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ScienceDirect
Energy Procedia
Energy Procedia 81 (2015) 644 – 654

69th Conference of the Italian Thermal Engineering Association, ATI 2014

Air quality data for Catania: analysis and investigation casestudy 2012-2013

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Abstract

This paper focuses on the principal atmospheric pollutants monitored in Catania (Italy) according to European Directive 50/2008. A couple of years, 2012 and 2013 have been considered as a study period. The monitoring system of Catania is made up of five stations that control the presence of the air pollutants in the most important anthropic areas of the urban territory. First of all the mechanisms of formation of the main pollutants have been summarized in order to identify the main causes and effects in urban environment. The raw data have been collected and validated according the UNI CEI EN ISO/IEC 17025:2005 by the Ecologic and Environmental research unit of the municipality of Catania. The trend of all pollutants during the two cited years have been investigated and the results highlight that the most principal polluting gas is NO_2 confirming the trend of the previous years. A further analysis of what the principal causes of pollution in Catania could be,has been conducted in order to evaluate possible actions to reduce the atmospheric pollution. As a result it has been demonstrated that the principal cause of the atmospheric pollutant emissions is connected to private urban mobility. The experimental results demostrated that the principal cause of the atmospheric pollutant emissions is connected to private urban mobility. A development of realistic mathematical model will be the object of future research works.

Peer-review under responsibility of the Scientific Committee of ATI 2014

Keywords: Air pollution; Urban area; NO_2; O_3; Private mobility.

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Peer-review under responsibility of the Scientific Committee of ATI 2014
doi:10.1016/j.egypro.2015.12.049

1. Introduction

In any urban context the topic of air quality represents one of the most important indicators of sustainability for the safeguard of human health and environment.

European Environment Agency (EEA) pays attention to the protection of human health and follows continuously the trend of pollution levels in urban environments by introducing more and more strict rules in order to reduce the minimum levels of emissions. Every year EEA publishes a report about air quality in Europe [1] that shows a map of the main air pollutants in European territory.

The main causes of pollution in urban environment concern anthropic activities and urban morphology [2] that influence the microclimate and air quality. In deeply industrialized areas the presence of power plants [3] represents one of the main sources of emissions. Catania does not presents any developed industrial area and the main sources of pollution are attributed to urban traffic [4].

In urban area where the public mobility is not well developed usually the principal source of pollution is correlatedto private mobility. The internal combustion engines (ICE) of motor vehicles and the domestic heating are the main sources of pollution. As reported in [5-6]many researches about the use of alternative fuels or renewable energy sourceshave been recently carried out, in order to reduce the pollutant emissions in urban areas.

2. The case study of air quality in Catania

2.1. The monitoring system and the measured pollutants

Catania is provided by a monitoring network of air quality made up of five stations that continuously monitor the following pollutants: CO,NO_2,SO_2,O_3,C_6H_6 and PM_{10}(Tab. 1).

The measurement instruments of NO_2 and PM_{10} are managed by the Regional Environment Protection Agency (A.R.P.A) while the others instruments (CO, SO_2, O_3 and C_6H_6 pollutants) by the Department of Ecology and Environment of municipality of Catania.

Mediterranean climate, characterized by hot summers, contributes to raise the levels of pollution of air in urban environment. In [7] a correlation between the pollutants and their effects in health in a Mediterranean city has been studied.

Table 1. Monitoring stations and measured pollutants in Catania for the years 2012-2013.

Station	Description	Measured pollutants (2012)	Measured pollutants (2013)
Viale Veneto	Heavy traffic	NO_2, SO_2, C_6H_6, PM_{10}, CO	NO_2, SO_2, C_6H_6, PM_{10}, CO
Piazza A. Moro	Medium traffic	NO_2, CO, O_3, PM_{10}	NO_2, CO, PM_{10}
Librino	Light traffic	NO_2,CO, O_3,PM_{10}	NO_2, CO, O_3, PM_{10}
Parco Gioeni	Urban-background	NO_2, SO_2, C_6H_6, PM_{10}, CO, O_3	NO_2, SO_2, C_6H_6, PM_{10}, CO, O_3
ZonaIndustriale	Industrial zone	CO, SO_2	CO, SO_2

2.2. Pollutants formation, health effects and normative limits

2.2.1. Nitrogen Oxides

The main causes of NO_x formation in urban areas are related to high temperatures of combustion processes (i.e. engine cars, domestic heating, power plants).

