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A COMPARISON OF EMISSIONS AND CONCENTRATIONS OF PRIMARY AIR-POLLUTANTS IN ATHENS WITH THOSE IN THESSALONIKI, GREECE

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Abstract. Athens and Thessaloniki, the two largest cities of Greece, present significant air pollution problems because of the overpopulation, bad city planning and topographic structure of the basins. The pollutant emissions in Athens are estimated to be one to four times greater than in the Thessaloniki area, while the potential for pollution in Thessaloniki is estimated one to three times greater than in Athens basin. Concentration levels of the primary air pollutants, CO, smoke and SO_2, during the years 1989-1997, were analysed to determine seasonal and long-term trends in air quality. The results of this study indicate that the levels of these pollutants were of the same magnitude in the two areas. Meteorological factors (largely winds and turbulence) and topographical features can partially explain the differences which occurred in air pollutants concentrations in the two regions.

Keywords: air quality data, primary air pollutant concentrations, seasonal patterns, pollutant emissions.

AIMS AND BACKGROUND

The concentration of commercial and industrial activities in Athens and Thessaloniki, in relatively small areas over the past 20 years, have resulted in severe environmental degradation, with high concentrations of measured pollutants and a serious visibility reduction. A comparison of emissions and concentration of primary pollutants, compounds that are undesirable in the form they are emitted (e.g., CO), provides a means for establishing the relative importance of atmospheric processes (transport, dilution and removal) that modify the local concentration.

Athens (38.0°N, 23.7°E), with an estimated population of 4.0 million, is located in a basin of approximately 460 km² surface area. It is surrounded by high mountains on three sides and the sea on the fourth side, and is bisected by a series of small hills running along the main north-south axis of the basin. Thessaloniki

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(40.5°N, 22.9°E), a city of over 1.0 million is located in a basin of approx. 200 km² area, with fairly high mountains on ENE side, the sea to the southwest and nearly flat terrain on the west side. The topographic structure and coastal exposure of the two areas are illustrated in Fig. 1. As can be seen, besides the difference in surface area, there are important differences in topographical features that should be noted in the comparison of pollutant potential in the two basins. The prevailing wind direction during the day in Thessaloniki is NW in the winter period. However, during the midday hours, the prevailing wind direction is SW-SE in the summer, mainly due to the sea-breeze cell[1]. The winds in Athens blow mostly along the N-NE/S-SW axis with the prevailing wind direction being NNE (local strong winds in late summer fall and winter) and SSW (usually lower speeds in spring and early summer)[2]. Most of the industrial activities are located to the west and southwest in Athens, and to the northwest in Thessaloniki.

EXPERIMENTAL

The air-pollution data, used in this study, have been measured at three monitoring networks, operated by the Air Quality Department of Greek Ministry of the Environment (11 stations in Athens)[3], the Environmental Department of Municipality of Thessaloniki (5 stations)[4] and the Environmental Department of Macedonia and Thrace Ministry (3 stations)[5]. The levels of carbon monoxide concentrations are measured by gas filter correlation analysers (infrared correlation photometry principle), while the sulphur dioxide and smoke concentrations are measured by the UV-fluorescence and filter reflectometry method, respectively.

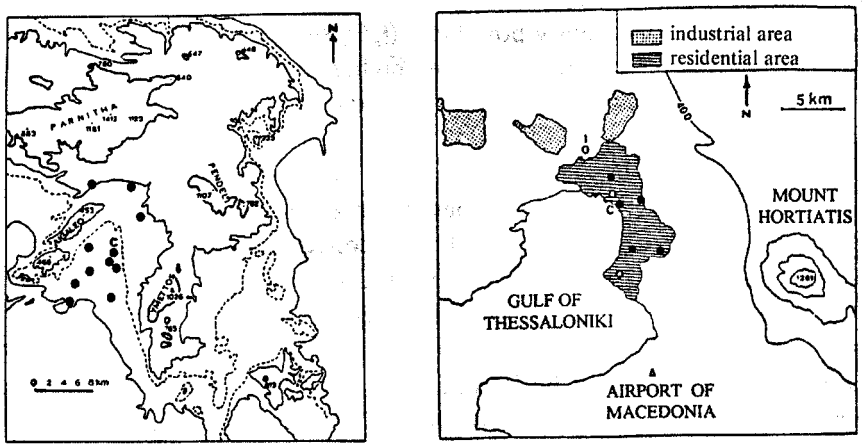

Fig. 1. The topography of the greater Athens and Thessaloniki area, showing the location (•) of the pollution-monitoring stations (C-city center, I – industrial area). Topographical features (height contours of 100 m, 200 m and 600 m above MSL in Athens and contours at 200 m intervals above MSL in Thessaloniki) are also shown together with the peaks of the mountains marked by their altitude

