PM10 EXTREME EPISODES IN WESTERN MACEDONIA: LOCAL EMISSIONS VS LONG RANGE TRANSPORT

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ABSTRACT

The current work focuses on the PM10 pollution extreme episodes in Western Macedonia, a heavily industrialized area in northwestern Greece. Three-years' period (2009 – 2011) PM10 concentrations and wind data from seven surface monitoring stations, covered an area of about 1500 km^2, were analyzed. The days in which the EU 24-h PM10 standard in all the above seven monitoring station was exceeded (extreme episode days) were selected and identified in relation to prevailing synoptic scale and local meteorological conditions. The results showed that the observed extreme episodes can be grouped into two separate categories: I) Long range transport of African dust and II) Regional anthropogenic emissions, under anticyclonic conditions. The analysis showed that the two categories occurred under different meteorological conditions resulting in the corresponding PM10 sources (long range transport and local emissions) not to contribute in the same time in the air pollution levels of the studied area. The higher percentage of the total episodes' days, which were observed, was attributed to regional anthropogenic emissions in this industrial area. However a considerable percentage (37%) of the episodes' days was attributed to long range transport, while the higher intensity's episode was found during the African dust intrusions.

Keywords: PM10 pollution episodes, industrial complex terrain area, long range transport

1. Introduction

Air Pollution Episode (APE) means a state of the ambient air environment in which the concentrations of air contaminants are elevated to or are in excess of certain defined levels and that certain meteorological conditions are expected to continue. These state can cause illness and death, this is why the APE's study is of special interest.

The air pollution episodes can be categorized according to the scale of the main source areas, i.e. those originating from regional and/or local emissions (RLE) and those coming from long-range transport (LRT). The RLE are usually caused mainly by stationary and/or mobile air pollutants' sources, while other incidents, such as the initialization starts of the industrial stacks or some random fire in rubbish dumps, can also be added in this category. The larger scale episodes are associated with both anthropogenic (e.g. Chernobyl Accident1986) and/or natural sources (e.g. Volcano eruptions). Additionally, in the category of LRT can be added the desert dust particulate matter, under the influence of which, the daily concentrations are augmented and often above the daily limits (Querol *et al*., 2009).

Regarding the atmospheric Particulate Matter (PM), large portions are derived from arid regions of the Earth and transported all over the globe (Shao *et al*., 2011). Saharan desert is responsible for up to half of the global mineral dust emissions, thus it is considered as the most important dust source worldwide. Particulate air pollution has serious impacts not only on human health, but also on the Earth's system (IPCC, 2007).Therefore, the meteorological conditions and the intensity of particulate air pollution episodes over an area, are considered necessary factors for the implementation of air quality and generally environmental management policies.

The aim of this study was the extreme PM10 air pollution episodes in a heavily industrialized area in northwestern Greece selection and the meteorological conditions favored these episodes investigation. For this purpose, the hourly PM10 concentrations during the period of 2009–2011from a monitoring air quality network operating in the area were used. More specifically, the data from seven monitoring stations covering an area of 1500 km^2, were analyzed. The objective was to identify high PM10 events, whereby simultaneous exceeding of the PM10 daily limit values occurred. Moreover, the relationship of the pollutants' concentration with the prevailing circulation, both synoptic and local scale, was investigated, since it is considered crucial for the forecasting of air pollution episodes (Triantafyllou, 2001; Flocas *et al*., 2009).

2. Site description

The area of interest is a mountainous complex industrial region located in the northwestern part of Greece, and specifically in the axis of Amyntaio – Ptolemais – Kozani basin (APKB). It is a broad, flat bottomed basin, encircled by tall mountains with heights ranging from 800 to more than 2000 m above Mean Sea Level (MSL). In the area there are also several lakes located in the south and north part of the basin. The climate is continental Mediterranean with high temperatures during summer and low ones during winter. APKB is a sloping terrain with NW/SE orientation and the prevailing wind in the center of the basin is blowing mainly from NW/SE direction due to channeling of the synoptic wind. In the area there are four lignite power plant stations (LPPS) of 4000 MW in total, which operate under the Greek Power Public Corporation (GPPC) (see Figure 1), producing the greatest amount of total electrical energy produced in Greece. Those lignite power plant stations are supplied with raw lignite as fuel from the nearby open-pit mines. The emissions arising from the excavation and transportation are also considered major PM emission sources. Environmental impacts in the wider region should also include operation of PS in the state of FYROM (PS6) (675 MW), which operates very close to the borders.

