Air quality data for Catania: analysis and investigation case study 2010-2011

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Abstract

This work analyses two years of air quality data for Catania, Sicily’s second largest city, which has been monitoring air pollution since 1992. In 2009, this monitoring network was substantially reduced from 17 to 5 monitoring stations in compliance with EU Directive 50/2008. These stations are managed by the Municipal Ecology and Environment office. The following pollutant species are monitored continuously: CO, NO2, SO2, O3, C6H6 and PM10. Those pollutants which strongly impact ecosystems, population and climate, have legally binding concentration thresholds established by the EU.

A robust study of all pollutants and their measurement methods has been carried out. The data was validated and interpreted by daily profiling each single pollutant during different seasons. This study revealed, as expected, how pollutant concentrations peak especially during commute times (early morning and afternoon).

The recent change towards DIESEL powered cars has increasingly effected NO2 and PM10 concentrations causing some public health concerns but fortunately, SO2 and CO concentrations have decreased. Moreover, it is important to highlight high concentrations of ozone during hot Summer days and PM10 proliferation. Because of Catania’s location, particulate matter also enters the scenario especially caused by natural sources such as sand from the Sahara desert and eruptions from Mount Etna.

Keywords: Air pollution, urban area, NO2, O3, PM10

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1. Introduction

In modern cities, air pollutants represent a serious problem for life expectancy. The European community has been focusing on monitoring air quality, by establishing links between climate and air pollution with the aim of reducing the latter and improving air quality. In [1] an overview of trends and air quality status in Europe from 2001 to 2010 has been reported. In urban areas, air pollutants are mainly due to human activity, especially road transport [2]. The influence of road traffic on urban air quality has also been reported in [3-4], while the role of electric vehicles in reducing air pollutants in Dublin has been brought into the mix. Not to isolate vehicular causes, air pollution in urban background sites has been included [6] as has the correlation between air quality and meteorological factors [7]. In the Mediterranean, particulate matter is influenced by natural sources like ash from Mount Etna and sand from the Sahara. These phenomena have been discussed in scientific literature such as the volcanic dust from the 2001 eruptions which were characterized by Lidar measurements [8]. Other natural pollution sources like sea salt and mineral dust are reported on for central Italy [9]. Sahara dust events and their interaction with other particulate matter are also considered [10-11]. In this work, Catania’s air quality has been discussed and researched so as to highlight the principal pollution factors affecting this city.

2. The monitoring system of the city of Catania

The city of Catania has been equipped with a network of air quality monitoring devices since 1992. The network is managed by the Ecology and Environment Office which has allowed the municipality to effectively identify pollutants and monitor the parameters which determine the city’s air quality. Normal wear and tear of these devices and rising maintenance costs, along with changes in the law, have necessitated streamlining the monitoring network. During 2009, the municipality substantially reduced the number of monitoring stations in compliance with the provisions of EU Directive 50/2008. The monitoring network, as was, of the Municipality of Catania included 17 fixed monitoring stations located mainly in the urban area (Fig. 1). The stations were almost all located near major road traffic junctions and, therefore, essentially aimed at measuring the main parameters of motor vehicle emissions.

![Air quality monitoring network of Catania](image)

Fig. 1. Air quality monitoring network of Catania

The revised monitoring network includes different background and residential monitoring stations along with traffic air monitors in five locations. Figure 1 shows the six-point monitoring network for the years 2010 and 2011. According to the 50/2008 Directive, the continuously measured principal pollutants are: CO, NO₂, SO₂, O₃, C₆H₆ and PM₁₀.
In Table 1 is reported the description of the monitoring stations in Catania for the years 2010 and 2011.

<table>
<thead>
<tr>
<th>Station</th>
<th>Description</th>
<th>Altitude (m)</th>
<th>Pollutants measured (2010)</th>
<th>Pollutants measured (2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viale Veneto</td>
<td>Heavy traffic</td>
<td>38</td>
<td>NO2, SO2, C6H6, PM10</td>
<td>NO2, SO2, C6H6, PM10</td>
</tr>
<tr>
<td>Piazza A. Moro</td>
<td>Medium traffic</td>
<td>76</td>
<td>CO, O3, PM10</td>
<td>CO, O3, PM10</td>
</tr>
<tr>
<td>Librino</td>
<td>Light traffic</td>
<td>71</td>
<td>CO, NO2, O3, PM10</td>
<td>CO, NO2, O3, PM10</td>
</tr>
<tr>
<td>Parco Gioeni</td>
<td>Urban-background</td>
<td>135</td>
<td>disused</td>
<td>NO2, PM10</td>
</tr>
<tr>
<td>Zona industriale</td>
<td>Industrial zone</td>
<td>10</td>
<td>NO2, SO2</td>
<td>CO, NO2, SO2</td>
</tr>
<tr>
<td>Stesicoro</td>
<td>Heavy traffic</td>
<td>26</td>
<td>CO, NO2, SO2, C6H6, PM10</td>
<td>disused</td>
</tr>
</tbody>
</table>