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RESULTS AND DISCUSSION

The measurements of primary air-pollutants (CO, smoke and SO_2) used in this study span over a period of almost ten years, from 1989 to 1997. Urban dimensions and estimates of primary pollutant emission rates for Athens[6,7] and Thessaloniki[1,8-10] are compared in Table 1. The pollutant emissions in Athens are estimated to be one to four times greater than in the Thessaloniki area. As can be seen, on per capita basis, pollutant emissions in Thessaloniki are calculated to be two to four times greater than in Athens, with the exception of CO for which the per capita emissions are almost equal. The areal emission density, and therefore the potential for pollution, is estimated one to three times greater in Thessaloniki than in Athens.

Table 1. Comparison of urban dimensions and estimates of pollutant-emission rates for Athens and Thessaloniki basins

	Urban dimensions		Pollutant-emission rates			
	area (km^2)	population (millions)	CO ($kt\ y^{-1}$)	SO_2 ($kt\ y^{-1}$)	TSP ($kt\ y^{-1}$)	smoke ($kt\ y^{-1}$)
Athens	460	4.0	325.0	18.9	25.5	5.2
Thessaloniki	200	1.1	78.0	23.1	32.3	3.5
Ratio:Ath./Thes.	2.3	3.6	4.16	0.82	0.80	1.49

The sources of primary pollutants are not distributed uniformly either in Athens or Thessaloniki, and atmospheric concentration will vary with local meteorological conditions and with distance from the source. In the present study we have compared the levels of primary pollutants (CO, smoke and SO_2) at the two city center (**C**) monitoring stations, where the highest concentrations occurred, with the exception of SO_2 for which higher concentrations occur in the industrial area of Thessaloniki (**I**).

Carbon monoxide is the least reactive of the primary pollutants. The main source of CO-emissions in the two cities is almost exclusively the automobile[9,10]. Fig. 2 presents the monthly values of the CO concentrations ($mg\ m^{-3}$), at the city center of Athens and Thessaloniki, for the observational period 1989-1997. It was estimated that the CO concentration in the city center of Athens was only 1.4 times greater than in Thessaloniki, despite the total number of vehicles which is 4 times greater in Athens than in Thessaloniki[12]. However, one must also consider the restriction in traffic which is imposed in the central part of Athens (between 08:00-20:00 h during weekdays), which reduce locally the generation of primary pollutants. Yet, because of the relatively small size and topography, the basin constitutes a well-mixed region in which local horizontal variations of source strength are finally unimportant because of the strong convection and recirculation[2]. From these data the overall linear trends were estimated. The observed de-

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creasing trends (-4.8%/y in Athens and -4.1%/y in Thessaloniki) are mainly due to the catalyst equipped cars, which occupied an important fraction of the total passenger cars only after 1992. The increasing fleet of new technology vehicles appears to reduce further the differences in CO concentrations in the two cities.

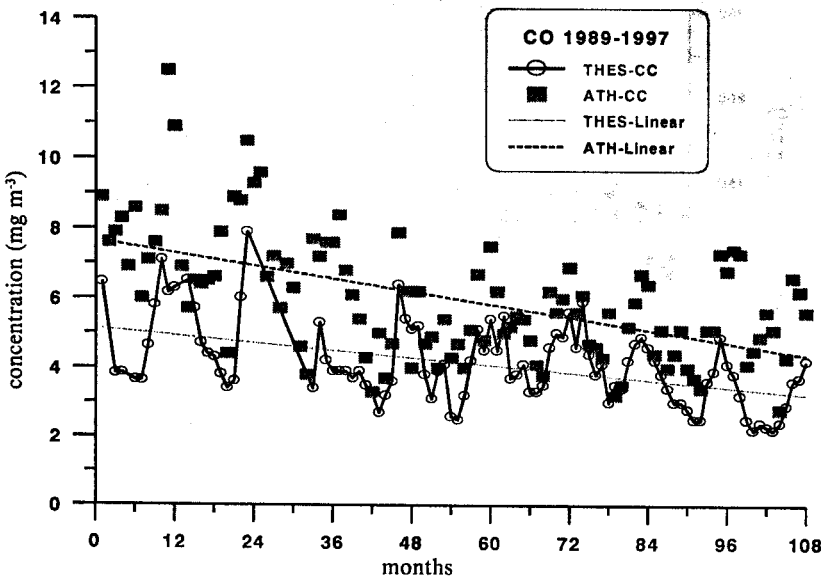

Fig. 2. Monthly values of the CO concentrations at the city center of Athens and Thessaloniki, for the observational period 1989-1997