The nitrogen monoxide is formed as a result of the relation between gaseous nitrogen present in the air with the atmospheric oxygen during combustion processes with temperatures higher than 1200 °C. Once formed, the nitrogen monoxide interacts with the oxygen during a process of soot cooling transforming partially in nitrogen dioxide and a mix of the two oxide called NO_x. The reaction processes are reported as follow:

$$N_2 + O_2 \rightarrow 2NO \tag{1}$$

$$2NO + O_2 \rightarrow 2NO_2 \tag{2}$$

Table 2. Limit and threshold values for NO_2 and NO_x as set out in the 2008 Air Quality Directive.

Objective	Averaging period	Limit or threshold value	Number of allowed exceedances
Human health	One hour	200 µg/m^3	18 hours per year
Human health	Calendar year	40 µg/m^3	
Alert (*)	One hour	400 µg/m^3	

(*) To be measured over three consecutive hours at locations representative of air quality at least 100 km^{2}or an entire zone or agglomeration, whichever is smaller.

The limit values for NO_2 and $NO_x$are reported in Tab.2.NO_2 is an irritant for respiratory system especially for individuals affected by asthma and bronchitis, old men and children [8].

2.2.2. Ozone

Ozone is a strongly instable compound, it is not originated by direct emissions but for the effect of a series of reactions that involve other substances (NO_x and VOC_s). The theoretical cycle of Ozone formation is in relation with the absorption of ultraviolet light by NO_2, which is separated in NO and oxygen atoms according the relation (3):

$$NO_2 + h\nu \rightarrow NO + O \tag{3}$$

The atomic oxygen is strongly reactive and interacts with the oxygen in the air forming Ozone (4):

$$O_2 + O \rightarrow O_3 \tag{4}$$

In Tab.3 the limit values in compliance with European Air Quality Directive 50/2008 are reported.

Table 3. Air quality standards for ozone as defined in the Air Quality Directive.

Objective	Period	Target or threshold value	Number of allowed exceedances
Human health	Maximum daily 8 hour mean	120 µg/m^3	25 days per year averaged over three years
Information	One hour	180 µg/m^3	
Alert (*)	One hour	240 µg/m^3	

(*) To be measured over three consecutive hours.

Among the effects on health the irritant action on mucous membranes and respiratory tracts is the most dangerous. Ozone is mainly concentrated in the tissues of the terminal part of the respiratory system between bronchioles and alveoli where exercises its intense oxidizing action as reported in [9].

2.2.3. Sulphur dioxide

The Sulphur dioxide (SO_2) present in atmosphere comes mostly from natural sources (volcanoes) and partially from human activities. The human contribution is especially related to combustion processes addressed to the production of electric energy, industrial processes, transport system and domestic heating.SO_2 and SO_3 gases are generatedfrom the combustion of fuels containing sulphurs.These compounds are called Oxides of Sulphur (SO_x). The reactions (5.a, 5.b) that cause these processes are reported:

$$S + O_2 \rightarrow SO_2 \tag{5.a}$$

$$2SO_2 + O_2 \rightarrow 2SO_3 \tag{5.b}$$

SO_3 could stay in air if humidity is particularly low, vice versa, in the presence of water vapour reacts with it and forms sulphuric acid (6) :

$$SO_3 + H_2O \rightarrow H_2SO_4 \tag{6}$$

Table 4. Air quality standards for SO_2 as given in the 2008 Air Quality Directive.

Objective	Averaging period	Limit or threshold value	Number of allowed exceedances
Human health	One hour	350 µg/m^3	24 hours per year
Human health	One day	125 µg/m^3	3 days per year
Alert (*)	One hour	500 µg/m^3	

(*) To be measured over three consecutive hours at locations representative of air quality over at least 100 km^2 or an entire zone or agglomeration, whichever is smaller.

