Ecological Indicators 18 (2012) 259–268

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Air quality assessment in a heavily polluted urban Mediterranean environment through air quality indices

P.A. Kassomenos[a], A. Kelessis[b], M. Petrakakis[b], N. Zoumakis[c], Th. Christidis[c], A.K. Paschalidou[a,*]

[a] University of Ioannina, Department of Physics, Laboratory of Meteorology, GR-45110, Ioannina, Greece
[b] Environmental Department, Municipality of Thessaloniki, Paparigopoulou 7, Thessaloniki 54630, Greece
[c] Laboratory of Atmospheric Physics, Technological Education Institute of Thessaloniki, P.O. Box 141, Sindos 57400, Thessaloniki, Greece

ARTICLE INFO

Article history:
Received 5 September 2011
Received in revised form
13 November 2011
Accepted 14 November 2011

Keywords:
Air quality Index
Urban air pollution assessment
Monitoring atmospheric data
Mediterranean city
Complex terrain

ABSTRACT

During the last years several attempts were made to introduce various air quality indices, defined for a specific air pollutant or a mixture of pollutants, based on standards and guidelines proposed by international organizations. In this work, air quality data (CO, SO_2, O_3, PM_{10} and NO_2) corresponding to the six-year period between 2004 and 2009 and collected at three monitoring stations in Thessaloniki, the second largest Greek city, were used in order to compute three different air quality indices. The first index was based on individual pollutants and was employed to characterise the air quality status for each one of the air pollutants separately, whereas the second index was based on a combination of pollutants in both the short and the long terms. The results showed that when individual pollutants were used, the air quality in the city-centre could be characterised as "bad" for 47% of the days for PM_{10}, "bad" for 89% of the days for NO_2 and "bad to severe" for 13% of the days for O_3. Similarly, the indices based on a mixture of pollutants showed that in the city centre 43% of the days are "problematic to very poor" in terms of the air quality, whereas in the suburbs 54% of the days are found in the range of "good to very good". Furthermore, the use of biometeorological air quality indices that take into account the adverse health effects of air pollution on public health showed that the overall air quality is poor in the city centre for 58% of the days studied, while at the peripheral sites and during Sundays the air quality seems to be improved significantly, with relevant percentages equal to 18% and 13% respectively. Moreover, weekly and neighbourhood patterns were detected by all groups of indices. On the whole, all of the methodologies used revealed that the air quality in Thessaloniki is poor and that PM_{10} is the main contributor to this.

1. Introduction

During the last decades, the continuous population inflow in large metropolitan areas, the large-scale industrialization and the increase of the vehicle's fleet riddled large urban centres with significant environmental problems. Thus, urban areas have received special attention for their high air pollutant concentrations and the associated degradation of the air quality and public health. The association between exposure to common pollutants and ill-health endpoints, such as decreased lung function, increased asthma attacks and hospital admissions for respiratory/cardiovascular diseases, as well as the association between poor air quality conditions and increased daily mortality have been demonstrated in many studies (see e.g. Cairncross et al., 2007). These studies revealed that the adverse health effects associated with the air pollution may be attributed to short or long-term exposure and to different exposure-response characteristics.

Due to the health effects described above, imprinting the overall air quality status in the cities, as well as the air quality status for each one of the most commonly measured air pollutants separately is of great interest. Local authorities and policy-makers worldwide are therefore asked to use a set of standards and guidelines, in order to characterise the air quality in their cities with respect to the levels of various air pollutants. Additionally, the actual values associated with these standards and guidelines become progressively stricter, as more information concerning health effects becomes available. Specifically, in the European Union the relevant directives on air quality (EC, 1999; EC, 2008) not only force the member-states to monitor and report the air quality but also to inform the public. Thus, it is essential to establish air quality indices describing the air quality conditions in the European cities in a way easily understood by the authorities and the public (Elshout et al., 2008).

Throughout the last years, several attempts were made to introduce various Air Quality (AQ) Indices based on standards and

* Corresponding author.
E-mail addresses: apaschal@cc.uoi.gr, paschal@env.duth.gr (A.K. Paschalidou).

1470-160X/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecolind.2011.11.021

