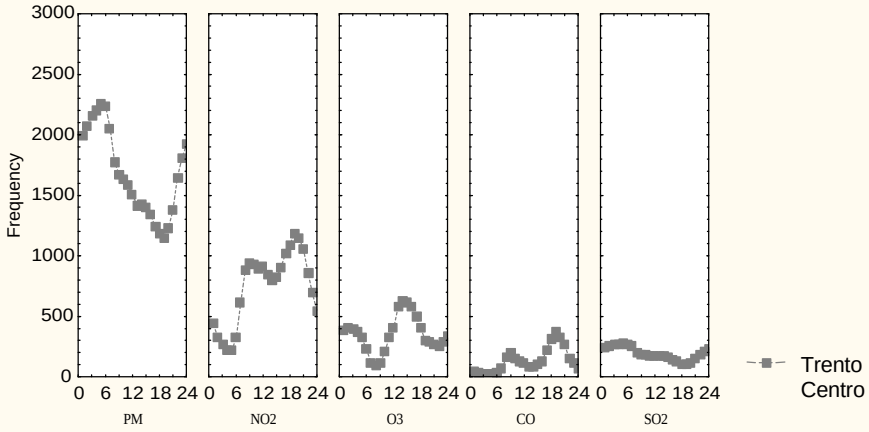
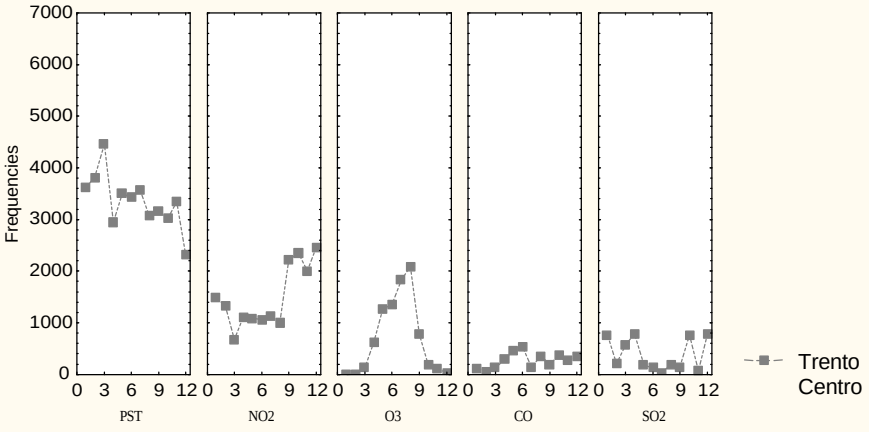
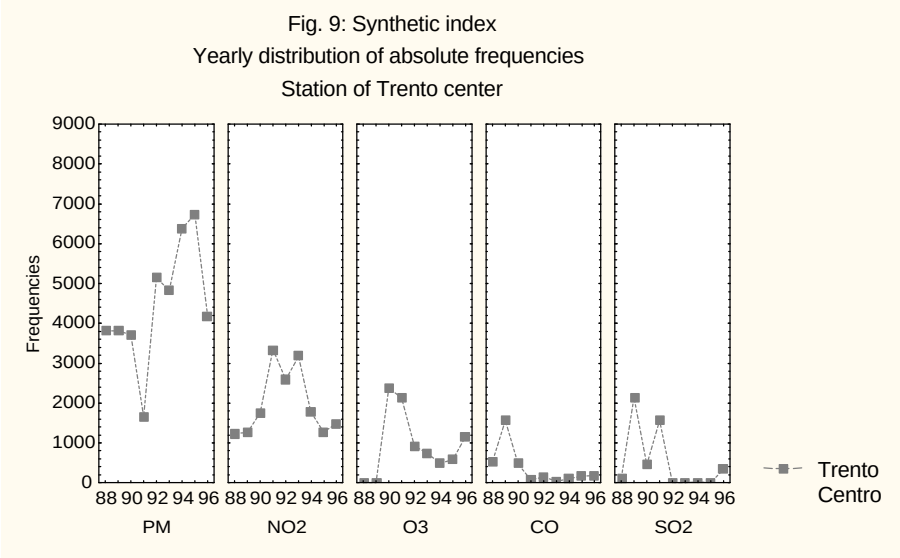


