PHENOMENOLOGICAL INTERPRETATION OF PM_{10} EPISODES OCURRING IN THE METROPOLITAN AREA OF PORTO

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ABSTRACT

At present, 15 monitoring stations are in regular operation in the metropolitan area of Porto in the Northern region of Portugal. The analysis of the data-sets of PM_{10} concentrations indicates that there is a systematic exceedance of air quality standards, either of the daily and yearly averages for a significant number of stations. Exceedances occur at all types of stations independently from being traffic-monitoring or background. Results obtained up to the moment indicate that PM_{10} episodes are a combination of several factors dominated by traffic and local emissions, background concentrations and thermal inversions.

1. INTRODUCTION

Operational air quality monitoring provides an invaluable resource to assess the temporal and spatial variations in PM_{10}. The assessment of PM_{10} data measured at the stations located in the region of Porto reveals the existence of a PM_{10} contamination problem, demonstrated with existing 24-hour levels that frequently exceed the respective limit value.

Air quality monitoring at these stations, and the results presented in this paper, should not be seen as an end in themselves; rather they offer us the best way of understanding our pollution problems, so they can be tackled effectively at local, national and international level.

2. METHODOLOGY

This paper focuses on the study of the phenomena affecting PM_{10} levels of non-compliant air quality monitoring stations in the Porto region. Time series of PM_{10} recorded in 2002 are interpreted to access the role of local, regional and distant sources in PM levels in this region. The influence of meteorology on PM_{10} levels recorded at various traffic and background stations is studied by interpretation of statistical correlations, the analysis of the influence of meteorological variables and periodical cycles.

3. RESULTS AND DISCUSSION

In the assessment carried out for the metropolitan area of Porto in 2002, the 24-hour limit value (LV) for PM_{10} suspended particles (50 $\mu g.m^{-3}$) plus the margin of tolerance (15 $\mu g.m^{-3}$) was exceeded beyond the number of times allowed (35) during each year. The annual LV for human health protection (40 $\mu g.m^{-3}$), plus the margin of tolerance (4,8 $\mu g.m^{-3}$) was also exceeded. After this diagnostic it is important to carefully analyse PM_{10} behaviour using the air quality and meteorological data available.

Pollutant correlation

From the analysis of the correlations obtained between PM_{10} and other pollutants measured on those same days it is possible to divide the network stations into two groups, considering the behaviour of PM_{10} atmospheric levels:

- Group 1 (3 stations): Correlation with CO and NO_X over 45%; Counter correlation with O_3; Nocturnal PM_{10} concentrations tend to be higher then the diurnal values; PM_{10} concentrations will be influenced by direct traffic emissions. These stations are located in sub-urban areas and are classified as background stations of the Porto monitoring network.
- Group 2 (4 stations): Correlation with CO and NO_X below 45%; PM_{10} is not correlated with O_3; PM_{10} variations do not present a constant daily pattern; Low correlation with SO_2; Traffic is not the only direct contributor to PM_{10} levels; Secondary emissions from dust resuspension may be equally important. These 4 stations are located in the central area of Porto and are classified as urban stations.

Daily and seasonal cycles

In order to understand the phenomenon that are likely to cause high levels of PM_{10} recorded in the Porto region, it is important to interpret the evolution of PM_{10} 1-hour averages at the stations belonging to the network.

Figures 1 shows the evolution of 1-hour average PM_{10} concentrations for both types of stations (traffic and background), each of these belonging to one of the groups mentioned above. Results are plotted for 2 different months of the year: January (winter) and July (summer).

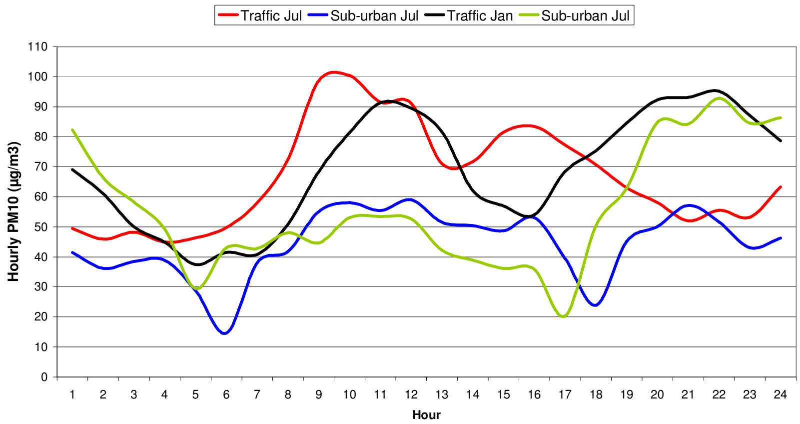

Figure 1 - Evolution of 1-hour average PM_{10} concentrations for a traffic and for a background (sub-urban) monitoring station in January and July 2002.