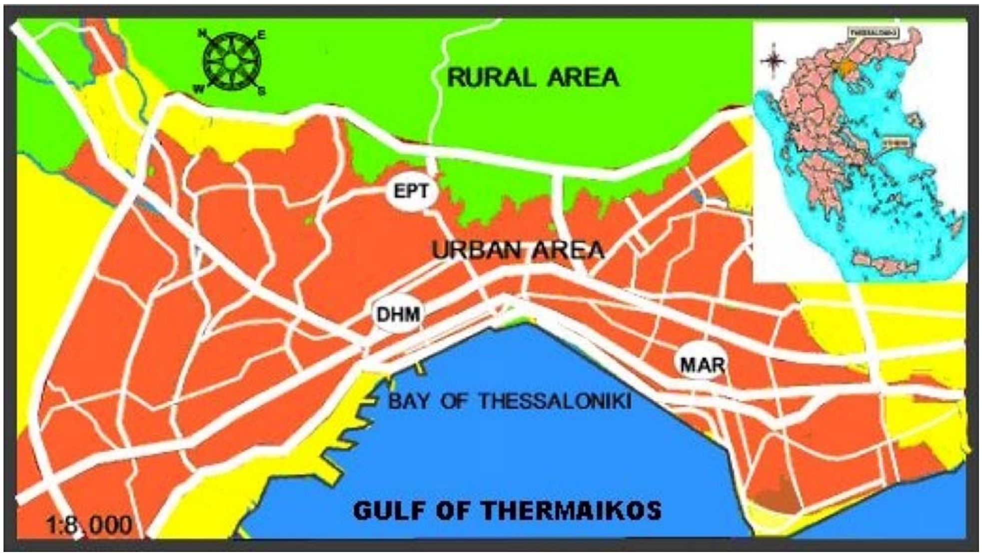

Fig. 1. Map of the Thessaloniki area showing the three monitoring sites.

guidelines proposed by international organizations such as the US Environmental Protection Agency, the European Commission and the World Heath Organization. These AQ indices were defined taking into account each pollutant separately. The idea behind this approach is that dealing with each pollutant separately is easier due to the known health effects resulting from the population's exposure to it (Kassomenos et al., 1999). Nevertheless, during the last years, considerable work has been also done to describe the adverse health effects caused by human exposure to a mixture of air pollutants, although their synergetic impact may not always be easily measured (Bell et al., 2005; Mayer, 2006; Mayer et al., 2008). These attempts have focused on ozone and other species (see e.g. Peterson and Williams, 1999).

A significant problem when establishing the scale that describes the exposure of humans to a mixture of pollutants is the definition of the number of possible weights for each one of the pollutants. Baumuller and Reuter (1995) introduced a set of integrated AQ indices for the city of Stuttgart both for the long and the short term, utilizing various groups of pollutants. Similar attempts were made for Helsinki by Hamekoski (1998), Taiwan by Liu (2002), Naples by Murena (2004) and other cities worldwide.

Kassomenos et al. (1999) proposed an AQ Indicator system based on the measurements of each pollutant measured in Athens, Greece separately, while Katsoulis and Kassomenos (2004) used biometeorological indicators to describe the air quality status in the same area. An aggregated air quality index was developed for the Athenian metropolis by Kyrkilis et al. (2007), in relation to potential pollutant health effects. On the whole, it was shown that the use of the above indices could serve urban planning purposes, as well as the alerting of the population about the status of air pollution in urban domains (Longhurst, 2005; Triantafyllou et al., 2006).

In the present work, the air quality was assessed in Thessaloniki, a Mediterranean city with more than a million inhabitants and significant industrial activity. This was achieved through the development of various AQ indices based on the following three methodologies: Firstly, various indices were estimated for each one of the main pollutants separately, while the second methodology included indices based on a combination of air pollutants in both the short and the long terms. Finally, the last group included indices based on the adverse health effects caused by human exposure to air pollution (i.e. biometeorological indices).

2. Area description, data sources and methodology

2.1. Area description

Thessaloniki covers an area of about 200 km^2 and hosts more than a million inhabitants. The mountain of Hortiatis, reaching 1200 m approximately, is located at the east of the area, while some more hills are located at the north. In the west, the area is flat and allows the connection of the city with the rest of the Macedonia mainland. The rather shallow gulf of Thermaikos is located in the south (Fig. 1).

Thessaloniki experiences a rather Mediterranean climate with mean temperatures during winter and summer at 7 and 25.3 °C respectively and mean annual rainfall at 445 mm. The highest frequency of air pollution episodes is associated with the presence of anti-cyclonic conditions over the Northern part of Greece, being characterised by weak or very weak surface pressure gradient intensity, according to the position and extension of the anticyclone (Flocas et al., 2009). Additionally, the terrain complexity and the pronounced terrain features of the Greater Thessaloniki Area lead to the formation of local atmospheric circulations, such as sea-land breezes and drainage flows that affect the development, evolution and maintenance of the air pollution levels (Helmis et al., 1997).

The main air pollution sources are the industrial activities taking place in the western part of the city and the automobiles, with more than 500,000 vehicles registered in the area (Petrakakis et al., 2008). The absence of a contemporary public transportation system forces people to overuse private cars and consequently leads to high emission regimes in the urban sites of the city (Organization for the Master Plan Implementation, 2000). The central heating also plays a significant role during the cold period of the year (October–April).

2.2. Data sources

The air quality in Thessaloniki is monitored through a complete network of monitoring stations located in traffic, residential and background sites and operated by the Environmental Department of the Municipality of Thessaloniki. Some of the main air pollutants routinely recorded are Particulate Matter (PM_{10}, $PM_{2.5}$), carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2), ozone (O_3) and sulphur dioxide (SO_2). The SO_2 and CO concentrations are measured through the UV-fluorescence principle and