A review of 26 years air quality monitoring program in the industrial area of Thriasio Plain – Greece

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Abstract
Thriasio Plain is the first and the major industrial zone of Greece that includes a significant number of heavy industries, various industrial installations and logistic facilities. This paper presents a review of a 26-years (1986 – 2012) air quality monitoring program carried out from two local environmental agencies and the Ministry of Environment. In order to present a more holistic approach, two Air Quality indices that include all air pollutants measured in the area, were used. The results indicated an improvement of air quality in the area during the last years. The air pollution episodes were reduced. The major contribution to the values produced by air quality indices was made by PM10 and Ozone, while the other pollutants showed a minor contribution.

Keywords: Air Quality Indices, Thriasio Plain

1 Introduction
Ambient concentrations of air pollutants are quite variable both in time, following the temporal profile of pollutant emitting human activities and in space. They depend, apart from the morphological and meteorological characteristics of the area concerned, on the distance from dominating sources and the location within a city. Within the context of urban, suburban and industrial areas the air pollutants considered as "classical" are sulphur dioxide (SO_2) and nitrogen oxides (NOx), emitted by various combustion processes and ground-level ozone (O_3), produced secondarily via chemical reactions between nitrogen oxides and of non-methane volatile organic compounds in the presence of sunlight.
Very few works have been published, regarding the air quality of the whole area Thriasio Plain (Lykoudis et al, 2008; Mavrakis et al, 2008). The vast majority of air quality studies for the greater Athens area have either neglected, or briefly assessed air quality over the Thriasio, using a single station (Abatzoglou & Asimakopoulos, 1993; Flokas et al, 2003; Helmi, 2007)
The Thriasio Plain exhibits the higher (a) industrial activity concentration, (b) fuel consumption and (c) pollution related to the production processes, in Greece (Mavrakis et al, 2005a; Mavrakis et al, 2009; Recent data (Salvati & Mavrakis 2014) reports at least 2200 large and small industrial plants, including all kinds of industries, such as oil refineries, chemical and steel production, metal and non-metal minerals' processing, and cement industries. Apart from the industrial activities the area is crossed by three freeways (two national roads and since 2003, a large part of the urban freeway Attiki Odos) as well as by two railroad lines (the national railway line and since 2005, the Athens' suburban railway). Furthermore, there are 9 large quarries and the 13 docks of Elefsis harbor accommodating 5500 ships per year, with a total cargo load 2.5 times larger than that handled by the Piraeus harbor.
This paper presents a review of a 26 year (1986 – 2012) air quality monitoring program carried out from two local environmental agencies and the Ministry of Environment. In order to present a more holistic approach, two Air Quality indices that include all air pollutants measured in the area, were used.

2 Data and Methodology

The data presented herein cover the period 1986 – 2012 and were obtained from Bureau of Environment, Municipality of Elefsis (GPDE) and Bureau of Environment, Municipality of Aspropyrgos (GPDA) and the Ministry of the Environment. From 1986 to 1993 air quality monitoring was performed using a single station (S-A). Every other month the station was moved among selected locations around the area, in an attempt to identify areas with pollution problems. These locations (Figure 1a) are marked with "S". In 1993 the station was permanently placed in location EL-1, while a second station (S-B) continued the moving-around measurement campaign till 1997. That second station measured pollution in three locations from 1998 to 2000, one location each year and since 2001 it is permanently placed in location MAG (Figure 1b). Since 2001, the air-quality monitoring network covers the urban areas of the 4 municipalities of the area with permanent stations.

Air Quality Indices (AQIs) have no direct relation to the quality of living and health of people. AQI indicate mainly the content of air pollution in the ambient air, and are expressed as sums of relative pollutant concentrations

$$AQI = \frac{1}{n}\sum_{i=1}^{n}\frac{C_i}{R_i} \qquad (1)$$

where, n is the number of air pollutants, Ci is the time-specific concentration, and Ri is the time-specific reference value of the air pollutant i.