Figure 1 illustrates the influence of traffic during a normal summer month (emissions and resuspension) on hourly concentrations at a traffic station (Antas), where higher concentrations are observed during the day when road traffic increases. The background station (Leça do Balio) presents two concentration levels: a first level from 8 a.m. to 3 p.m., followed by a slight reduction from 4 p.m. to 5 p.m., and a new level from 6 p.m. to 2 a.m.

A similar behaviour is observed during winter months, with higher PM_{10} concentrations at the traffic station occurring with traffic increase during the day, but also nocturnal peak concentrations at both type of stations (usually exceeding 80 $\mu g.m^{-3}$), possibly as a consequence of meteorological phenomena and local emission sources.

Natural contributions

Considering the localization of the traffic stations that make up Group 2, it is possible that a decisive factor in measured PM_{10} levels and high number of exceedances occurred in 2002 may either be dust resuspension from soil due to wind or turbulence generated dust from passing traffic (Chaloulakou, *et al.*, 2003). Several monitoring stations in Porto had been under the strong influence of construction works in their proximity throughout 2002.

To confirm this assumption, a study to test dependencies of PM_{10} levels with wind speed and relative humidity (RH) was performed. Stronger winds lead to greater land erosion and consequent scattering of dust accumulated near large construction sites. Although admitting that the existence of a strong correlation with wind speed would be an indication of local sources, this assumption was not confirmed since the assessment of the data revealed that there wasn't any significant correlation with wind velocity.

With respect to correlation with relative humidity (Figure 2), a slight correlation can be observed although not significant from a statistical point of view:

- When RH is higher then 80% there are few situations where the 1-hour average PM_{10} concentration exceeds 150 $\mu g.m^{-3}$;
- PM_{10} concentrations over 200 $\mu g.m^{-3}$ only occur when HR is lower then 50%;
- When RH is lower than 20% the PM_{10} concentration is always higher then 50 $\mu g.m^{-3}$.

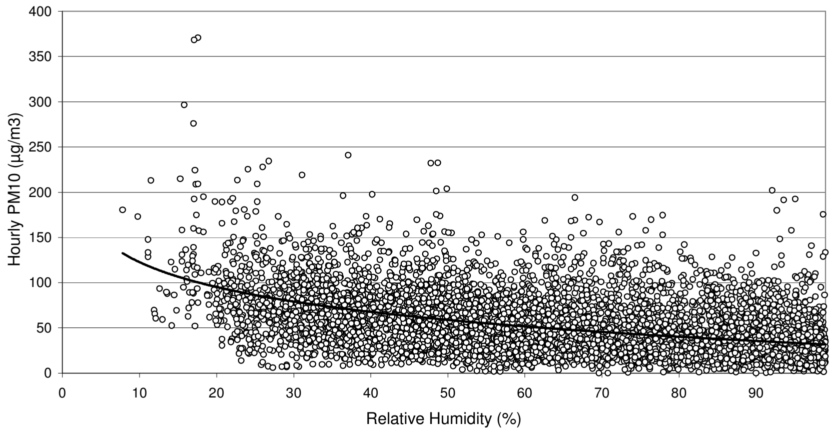

Figure 2 – Correlation between PM_{10} levels measured at a traffic station (Sr^a da Hora) and relative humidity.

The possibility of occurring natural contamination with mineral dust is equally important to study at larger spatial scale. In fact, one of the most pointed out causes for the occurrence of natural dust particle episodes in southern Europe, and in particular in the Mediterranean basin, has been airbourne dust carried from northern Africa (Sahara and Sahel deserts). Long-range transport of Saharan dust events has been described in previous studies (Artiñano *et al*., 2003; Dordević *et al*., 2004; Rodríguez *et al*., 2001). This scenario might be responsible for extraordinary peak situations. However, an increase of background levels may occur every time air masses are originated form the inner peninsular or northern Africa.

