TRENDS IN ATMOSPHERIC PARTICULATE MATTER AND GASES IN LEÓN (SPAIN): EFFECTS OF AIR QUALITY REGULATIONS

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INTRODUCTION

Several studies have demonstrated that the exposure to air pollutants may cause a negative impact on human health and the environment (Kampa & Castanas, 2008; Tang et al., 2005) . For many years, in Europe some efforts have been made for diminishing the air pollutants emissions. Thus, the *Directive 2008/50/EC* relative to *Ambient Air Quality and a Cleaner Atmosphere in Europe* was approved in 2008. In Spain, the legal basis relative to the *Air Quality and Atmosphere Protection* and *Improvement of Air Quality* is contained in the *Law 34/2007* and *Real Decreto102/2011*, respectively. The study of the air pollutants trends is essential to show the evolution of emission sources over the years and to assess the effectiveness of emission control policies. The studies show that the Spanish Government efforts for the reduction of the air pollutants emissions have achieved convincing results (Querol et al., 2014).

STUDY AREA

León city, belonging to the Province of León, is located in the northwest of the Iberian Peninsula (42° 36′ N, 05º 35′ W and 838 m above sea level) (Fig. 1). The population of León city and nearby municipalities (San Andrés de Rabanedo, Villaquilambre, Valverde de la Virgen and Onzonilla) has suffered a progressive increase, from the year 1998 (176,333 inhabitants) to 2016 (185,393 inhabitants).

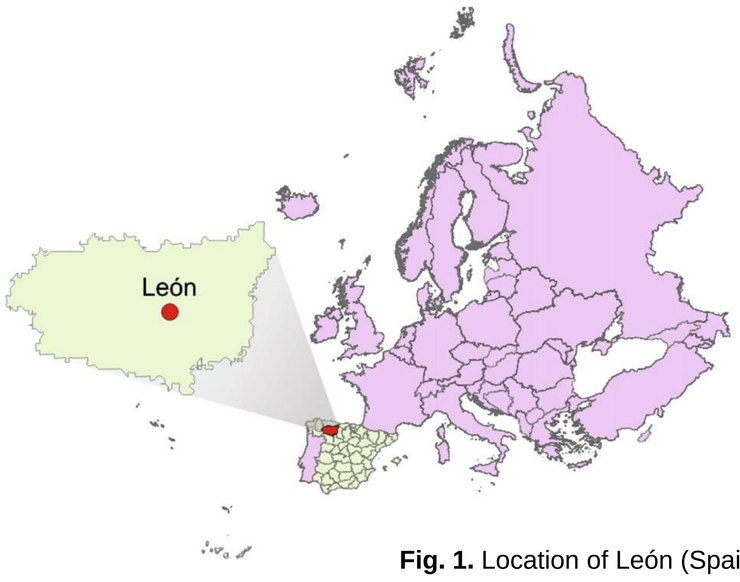

Fig. 1. Location of León (Spain)

METHODOLOGY

Data from four air quality stations (three traffic and one background stations) corresponding to the Castilla y León Air Quality Network (www.jcyl.es), have been used (Table 1).
The calculations of trends were made with the ThielSen methodology that derives from the non-parametric Mann-Kendall test (Hipel & McLeod, 2005).

Table 1. Information related to the four Air Quality stations of León city (Junta de Castilla y León, www.servicios.jcyl.es/esco/)

Station	Location	Type	Sampling period	Pollutants analyzed
1	San Ignacio de Loyola Avenue (05° 35'14"W 42° 36'14"N)	Traffic	January 1997-December 2016	CO, NO, NO_2, O_3, PM_{10}, SO_2.
2	León Arena (05º34'17" W 42º35'19" N)	Traffic	January 1997- August 2009	
3	San Juan de Sahagún Street (05° 33'53"W 42° 36'32"N)	Traffic+ Industrial	January 2001-May 2013	NO, NO_2, O_3, PM_{10}, SO_2.
4	Coto Escolar (05° 33'59"W 42° 34'31"N)	Background	January 2010-December 2016	