A long-term planning-related index for the evaluation of mean annual "stress" of air pollution, AQI_1 is calculated by the relationship: (Katsoulis & Kassomenos, 2004):

$$AQI_1 = \frac{1}{4}\left[\frac{C(SO_2)}{20} + \frac{C(NO_2)}{40} + \frac{C(O_3)}{120} + \frac{C(PM_{10})}{50}\right] \qquad (2)$$

where C indicates the annual mean concentration of the respective pollutant expressed in μg/m3, and the denominators correspond to the Commission of the European Communities (CEC) annual limit values.

A planning Air Quality "Stress" Index (AQI_2), for short-term air pollution "stress" is expressed by the relationship:

$$AQI_2 = \frac{1}{4}\left[\frac{N(SO_2)}{24} + \frac{N(NO_2)}{18} + \frac{N(O_3)}{25} + \frac{N(PM_{10})}{50}\right] \qquad (3)$$

where N indicates the number of times in a year, the respective pollutant exceeds the CEC threshold value, and the denominators correspond to the annual number of exceedances allowed by the CEC.

3 Results

The AQI_1 and AQI_2 average values calculated using equations 2 and 3 are presented in Figures 2a and 2b respectively. The assessment of air quality based on AQI_1 and AQI_2 indices are presented in Table 1.

Index AQI_1 is characteristically determined by the high SO2 concentrations up to 1991, while later on, the pollutants that determine the air quality status of the area are O3 and PM10. NO2 on the other hand was important only during the period 1998–2000, leading to an overall degradation of the air quality of the area due to the increased traffic volume caused by the construction and improvement works of the major road axes (Christides et al, 2005).

In Figure 2a a strong trend since 1993 is shown and then variability increased with time This is because of the two time periods of measurements: the first was the move-around campaign during 1986-1993 while in the second period, the air-quality monitoring network covers the urban areas of the 4 municipalities of the area with permanent stations. Details regarding the stations are presented in Figures 1a and 1b (Mavrakis et al., 2008). Notably, until 2006 all stations present a decreasing trend of the AQI_1, even though there are still high values remaining more or less stable (between 0.6 and 0.8) indicating the air quality problems of certain areas in the industrial zones.