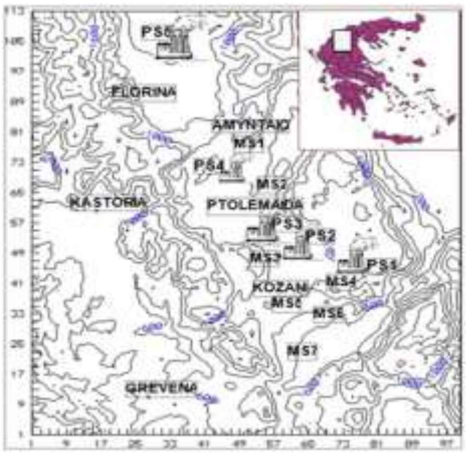

Figure 1: Topography in (m) of APKB.PS1-5 (power plants), MS1-7(monitoring sites).

3. Data and methodology

Hourly average observations from monitoring stations located at several locations were used. More specifically, hourly average values of wind speed (ws) and direction (wd), as well as PM10 concentrations were used from the air quality network of the Technological Educational Institution (TEI) of Western Macedonia and GPPC respectively. As extreme episodes were characterized these cases, in which the 24-h EU legislative limit (50μg/m^3) was exceeded simultaneously in the seven monitoring stations (these stations cover as mentioned above, an area of about 1500 km^2). For each day, local meteorological conditions and PM10 observations were analyzed in conjunction with synoptic surface pressure maps by MetOffice. NCEP synoptic pressure meteorological maps at 500 hPa and surface daily precipitation (mm/day), as well as omega forcing at 700 hPa (Pa/s), were also analyzed and retrieved by the Earth System Research Laboratory (ESRL) from the NOAA (http://www.esrl.noaa.gov/psd/).

4. Results and discussion

4.1. Extreme episode classification

The analysis indicated that the extreme PM10 episodes in APKB can be grouped into two individual categories: I) Long range transport of African dust and II) Regional anthropogenic emissions, under anticyclonic conditions. Table 1 depicts the extreme PM10 pollution episodes categorized by the above analyses, including their occurrence period and their duration in consecutive days. It is evident that 63% (29 out of total 46 days) are due to local anthropogenic emissions, while a considerable percentage of extreme episodes (37%) are due to long range transport. At this point it should be mentioned that the air pollution episodes in second category were observed in the same month (November) every other year (2009, 2011).

Table 1: PM10 extreme episodes observed in a three-year's period in APKB.

Cold(Nov., Dec., Jan., Feb.) Warm(Jun, July, Aug, Sep) Transient(Mar, Apr, May, Oct)	Category I (number of episodes/ total duration in days)	Category II (number of episode/total duration in days)	Total (episode/total duration in days)
Cold	3/6	2/29	5/35
Warm	2/9		2/9
Transient	1/2		1/2
Total	6/17	2/29	8/46

4.2. Typical cases

4.2.1.1st category-African dust episodes

African dust is transported to the eastern part of the Mediterranean with the eastward passage of surface frontal low-pressure systems (Querol *et al*., 2009). Most of the winter African dust episodes observed in the APKB were associated with a low pressure system in the gulf of Gabes moving eastward or with a surface deep low located in the central Mediterranean, the frontal of which extended from North Africa to Greece. A typical case is presented in 20 February 2010, when dust intrusions were recorded in Greece (Figure 2a, Figure 2b). During the summer and spring cases, African dust were recorded in Western Macedonia in a three-year period when warm advection was observed in the lower troposphere.

4.2.2. 2nd category- Anticyclonic circulation

Regarding the PM10 pollution episodes in the 2nd category, they occurred under stagnant anti-cyclonic systems over Balkan Peninsula and Greece area (Figure 2c), which dominated all southeastern Europe and forbidden the general upper circulation by producing a jet stream (Figure 2d). Long in duration, both adverse meteorological conditions lasted eight and twenty days respectively, and as a result, poor ventilation and dispersion conditions were evidenced.

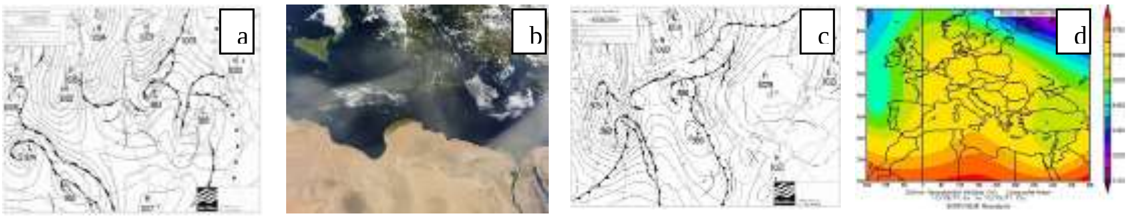

Figure 2: a),c) Synoptic surface maps during African dust and anticyclonic circulation episodes at 20/02/10 and at 19/11/11 respectively, b) satellite image during African dust intrusion at 20/02/10 and d) Geopotential heightmapin 500 hPa at 19/11/11.