3. The main pollutants measured

3.1. Carbon Monoxide (CO)

Carbon monoxide gas is very dangerous because of the ease with which it binds to haemoglobin in the blood, preventing the oxygenation of tissues. It is formed during the incomplete combustion of fossil fuels so, in urban areas where pollution from motor vehicle exhausts is high, CO levels are also high. The legal limit of CO concentration is a daily 8-hour mean of 10 mg/m³. The reference method for measuring carbon monoxide is described in EN 14626:2005 as the “Environmental air quality; Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy”. A Philips Gas Filter Correlation (GFC) CO analyzer was used as per UNI EN 14626:2005. The measuring principle is based on the absorption of infrared radiation (IR) by molecules of CO, whose intensity variation is proportional to the CO concentration. This IR absorption is governed by the Beer-Lambert law which defines how much light of a specific wavelength is absorbed by a particular gas molecule.

3.2. Nitrogen Dioxide (NO2)

Nitrogen dioxide is an oxidant pollutant considered a precursor of photochemical smog. In urban and industrial areas, the major sources of NOx (the term used to describe the sum of NO (Nitrogen monoxide) and NO2) are high temperature combustion processes. Of all NOx emissions, NO is the great majority the small remainder being directly emitted as NO2, typically 5–10 % for most combustion sources, with the exception of diesel vehicles. For traffic emissions, the direct NO2 fraction is increasingly significant due to the increased market share of diesel vehicles, especially newer diesel vehicles (Euro 4 and 5). Such vehicles can emit up to 70 % of their NOx as NO2 [12] because their exhaust after-treatment systems increase direct NO2 emissions. The legal limit of NO2 concentration in one hour is 200 μg/m³, and should not be exceeded more than 18 times in a calendar year, and the annual mean is 40 μg/m³ in a calendar year. The reference method for measuring nitrogen dioxide and other oxides of nitrogen is described in EN 14211:2005 “Ambient air quality; Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence”. The Nitrogen dioxide analyzer was a Philips chemiluminescence NO/NOx model 200 E as per UNI EN 14211:2005. The measurement principle is based on the oxidation of nitrogen monoxide molecules by ozone produces a characteristic luminescence intensity proportional to the concentration NO.

3.3. Sulphur Dioxide (SO2)

Sulphur dioxide in the atmosphere is both natural and manmade, the latter mainly deriving from fossil fuels and the biofuels used for domestic heating, stationary power generation and transport. Volcanoes are the most significant natural source. The legal limit of concentrations per hour is 350 μg/m³, not to be exceeded more than 24 times a calendar year and in one day by not more than 125 μg/m³, not to be exceeded more than 3 times a calendar year. The reference method for measuring sulphur dioxide is described in EN 14212:2005 “Ambient air quality; Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence”.


The SO₂ analyzer was a Philips pulsed fluorescence model K50206/00 as per UNI EN 14211:2005. Measurements were based on pulsed fluorescences. Ultraviolet radiation is filtered, focused and channeled into a fluorescence chamber. Simultaneously, an environmental air sample is injected into the chamber. The ultraviolet radiation excites the SO₂ molecules leading to higher energy levels. Subsequently, the excited SO₂ molecules emit a characteristic radiation which, when properly filtered is fed into a photoamplifier tube which transforms the data into an optical/electrical type.