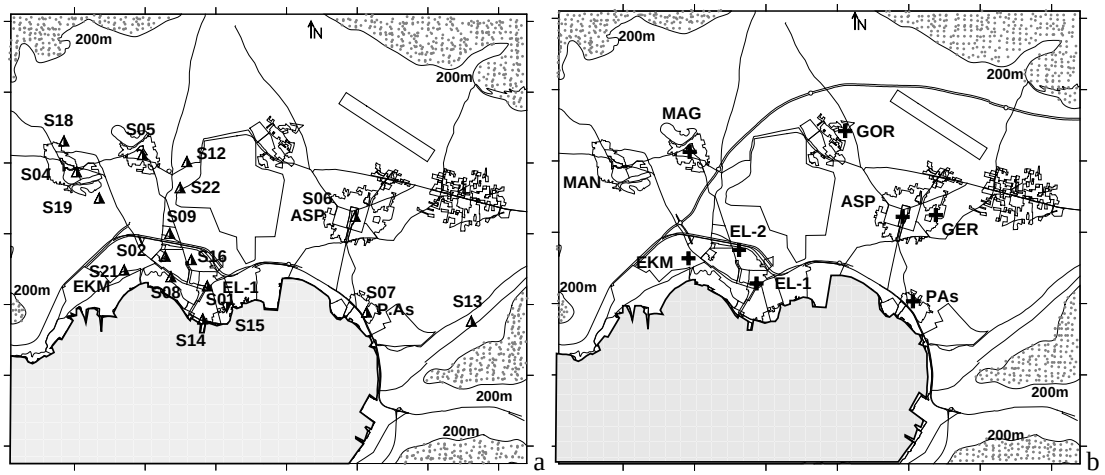
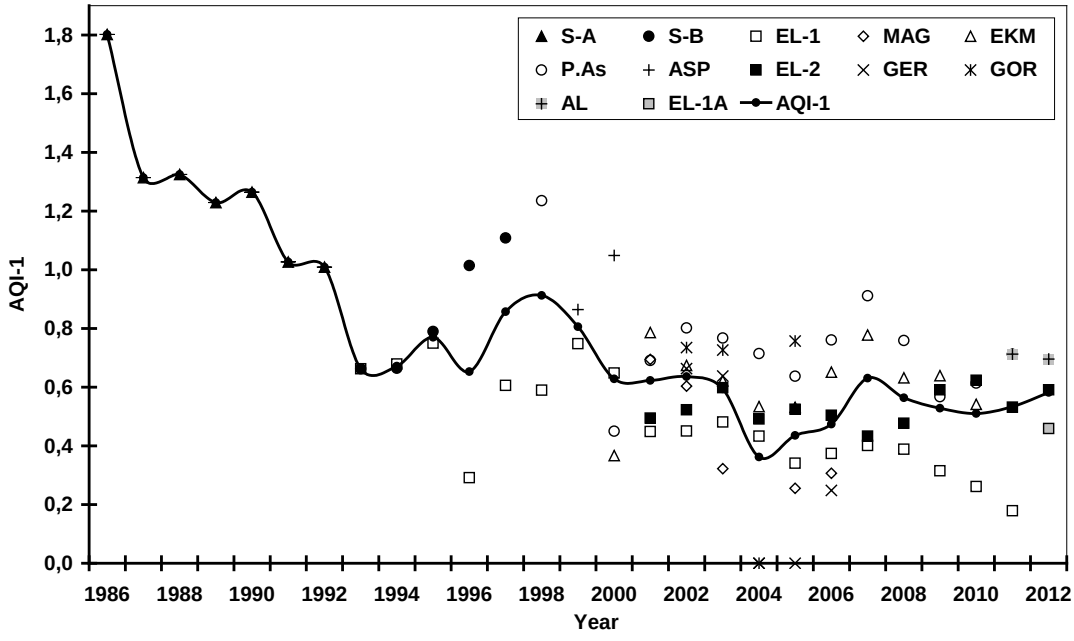


Fig. 1. Air quality monitoring locations across the Thriasio Plain: a) "S" locations were used during the move-around campaign during 1986-1993: b) EL – Elefsis, ASP – Aspropyrgos, MAN – Mandra, MAG – Magoula. Locations PAs, GOR, GER, AL, belongs to the municipality of Aspropyrgos, while EKM belongs to municipality of Mandra. PAs and EKM are industrial locations.