4.3. Episodes' comparison and contribution

Figure 3a, 3b depicts the diurnal variation of concentrations and local winds in a typical 1st category episode (20 February 2010) and during the 2nd category at (14 to 16 November 2011). In the 1st category, the variation of concentrations follows that of the winds, while, on the contrary, in the 2nd category, the concentrations and local winds follow a different opposing variation. More particularly, it is noticeable the simultaneous peak of PM10 concentrations and wind speed that is evident in the 1st category and during its duration the wind speed in the center of the APKB (MS5, see Figure 1) reaches 15 m/s from south directions, while the PM10 concentration at the same time is 700 μg/m^3 (Figure 3a). In contrast, the 2nd category illustrates that during the 14th of November the wind is strong and the PM10 concentrations are kept in moderate levels, while, as the wind weakens, a gradual increase of the PM10 concentrations is observed. Similar variation trend were recorded in all monitoring sites for all the episodic days, classified in the two categories. Figure 3c and Figure 3d depict the mean intensity and its standard deviation for each category in the seven monitoring stations of APKB, where intensity is defined the quotient of the measured PM10 concentrations with the 24-h EU limit of 50 μg/m^3. It is apparent that the mean intensity is higher in the category I (LRT African dust) and equal to 1.71 ± 0.88, while in the category II (anthropogenic emissions under stagnant anti-cyclonic systems) the mean intensity is significantly lower (1.40 ± 0.57).

5. Conclusions

The extreme PM10 pollution episodes in Western Macedonia were investigated for a three-years' period. The analyses included hourly surface measurements from seven monitoring stations of PM10 in conjunction with wind speed and direction, as well as synoptic surface and upper pressure maps and satellite imaginary. As an extreme episode was defined the day or days in which a simultaneous exceed in the 24-h limit value was recorded in all monitoring stations in an area of about 1500 km^2. From the analyses two categories emerged, 63% of which is due to regional anthropogenic emissions, while the remaining 37% is due to LRT African dust. The two categories occur under different meteorological conditions, which are also confirmed by the PM10-local wind variations, indicating that PM10 and winds have a similar variation pattern in the category I and opposite variation in category II. Finally, the episode's intensity was found higher during African dust intrusions than local-regional anthropogenic emissions.

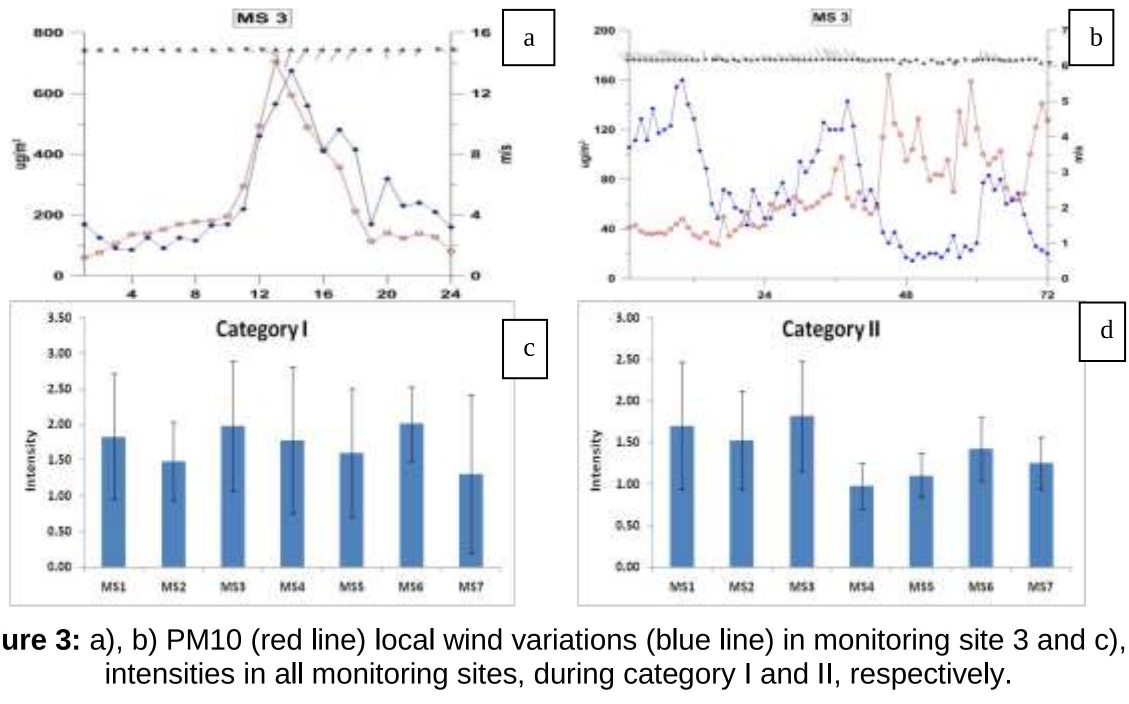

Figure 3: a), b) PM10 (red line) local wind variations (blue line) in monitoring site 3 and c), d) intensities in all monitoring sites, during category I and II, respectively.

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