Tab. 4 shows the limit value of 50/2008 Directive. SO_2 is harmful especially for the respiratory system by liquefyingin the mucus. In association with dust and liquid particles where it is absorbed, it could reach pulmonary alveoli where it exercises directly a more serious toxic action.

2.2.4. Carbon monoxide

The Carbon monoxide is produced principally by the combustion hydrocarbons process, or generally, by organic substances in conditions of oxygen deficiency. The principal causes due to human activities are vehicular traffic and industrial production processes. The following reactions (7.a, 7.b, 7.c, 7.d) show the formation of CO:

$$2C + O_2 \rightarrow 2CO \tag{7.a}$$

$$2CO + O_2 \rightarrow 2CO_2 \tag{7.b}$$

$$CO_2 \rightarrow CO + O \tag{7.c}$$

$$CO_2 + C \rightarrow 2CO \tag{7.d}$$

CO presents a high persistence time in atmosphere, about four months, and usually is removed thanks to natural processes such as the oxidation of CO in CO_2 or the action of microorganisms.

Table 5. Air quality limit values set by the Air Quality Directive and the WHO air quality guideline for CO.

	Hourly CO	8-hour average CO
Air Quality Directive	-	10 mg/m^3
World Health Organization	30 mg/m^3	10 mg/m^3

CO present in human body usually combines with haemoglobin in place of oxygen. The effects of this combination are above all harmful for the cardiovascular system (hypertension, heart attacks), nervous system and foetuses.

2.2.5. Benzene

Benzene (C_6H_6) is an aromatic hydrocarbon exclusively caused by human activities. It is present in atmosphere and principally because of vehicular emissions or losses during refueling phases. Also cigarettes smoke contains high concentrations of this substance and represents a significant source of exposition for active and passive smokers. The International Agency for Research on Cancer (IARC)considers C_6H_6 a carcinogen pollutant. In Tab. 6 the limit value of $C_6H_6$are reported.

Table 6. Air quality limit and target values for annual mean concentration of C_6H_6 as set out EU legislation.

Objective	Averaging period	Limit or threshold value
Human health	Calendar year	5 μg/m^3

2.2.6. Particulate Matter

The particular matter, especially PM_{10}, is principally due to human activities: production processes, agricultural activities, vehicular traffic (flue gas, breaks and tires use, abrasion of road surface) domestic heating. A little part of PM_{10} formation is caused by natural processes (fires, erosions, volcanic eruptions, etc.).

Table 7. Air quality limit and target values for PM_{10} and $PM_{2.5}$ as given in the Air Quality Directive.

Size fraction	Averaging period	Value	Comments
PM_{10}, limit value	One day	50 μg/m^3	Not to be exceeded on more than 35 days per year. To be met by 1 January 2005
PM_{10}, limit value	Calendar year	40 μg/m^3	To be met by 1 January 2005
$PM_{2.5}$, target value	Calendar year	25 μg/m^3	To be met by 1 January 2010
$PM_{2.5}$, limitvalue	Calendar year	25 μg/m^3	To be met by 1 January 2015
$PM_{2.5}$, limitvalue (*)	Calendar year	20 μg/m^3	To be met by 1 January 2020

(*) Indicative limit value to be reviewed by the Commission in 2013 in the light of further information on health and environmental effects, technical feasibility and experience of the target value in Member States.

In processes of respiration particles larger than 15 μm are generally removed by the nose. PM_{10} that is deposited in the respiratory tract (nasal cavity, pharynx and larynx) could generate several irritation effects like inflammation and dryness of nose or throat. The smallest particles ($PM_{2,5}$) penetrate into the respiratory system at various depths and spend long periods before are removed. These dusts are very dangerous and could aggravate chronic respiratory diseases such as asthma, bronchitis and emphysema.

In [10] the principal effects of particulate matter air pollution on human health are treated.