RESULTS

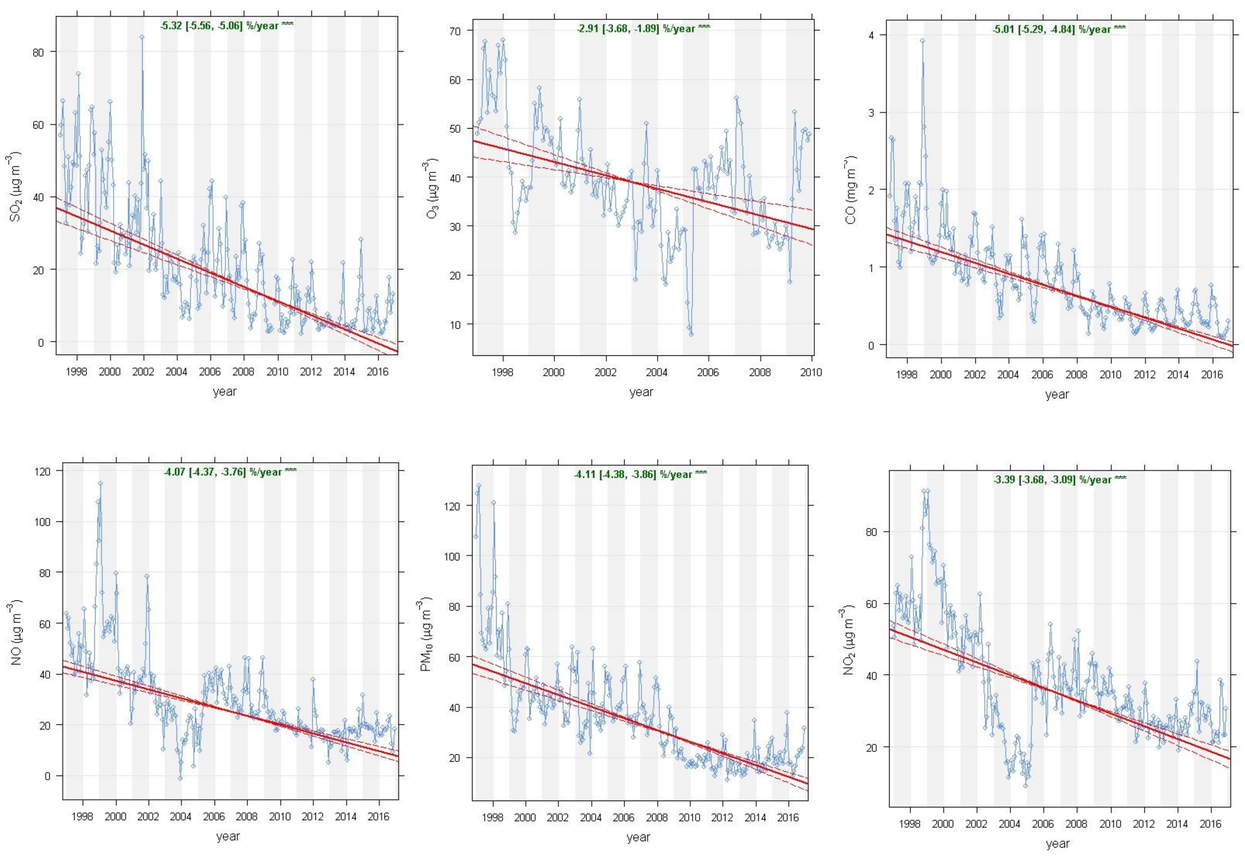

Fig. 2. Long-term trend for SO_2, O_3, CO, NO, PM_{10} and NO_2 in Station 1. The solid red lines show the trend estimate and the dashed red lines show the 95% confidence intervals for the trend.

The trend shows in general, a statistical significant decrease in the CO, NO, NO_2, SO_2, O_3 and PM_{10} concentrations (up to -7.25, -6.04, -3.79, -8.54, -2.91 and -6.53 %/year, respectively, $p < 0.001$) (Fig. 2). This pattern has also been observed by the Spanish System of the Emissions Inventory (MAGRAMA), which reports a statistical significant decrease in the air pollutant concentrations mainly due to the reduction in the emissions from road traffic and public power in Spain between 1997 and 2014. Also, the change in the energy consumption and production in the province of León (Fig. 3) has had an important impact on these decreasing trends.