Pollution roses considering 10 m height wind direction were built for each air quality station. As an example, the S^{ra} da Hora station pollution rose for 2002 in presented in Figure 3. This pollution rose reveals the presence of a marked sector, where higher concentrations characterise the air arriving from the East (99th percentile is 180 µg.m^{-3}). In average terms, a more marked effect is observed in the presence of East-Southeast winds, where PM_{10} average levels rise to 90 µg.m^{-3}. This suggests the existence of long range dust transport, namely Saharan dust.

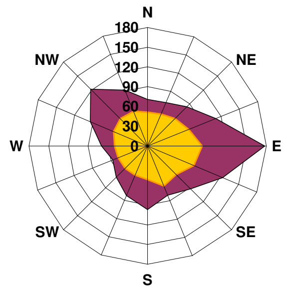

Figure 3 – PM_{10} pollution rose (average (yellow) and 99th percentile (bordeaux)) for Sr^a da Hora, with 10 m height wind direction.

The possible contribution of sea spray to the increase of particle levels in the Porto region can equally be assessed with the study of pollution roses. Figure 3 reveals yet another marked sector for peak levels with Northwest wind (99th percentile is 120 µg.m^{-3}). This NW peak clearly corresponds to the presence of sea air masses.

Thermal inversions

The innumerable PM_{10} exceedances occurred on cold winter days can be associated with the thermal inversion phenomenon, which occurs mainly in large urban centres, e.g. Madrid (Artiñano *et al*., 2003). Figure 4 assesses the correlation between hourly PM_{10} concentrations registered from January to March 2002, at a background station (Leça do Balio) and the temperature gradient, obtained from modelling, for the layer between ground level and an altitude of 200 m. The importance of atmospheric stability in episodic PM_{10} contamination phenomenology is quite clear. It is evident that at all situations where concentrations over 150 µg.m^{-3} were observed, occurred in stable circumstances, when temperature gradient was greater then -1ºC/100 m.

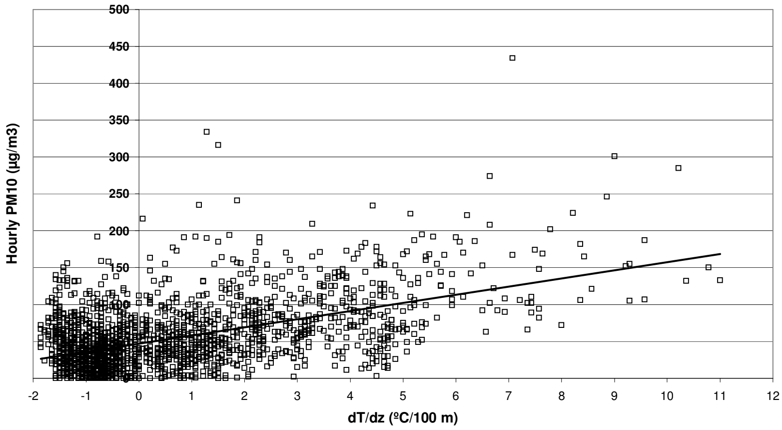

Figure 4 – Dispersion of atmospheric PM_{10} in the presence of thermal inversion.

It must be pointed out that this interpretation not only shows the importance of the vertical structure of the low troposphere in the dispersion of atmospheric pollutants, but also the contribution that surface emitting sources, probably of non-industrial origin, are able to have on the degradation of air quality.

4. CONCLUSIONS

One of the consequences of this study was to demonstrate the regional nature of this phenomenon. PM_{10} levels increase simultaneously at the various stations of the monitoring area, although the correlation study performed with other pollutants revealed 2 different groups. In any case, road traffic makes up as one of the main emission sources of this atmospheric pollutant during summer months. At some of the stations there are indications that particulate matter resuspension originated from passing traffic has an equally significant role. During winter, meteorological conditions, like the presence of a strong surface thermal inversion at the beginning of the night, will be able to contribute to an increase of PM_{10} atmospheric levels, even in the presence of small local sources.

The methodology applied in this study intended to separately evaluate the influence of various factors on the increase of PM_{10} levels. However, it must be taken into consideration that some of the studied phenomena occur simultaneously. An example of this situation is the East wind winter episodes that are coincident with low temperature and low RH and strong temperature inversions. In this case, while geological content of particulate matter is increased, particle resuspension is fomented and simultaneously limited atmospheric mixture occurs. This is an example of eventual synergistic effects that make it difficult to identify a unique responsible for the identified exceedances.

5. ACKNOWLEDGMENTS

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