3. DATA ANALYSIS

The scenario described in [11] is not essentially changed, especially concerning the polluting sources. As a matter of fact, the polluting sources such as domestic heating, vehicular traffic and industrial sites generate an important contribution in terms of pollution because of a mild climate. Thereforethe main cause of air pollution in urban environment still remains the private mobility. The phenomenon of commuting, very significant in Catania, is characterized by flows of citizens that involve people coming from everywhere around the province territory. In most cases people reach the city by private vehicles and the traffic is very intensive especially because the city is structurally insufficient. The first criticality of this traffic is characterized by the vehicular flows during the scholastic periods with irregular stops and transfers. The incidence of this kind of traffic is particularly strong during the early and late hours.

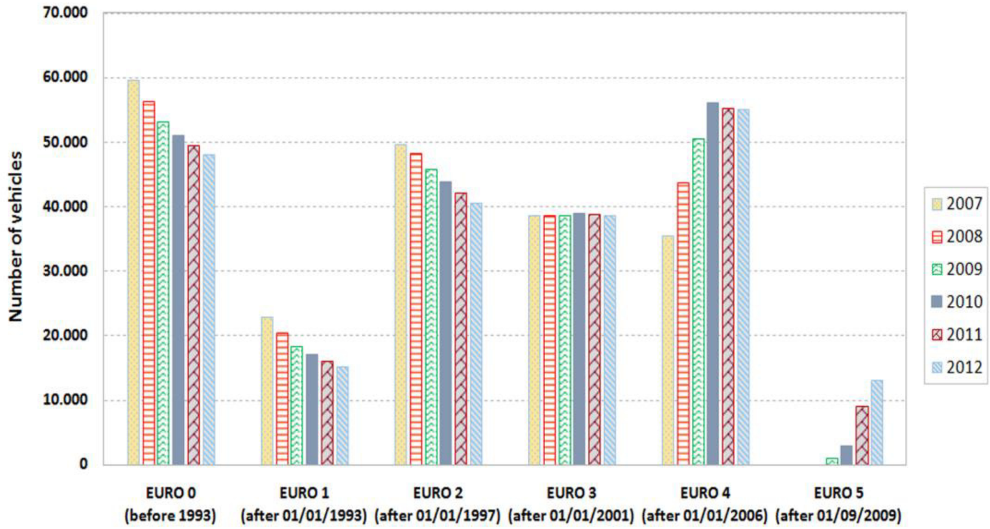

Figure 1. Number of vehicles in Catania from 2007 to 2012

The measures adopted during last years, especially those rules concerning the quality of fuels and emissions by vehicles (Fig. 1 and Fig. 2) have led positive effects regarding SO_2 (Fig. 3), CO (Fig. 4) and C_6H_6 (Fig. 5), the primary pollutants caused by vehicles. CO and C_6H_6 decrease thanks to the progressive reduction of the number of fossil fuel vehicles and above all those ones not catalysed (EURO 0) registered before 1993. The reduction of SO_2 is probably due to a better quality of fuel used both for automotive and domestic field, obtained because of the elimination of sulphur during the refining of hydrocarbons derived from petroleum.

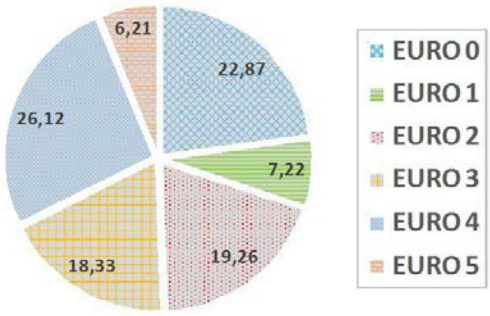

Figure 2. Percentage of the distribution of Euro vehicles in Catania in 2012.