Figures 3 and 4 present the monthly averages of the smoke and SO_2 concentrations ($\mu g\ m^{-3}$) together with linear trends, for the observational period 1989-1997. It was found that the smoke concentrations in the two city centers were of the same magnitude (≈13% higher in Thessaloniki than in Athens). A general trend toward smaller values seems to exist in both cities (-0.5%/y and -2.3%/y in Athens and Thessaloniki, respectively). However, smoke concentrations in the two cities occasionally reach levels that are recognized as harmful to human health and also decrease significantly the total solar flux at ground level and thus increase atmospheric turbidity[11-13]. Although SO_2 emissions by automobiles are estimated to represent only 5-10% of the total load[6,14,15] in both cities, the region of highest SO_2 concentration in Athens roughly corresponds with the area of greatest traffic density which is maximum in the city center and has a secondary maximum in the port area of Pireas in Athens. The region of greatest SO_2 concentrations in Thessaloniki is displaced northwest of the city center, possibly as a result of additional industrial SO_2 emissions[1,8,15]. Concentrations of SO_2 in Thessaloniki

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were estimated 26% higher than in Athens basin. In addition, the SO_2 measurements in the two city centers were found to be of the same magnitude. The observed significant decreasing trends in SO_2 concentrations (-10.5%/y and -7.3%/y in Thessaloniki and Athens, respectively) are due to the usage of low-sulphur fuels in the last 15 years.

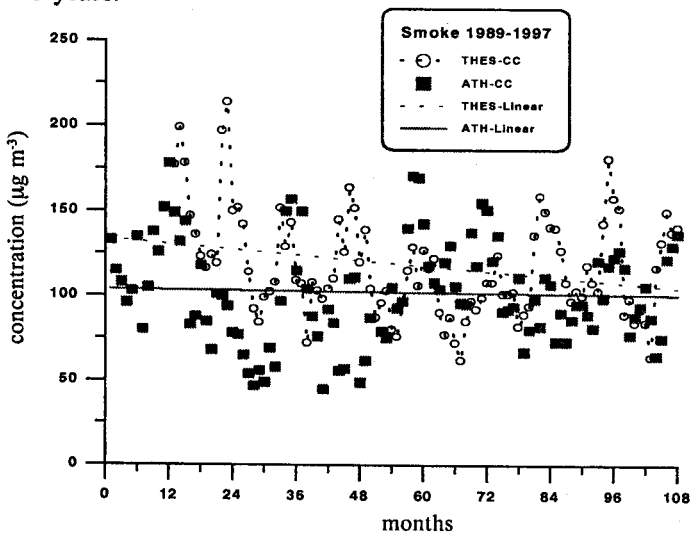

Fig. 3. Monthly values of the Smoke concentrations (μg m^{-3}), at the city center in the Athens and Thessaloniki area, for the observational period 1989-1997

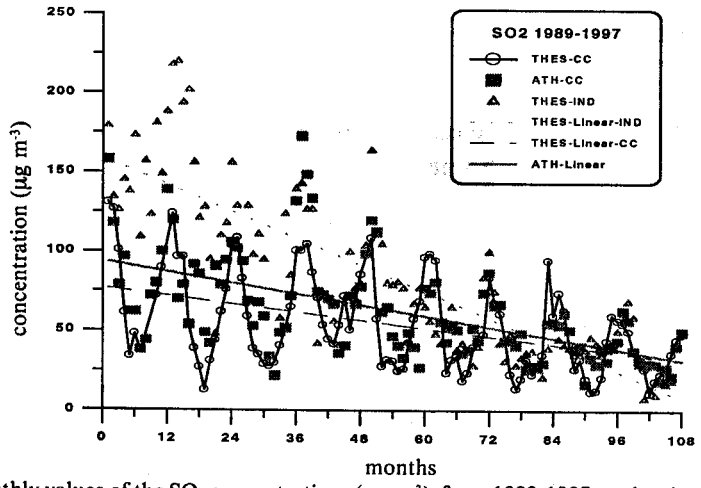

Fig. 4. Monthly values of the SO_2 concentrations (μg m^{-3}), from 1989-1997, at the city centers and an industrial area, in the region of Athens and Thessaloniki

As noted earlier, primary pollutant concentrations in Thessaloniki are of the same magnitude (or higher) than in Athens. The reason for these contrarieties can

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be partially explained by the differences in the meteorological conditions (wind speed and direction) and topographical features (Fig. 1) in the two regions. In addition the knowledge of the local flow fields which are indeed complex, since they are a combination of sea breeze, heat island and variable surface roughness, will assist in describing in more detail the transport and dispersion of the primary pollutants concentrations in the Athens and Thessaloniki basin.

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