3.4. Ozone (O₃)

Ozone in the stratosphere protects us from harmful ultra-violet radiation from the sun. In the troposphere, the layer of atmosphere closest to Earth, high concentrations of ozone are, however, a problem. Ozone is harmful to humans, it irritates our throats and lungs and makes it difficult to breathe. Ground-level (tropospheric) O₃ is not directly emitted into the atmosphere but formed from a chain of chemical reactions following the emissions of the precursor gases NOₓ, VOC and CO. Nitrogen oxides are emitted during fuel combustion, for example by industrial facilities and road transport. Nitrogen oxides play a complex role in O₃ chemistry: close to its source NOₓ will deplete O₃ due to the reaction between the freshly emitted NO and O₃. The concentration limit is a mean of 120 mg/m³ over 8 consecutive hours (not to be exceeded for more than 25 days per calendar year averaged over three years). The reference method for measuring ozone is described in EN 14625:2005 “Ambient air quality; Standard method for the measurement of the concentration of ozone by ultraviolet photometry”. The Ozone photometric analyzer was an API model 400A. The basic principle on which the ozone analyzer M400E is based is the Beer-Lambert equation. It defines the amount of light at a specific wavelength that is absorbed by a particular gas molecule at a certain distance and at a given temperature and pressure.

3.5. Benzene (C₆H₆)

Benzene is a manmade aromatic hydrocarbon found in air due to auto-vehicular emissions and dispersion during refuelling. Benzene is a fuel additive and 80–85 % of C₆H₆ emissions are due to vehicle traffic in Europe. At room temperature, benzene is a colourless liquid that evaporates very quickly. The international agency for research on cancer has classified benzene as carcinogenic to humans. The benzene emitted in air has a half-life concentration of about 1 day in air polluted by nitrogen oxides and sulphur oxides which are decomposition catalysts. The legal limit of concentrations per calendar year is 5 μg/m³. The reference method for measuring benzene is described in EN 14662:2005, parts 1, 2 and 3 “Ambient air quality; Standard method for measurement of benzene concentrations”. The benzene analyzer is a “Chromatotec GC366 airToxic” manufactured as per EN14622:2005. It is a high-performance gas chromatograph with photo-ionization detection.

3.6. Particulate Matter (PM₁₀)

Particulate matter is the term used for a composition of particles (solid and liquid) suspended in air, known as aerosols, with a varying range in size and chemical composition. PM₁₀ refers to the particles with an aerodynamic diameter of 10 micrometres or less. Particulate matter is both of natural origin, e.g. volcanic ash, desert dust, sea salt, naturally suspended dust, pollen, or from manmade sources, mainly from fuel combustion in thermal power generation, incineration, households for domestic heating and vehicles, amongst others. In cities vehicle exhaust, road dust re-suspension and burning of wood, fuel or coal for domestic heating are significant local sources. The legal limit of concentration per day is 50 μg/m³, not to be exceeded for more than 35 days per calendar year, and 40 μg/m³ during a calendar year.

The reference method for sampling and measuring PM₁₀ is described in EN 12341:1999 “Air quality; Determination of the PM₁₀ fraction of suspended particulate matter; Reference method and field test procedure to demonstrate reference equivalence of measurement methods”. PM₁₀ is measured by a PM₅ monitor model “Swam 5A” manufactured by FAI instruments. Measurement is gravimetric utilising the mass measurement of attenuation through β rays using a source of low-activity ¹⁴C.
4. Data analysis

The air quality of the city of Catania is continuously monitored by 5 stations across the city. Each monitoring station is equipped to measure air quality, all the instruments conforming to UNI EN law. The city of Catania is a metropolitan area with about 750000 inhabitants with a massive commuting of private vehicles caused by inadequate public transports system. The first peak is usually during the early morning (about 7.30-9.30) while the second one is during the late afternoon (about 18.30-20.30). The data recorded by the control units was analysed, computed and plotted. Figure 2 shows a typical daily Winter trend of NO2 hourly concentrations compared to O3 hourly concentrations on both weekdays and at weekends. As expected, NO concentrations (engine combustion) at weekends is very low because urban traffic is moderate, which according to the O3 cycle causes an elevated concentration of O3 while weekdays, NO concentrations are very high during the daily commute causing a peak decrease of O3 and a corresponding increase in NO2.

![Fig. 2. Daily trend of O3 vs. NO2 hourly concentrations in January 2011 at Librino.](image)

Figure 3 shows a typical Summer day trend of NO2 vs O3 hourly concentration. The Summer O3 concentration is very high due to the high temperatures. The relationship between NO2 and O3 is the same as in Winter. According to the chemical reactions between O3, NO and NO2 [13], the relationship between NO2 and O3 its the same of Winter season.