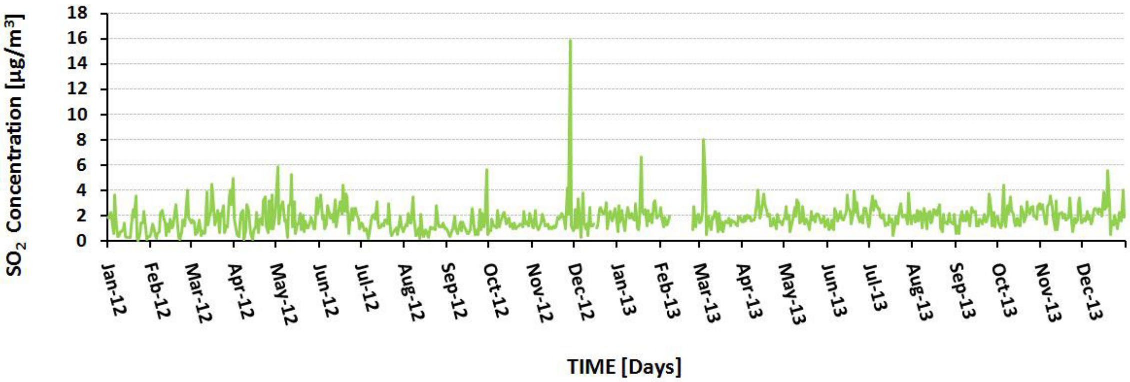

Figure 3. Daily mean trend analysis of SO_2 concentration in Viale Veneto monitoring station during years 2012 and 2013.

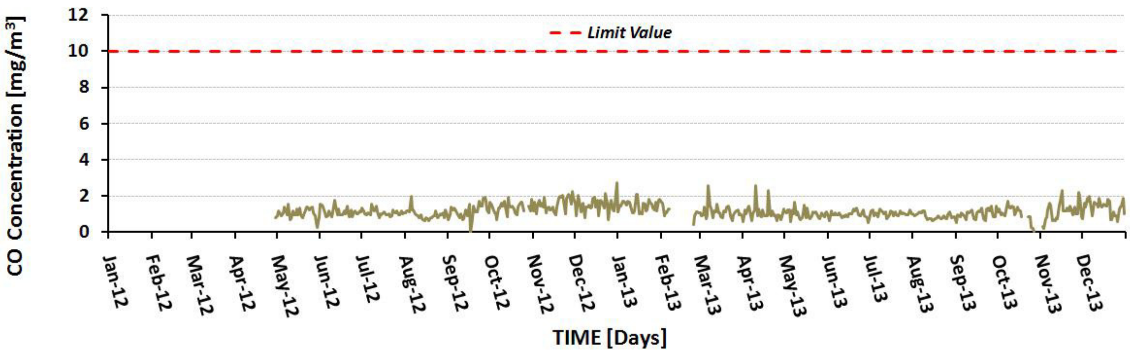

Figure 4. Analysis of annual Maximum daily 8-hour mean CO concentration in Viale Veneto monitoring station during years 2012 and 2013.

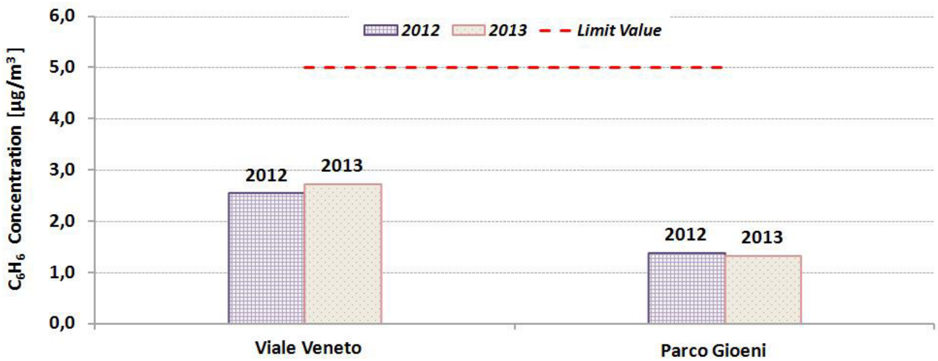

Figure. 5. Annual value of C_6H_6 concentrations at the Viale Veneto monitoring station during 2012 and 2013, the limit valueof C_6H_6 concentration per yearis represented with a red line.