Fig. 8: Synthetic index
Monthly distribution of absolute frequencies
Station of Trento center



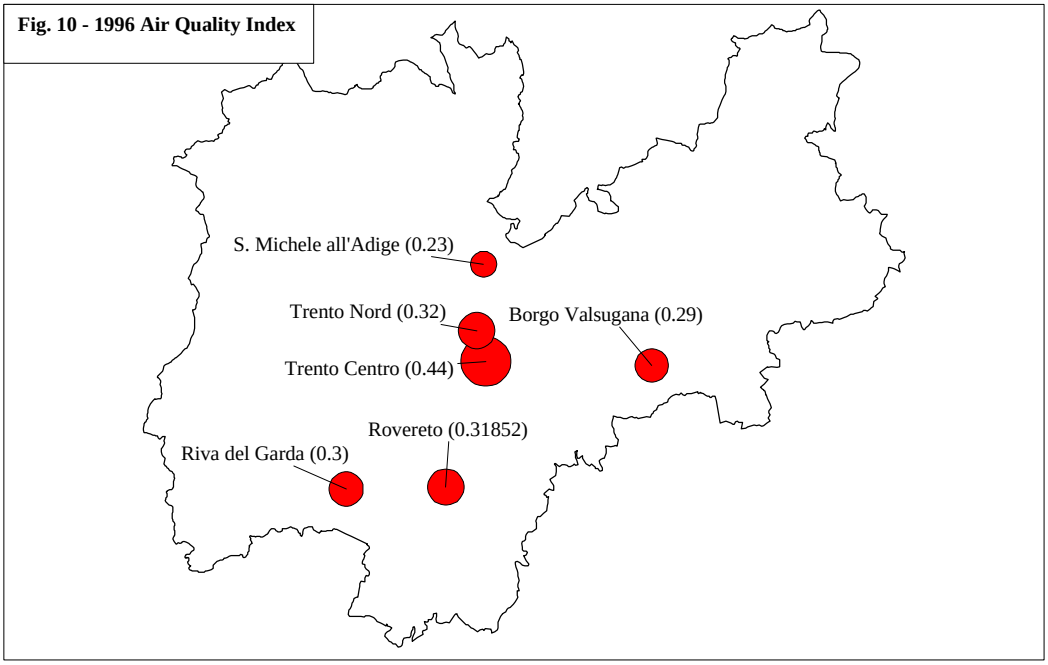
Analyzing the trend of graphs, it's evident that, in the hourly distributions (Fig. 7), the higher frequencies are registered for PM. This pollutant results responsible of the bottom pollution while NO_2 registers the maximum value in the hours of more intense traffic (between 7.00 and 9.00 a.m. and between 6.00 and 8.00 p.m.). Perhaps O_3 is the worse pollutant in the central hours of the day (period of maximum insulation).

The monthly distribution (Fig. 8) shows more frequent presence of O_3 in summer. Finally the yearly distribution (Fig. 9) shows the increase, in the last years, of the number of times in which ozone and nitrogen dioxide realize the higher value of the Air Quality Index and the reduction for SO_2.



4.4. Air Quality Index intercomparison for all Trento network

In Fig. 10 a comparison, for the year 1996, of the Air Quality Index in all the stations of the network is shown to give a global picture of the pollution in the region.



The figure show as the main urban center stations, and particularly the Trento center station, present the higher values for Air Quality Index.

5. Conclusions

The paper introduces an Air Quality Index and evidences its rule within the air quality management plans. It can help to understand the air quality in a specific geographical area a part from the pollutant taken into account. Historical analysis of the number of times in which every pollutant presents the worse value is used to evaluate the historical trend of pollution and the seasonal and daily fluctuation.

Acknowledgement

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References

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