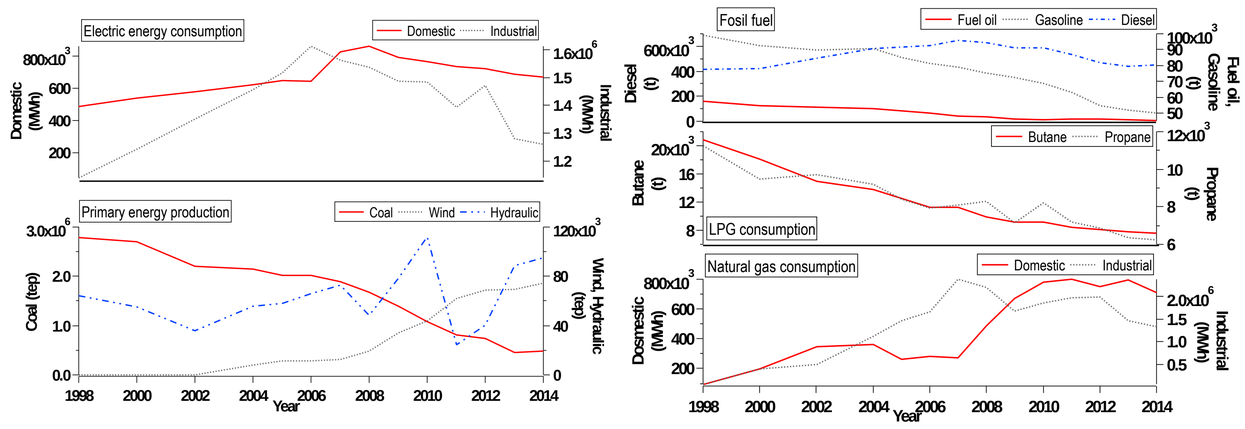

Fig. 3. Trends in production and consumption of energy and fuel in Province of León (www.energia.jcyl.es)

The Pearson correlation coefficient shows a high and significant correlation between PM_{10} and CO ($R > 0.6$, $p < 0.001$) reflects the relationship with the primary emissions from combustion process. The PM_{10} was also correlated with SO_2 ($R > 0.5$, $p < 0.001$) due the contribution of heating systems in urban areas and fossil fuel combustion. The O_3 was anti-correlated with PM_{10} ($R < 0.1$) in the four stations due to the depletion during the oxidation of NO and NO_2.

The application of the Mann-Kendall test to the data available for the station 1 shows that between the years 2006-2008 there is an evident and significant decreasing trend in the concentrations of all the air pollutants in León. However, from 2008-2010 the recorded values are within the allowed limit values, especially in the concentrations of PM_{10} and SO_2 (Fig. 4).