The results about the trend of “secondary” pollutants such as NO_2 (Fig. 6 – 9) and O_3 (Fig. 10) are not so positive. Their formation is determined by chemical reactions taking place in atmosphere involving other chemical species, such as NO, emitted by motor vehicles and more generally combustion reactions. Moreover, climate parameters such as air temperature, solar irradiance and humidity influence these reactions.

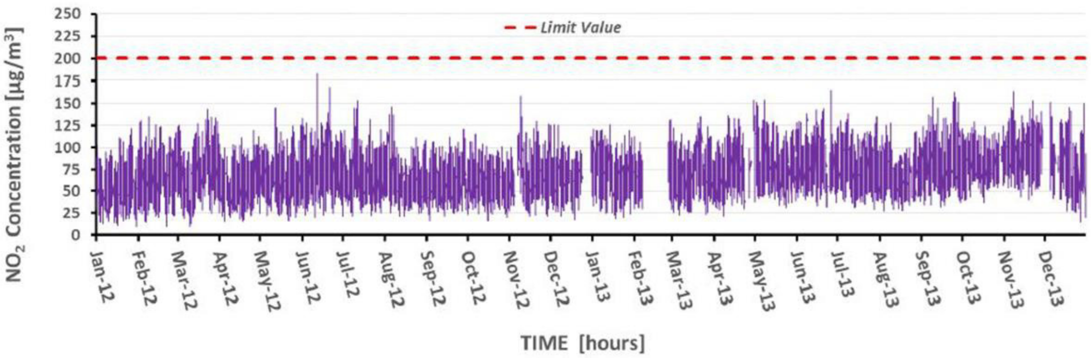

Figure. 6. Daily trend analysis of NO_2 concentrations at the Viale Veneto monitoring station during 2012 and 2013.

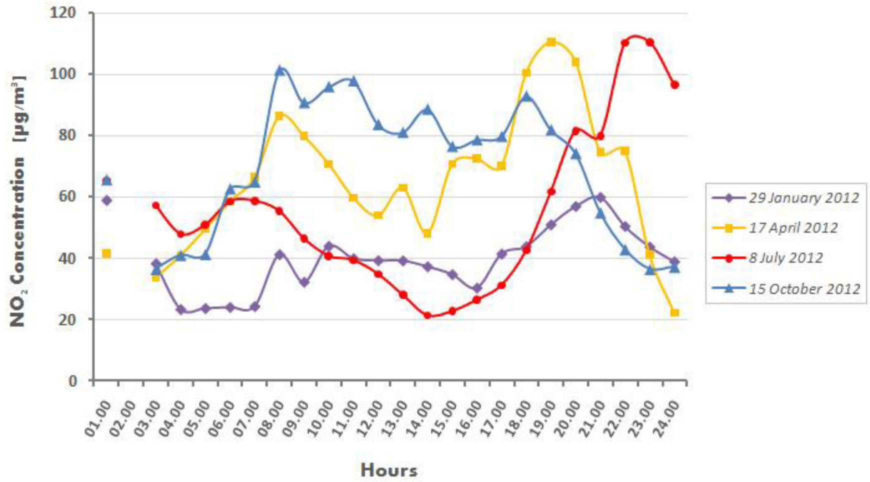

Figure. 7. Daily trend analysis of NO_2 concentrations at the Viale Veneto monitoring station during the different seasons in 2012.