![Fig. 3. Daily trend of O3 vs. NO2 hourly concentrations in July 2011 at Librino.](image)

Figure 4 shows a comparison of CO concentrations in three monitoring stations during a weekday in 2010.

![Fig. 4. Comparison of CO concentrations in three monitoring stations during a weekday in 2010.](image)
The daily profile of CO concentrations for the stations of Piazza A. Moro, Piazza Stesicoro and Librino is show in Figure 4. The different values are due to the different levels of urbanisation of the zones. Piazza Stesicoro is in the centre of Catania and shows the highest CO concentration which exceeds the legal limit of 5 mg/m³. The Librino station is in a suburban area and shows the lowest CO concentration.

![Graph showing CO concentrations](image1)

**Fig. 5.** Comparison of CO concentrations in three monitoring stations during a weekend in 2010.

Figure 5 shows the CO concentration on a weekend day for three different monitoring stations: in green Piazza Stesicoro's daily trend, in red Librino’s daily trend and in blue Piazza A. Moro’s daily trend. In Piazza Stesicoro station, characterized by heavy traffic, it is possible to notate the peak in the early morning and in the late afternoon.

![Graph showing SO₂ concentrations](image2)

**Fig. 6.** Typical Summer daily trend of SO₂ concentration at the Viale Veneto monitoring station during a weekday and a weekend day in 2011.

Figures 6 and 7 shows respectively in summer and winter the SO₂ typical summer daily trend of a weekday (continuous line) and a weekend day (dashed line).

![Graph showing SO₂ concentrations](image3)

**Fig. 7.** Typical Winter daily trend of SO₂ concentrations at the Viale Veneto monitoring station during a weekday and a weekend day in 2011.
The daily profile of C₆H₆ concentrations during a weekday and a weekend day is shown in Figure 8. During the weekday people are commuting (early morning and afternoon). During the weekend day, C₆H₆ concentrations are lower, as expected.

Figure 9 shows the SO₂ concentration trend during 2010 and 2011. Some periods show no data acquisition probably due to system malfunction. However the SO₂ concentration values are much lower compared to the legal limits even by one order of magnitude.

PM₁₀ concentrations in Catania are generally not very high, with very few cases of the legal limit being exceeded in two years. The data also shows some data acquisition failure from November 2010 to January 2011 probably due to a breakdown in the monitoring system. The legal limit of 40 μg/m³ for a calendar year is not exceeded.
NO$_2$ concentrations depend principally on urban traffic from diesel engines and do not exceed the legal limit individually. However, the calendar year value is exceeded.

Figure 12 shows the O$_3$ concentrations during 2010 and 2011. In 2010, the percentage of valid measurements is lower than 75 % so they are invalid.

As regards the legal limit of PM$_{10}$ concentrations, at the Parco Gioeni station it was not reached in 2010, while at the Piazza Stesicoro station it was until 2010. Generally, PM$_{10}$ concentrations in 2011 decreased compared to 2010 (Fig.13).
The NO$_2$ concentrations are reported in Figure 14 for different stations. At the urban stations (Viale Veneto, Piazza Stesicoro) the legal limit is exceeded. The recent increasing use of DIESEL car engines has effected NO$_2$ and PM$_{10}$ concentrations more, causing some public health issues but fortunately, SO$_2$ and CO concentrations have decreased (Fig. 15-18).
Conclusions

Air quality monitoring has been studied in Catania (Italy). Currently, there are five continuous monitoring stations. In this work, two years’ air quality data for Catania have been analyzed. The main pollutant trend and its principal causes has been investigated by typical daily and seasonal profiles. The legal limit concentrations of the pollutants as defined by the UE/50/2008 Directive have been complied to for CO, PM$_{10}$, SO$_2$, C$_6$H$_6$ and O$_3$. The most dangerous pollutants in urban area of Catania are NO$_2$ and PM$_{10}$ due to the increase in Diesel engine use in recent years, while the values of CO and SO$_2$ are decreasing. The source of these principal pollutants is urban mobility given that the industrial zone is undeveloped. The monitoring system has some shortfalls in meteorological instruments since not one of the five station has a wind speed velocity meter, a humidity meter nor an environmental temperature meter. This meteorological data could be very significant in implementing a mathematical model for the dispersion of pollutants. In terms of the limits value of concentrations for NO$_2$ alone, there is an exceedance. In Catania, the effect of natural sources (Mount Etna, sea salt, Sahara dust) on pollutant concentrations must be further investigated.

References