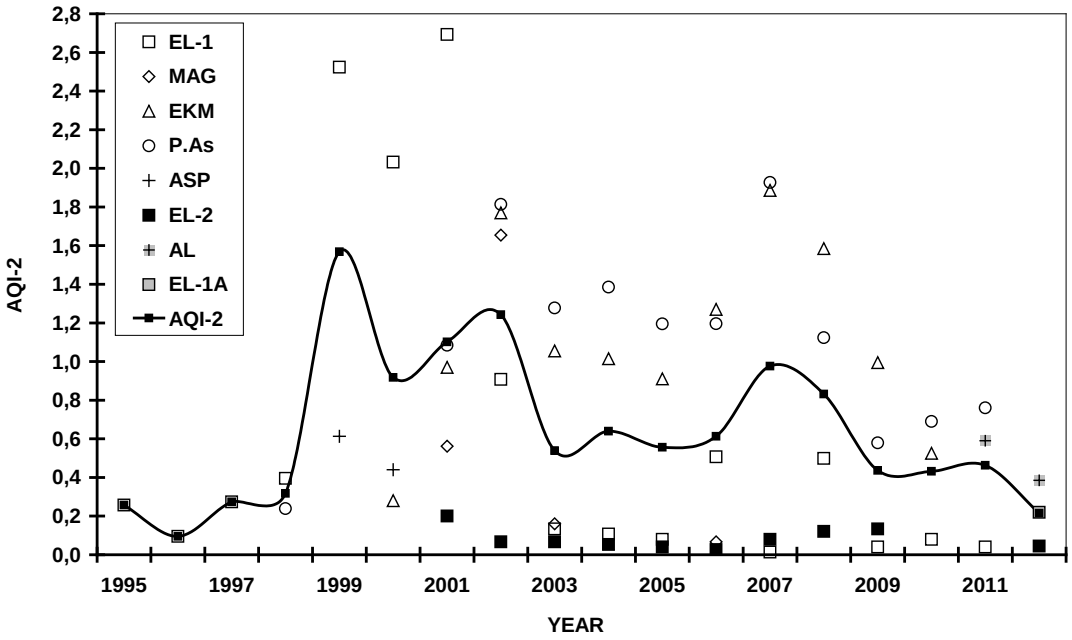
Index AQI_2 can not be calculated during the move around campaign during 1986-1993 time period due to luck of data. AQI_2, suggests that there are excessive exceedances at the Thriasio, along with the overall elevated pollution concentrations. Station EL-1 for which AQI_2 values during the period 1999-2000 are off-scale namely due to very high number of NO_2 exceedances. This is due to the public works on the major road axes during that period that re-routed traffic through the city of Elefsis causing these extreme air quality conditions. For the period 2001-2002 AQI_2 values are off-scale namely due to very high number of O_3, NO_2 and PM_{10} exceedances (Mavrakis et al., 2005b; Mavrakis & Christides, 2009; Mavrakis et al., 2010).
Industrial areas of PAs and EKM shows continuing elevated values due to production activity. But during last few years, the economic crisis seems to have a remarkable impact to air pollution, causing less pollution episodes.
For municipality centers the results of indices shown a better air quality conditions than industrial areas

Table 1. Assessment of air quality based on AQI_1 and AQI_2 values (Katsoulis & Kassomenos, 2004):

Level	Description of Stress Category	Indices Value
I	Very low	AQI_1, AQI_2 <0.2
II	Low	0.2<AQI_1, AQI_2 <0.4
III	Moderate	0.4<AQI_1, AQI_2 <0.6
IV	Distinct	0.6<AQI_1, AQI_2 <0.8
V	Strong	0.8≤AQI_1, AQI_2
VI	Extreme	Independent of AQI_1 and AQI_2



a



b

Fig. 2. The annual evolution of: a) AQI_1, mean annual "stress" of air pollution, b) AQI_2 – planning Air Quality "Stress" Index

4 Conclusions

This work presents the air quality problem of Thriasio Plain – the largest industrial area of Greece – in terms of SO_2, NO_2, O_3 and PM_{10}. The pollutants considered in this study present a predominantly industrial profile across the whole area. Nevertheless, road traffic also seems to be playing a significant role. Summarizing the remarks presented above we can conclude that:

Sulphur dioxide concentrations, once significant, gradually decrease over the years, as a result of fuel improvement.

AQI_1 has high values suggesting the existence of an air quality problem in the Thriasio Plain. It also indicates a shift of the main contributor from SO_2 to O_3 and PM_{10} during the last decade.

The results indicated an improvement of air quality in the area during the last years. The air pollution episodes were reduced. The major contribution to the values produced by air quality indices was made by PM_{10} and Ozone, while the other pollutants showed a minor contribution.
Local circulations, like sea breeze may prove either beneficial for an area by effectively ventilating it, or harmful by transporting significant amounts of pollutants emitted upstream.
The study of the spatial and temporal evolution of air pollutants as a result of certain pollution abatement measures and policies, along with a careful consideration of the dispersion conditions and the knowledge of the particular contribution of each source category to the aggravation of pollution across the area, could help in the development of abatement strategies for the industrial environmental impact, and thus act as a useful tool for residential planning adopting environmental criteria.

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