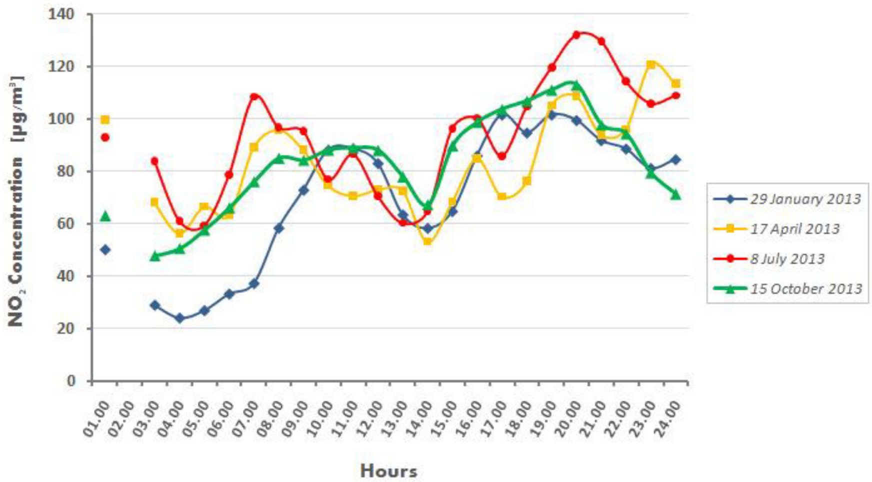

Figure. 8. Daily trend analysis of NO_2 concentrations at the Viale Veneto monitoring station during the different seasons in 2013.

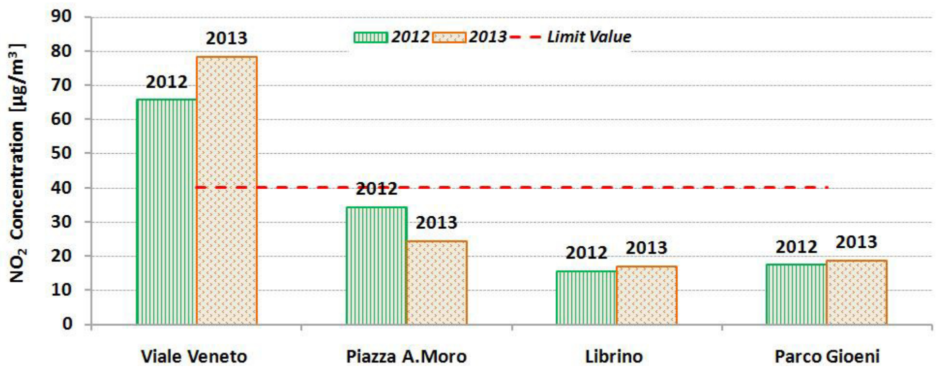

Figure. 9. Annual values of NO_2 concentrations for different monitoring stations in Catania in the years 2012-2013.

NO is emitted especially by diesel vehicles, that have been sold more and more during last years. The increase of O_3 concentration could be attributed to the atypical climate situation characterized by a long sequence of hot summers. The measurement techniques of this pollutant are objectively problematic because the concentrations could diverge substantially depending on the measurement site and the presence of chemical species that influence their formation in atmosphere.

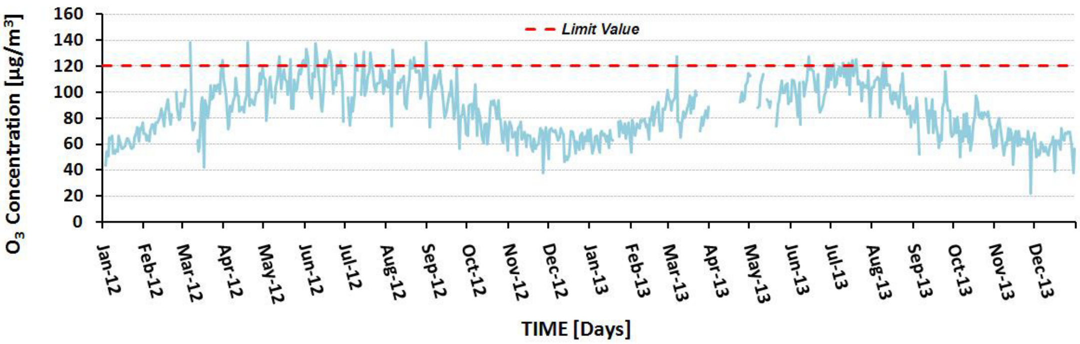

Figure 10. Analysis of annual Maximum daily 8-hour mean O_3 concentration in Viale Veneto monitoring station during years 2012 and 2013.