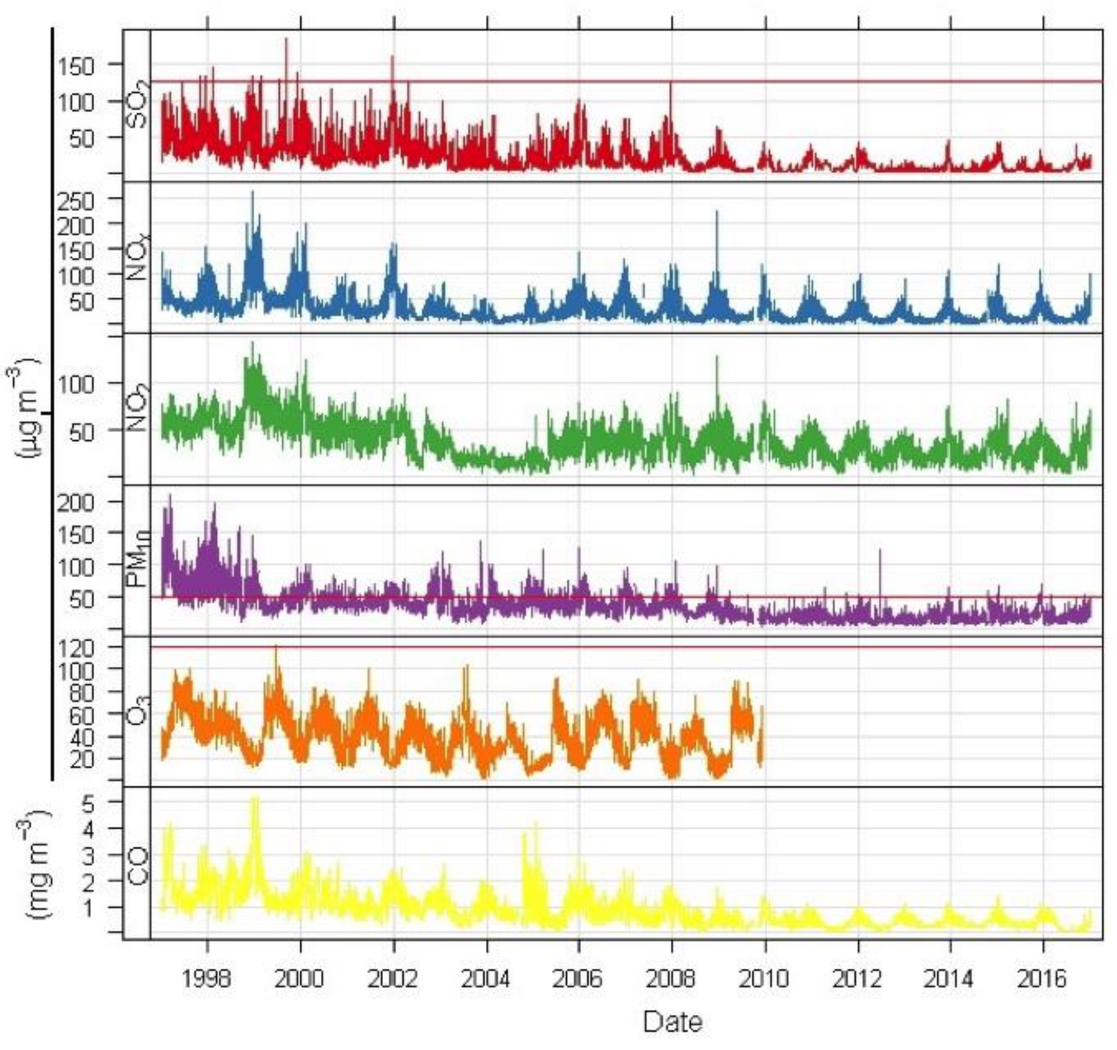

Fig. 4. Trend with daily mean values for CO, NO, NO_2, PM_{10}, SO_2 and O_3 on Station 1. The solid red line shows the daily limit value.

The local Government has taken a series of measures over the period of study that have cause a reduction in the levels of emission from different sources. Thus, the Autonomous Community of Castilla y León approved in 2002 the *Strategy of Control of the Quality of the Air of Castilla y León 2001-2010*, which has as main objective prevent and reduce the concentrations of harmful air pollutants in order to protect the environment and human health. To continue with this Strategy, the City Council of León implements in 2003 the *Strategic Plan of Control of the Air Quality*. In addition, in 2012 is approved in León, the *Municipal Ordinance of Atmosphere Protection*, which aims is regulate any activities, situations and facilities that can produce fumes, dust, gas, vapors and odors in the municipal area, to avoid air pollution.

CONCLUSIONS

- In general, there are a significant decreasing trend in the atmospheric pollutants concentrations in León city due to the efficiency, not only for the international and national policies, but also for the local measures taken for the reduction of the emissions source like road traffic, industrial and power public.
- Since 2008, León city reports values of air pollutants that are within the allowed limit values, especially in the concentrations of PM_{10} and SO_2. The general decrease is coincident with the changes observed in the Province of León for the energy consumption and production in the period of 1998-2014.

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