The reduction of emissions of PM_{10} (Fig. 11-12) by Diesel engine vehicles seems to be counterbalanced by a significant increase of percentage of these vehicles in the distribution of carsfleet.

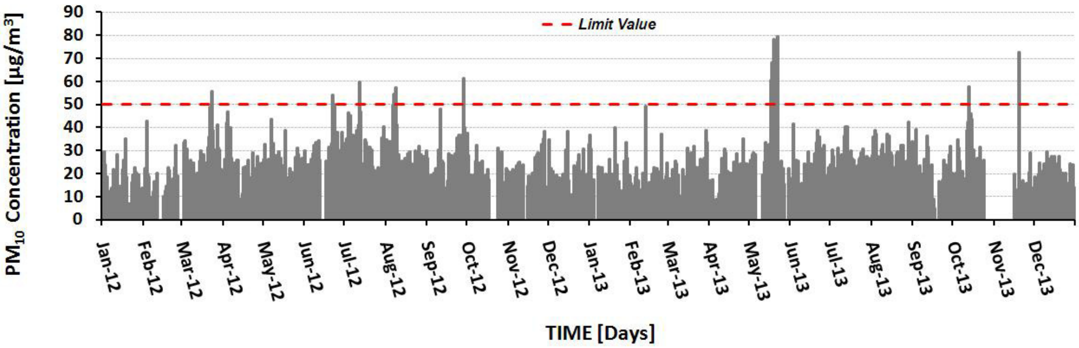

Figure 11. Trend analysis of PM_{10} concentrations at the Piazza A. Moro monitoring station during 2012 and 2013, in red dashed line is represented the limit value not to be exceeded on more 35 days per year.

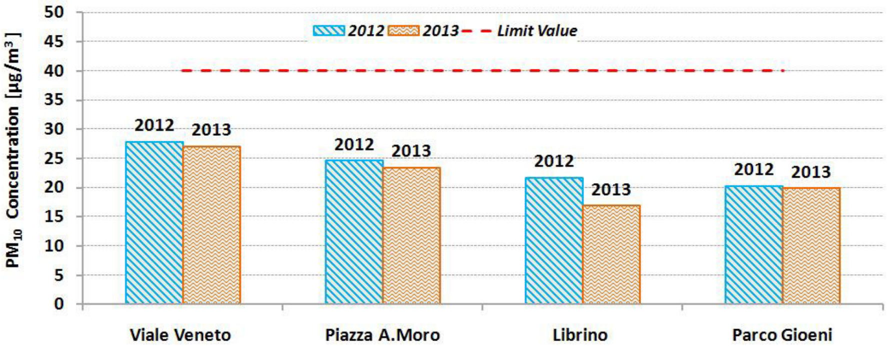

Figure. 12. Annual value of PM_{10} concentrations for different monitoring stations in Catania in the years 2012-2013, the limit value of PM_{10} concentration per yearis represented with a red line.

4. Conclusion

The air quality in urban areas represents one of the main problems for the safeguard of human health. In last decades the public attention to these topics has induced European community to legislate on environmental issues decreasing more and more the minimum limits of pollutants emissions. This research analyses air quality data of Catania city in 2012-2013. Catania, as imposed by law, presents an air quality network system. By the analysis of data in 2012-2013 it is highlighted the excess of the average annual value of NO_2 (40µg/m^3) keeping the negative trend of the previous two years.O_3gases in 2012 presents the excess of the concentration value of 120 µg/m^3 (8-hour mean) for more than 25 times per year.The other pollutants does not overtake the limits imposed by law, probably because Catania does not include an high level developed industrial area. Furthermore, the tendency of cars fleet during last year has increased the Diesel engines car causing the increase of NO_2. The easiest solutions could regard the development of an efficient and sustainable public mobility that could be a concrete alternative to the private cars mobility. The Institutions, (i.e. Public Administration) with the aim at helping the promotion of a culture about sustainable mobility and the safeguard of human health, are delegated to activate civil society about these important topics.

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