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AIR QUALITY NEARBY MOTORWAYS: DEVELOPING NEW MONITORING METHODOLOGIES

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ABSTRACT

A study has been carried out to evaluate the air quality impact of the motorway '*A2 South*'' that links Lisbon to Faro in Portugal. The monitoring of atmospheric pollutants with the use of two simultaneous measurement methods (indicative and continuous measurements) was one of the strategies to evaluate the conformity with the air quality legislation. This paper gathers the results obtained in two air quality monitoring campaigns. Four sampling points located along three sections were selected. Several pollutants were measured under different sampling methodologies. Meteorological and traffic data were also collected. High level concentrations of particles were found close to the motorway toll booths, and benzene seems to be the best descriptor to evaluate the impact on air pollution.

Key Words: Motorway air emissions; air quality monitoring; indicative and continuous measurements; traffic measurements; pollutants dispersion.

1. INTRODUCTION

Air pollution represents one of the biggest threats to public health and ecosystems. The fast technological progress of the modern world brought an increase in the amount of pollutants deposited in the atmosphere, harming in a very serious way the quality life of our planet (Castro *et al.*, 2003). The pollutants emitted by traffic and the consequent effects in public health are assuming a larger relevance. That has been verified by epidemiological studies developed in different capitals and cities in order to establish relationship patterns with air quality (Castro *et al.*, 2003).

The transport sector is also one of the most important sources of greenhouse gases like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). It is also responsible by the emission of pollutants associated with transboundary transport such as sulphur oxides (SO_x), nitric oxides (NO_x), carbon monoxide (CO), and nonmethane volatile organic compounds (COVNM) (Borrego *et al*. 2002). This activity also brings substantial emissions of particles and heavy metals (Eggleston *et al.*, 1989).

The turbulence induced by traffic circulation is a determinant factor in the dispersion of pollutants in the vicinity of roadways (Rao *et al.*, 2002). Vehicles contribute for

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the degradation of air quality, essentially through the emission of CO, hydrocarbons (HC), NO_x and particles (Mihau and Boulhol, 1990). Once introduced in the atmosphere, pollutants are transported by the wind and diluted under a dispersion process. In many cases, a chemical transformation or deposition can also occur. Monitoring emissions from line sources has increased in the last years in order to make possible to establish relations between the deterioration of air quality and the increment in the number of vehicles (Hansel *et al.*, 2004).

Pollutants concentrations depend on many parameters and change considerably as a function of the atmospheric conditions, mainly wind. In roadways, pollutants are randomly emitted since traffic volume and speed are dependent on the human behaviour. Thus, these two practically independent factors define the environmental impact of the roadway (Murgel *et al.*, 1997). However, the methodology of continuous measurements is associated with a very high cost and a constant operational activity and logistic, only promoting the control of the area where the monitoring station is installed (Murgel *et al.*, 1997).

The air quality in Portugal is known mainly from the data collected in monitoring stations predominantly located in the great urban areas (areas of traffic influence), and in some industrial areas, but also through multiple environmental impact assessment studies (Ferreira *et al*., 2001).Moreover, numerical air quality modelling is contributing to the evaluation of the national air pollutants levels and distribution (Monteiro *et a*l., 2005).

The *A2 South* motorway is characterized for being one of the first existing projects in Portugal within the new environmental impact evaluation regulations where assessment goes behind construction. The objective of this study was to evaluate the traffic impact in the air quality in three sections of the "A2 South".

2. THE CASE-STUDY OF *A2 SOUTH* MOTORWAY: AIR QUALITY EVALUATION METHODOLOGY

Three main sections of the A2 South (sections Castro Verde / Almodôvar, Almodôvar / S. Bartolomeu de Messines and S. Bartolomeu de Messines / Via Longitudinal do Algarve - VLA) were studied using two measurement-monitoring methodologies. Four sampling locations were selected: Castro Verde, Gomes Aires, Paderne, and VLA. The campaigns took place between March 8 and April 12, 2004 (1^{st} campaign), and between June 28 and July 26, 2004 (2^{nd} campaign). Nitrogen dioxide, ozone (O_3), SO_2, particles, CO, and benzene (C_6H_6) were measured under different sampling methodologies.

The studied roadway has a peculiar characteristic meant for intense traffic peaks associated with the seasonal affluence increase since it bridges a connection to a very required tourist area (Algarve Region). Daily mean traffic of about 7 000 vehicles, and in peak days around 26 000 vehicles, were identified during the campaigns.

The campaigns implied the continuous measurement of gases and particles, and the weekly averaged concentrations of SO_2, NO_2, O_3 and C_6H_6 with diffusion sampling tubes placed at some particular points, previously chosen. Also, meteorological parameters were simultaneous measured due to their influence in the dispersion of atmospheric pollutants, namely wind speed and direction, rainfall, temperature and humidity . The meteorological station was always placed in the same location where pollutants were monitored - in the vicinity of the SNIF - AIRLAB (mobile laboratory of the Universidade Nova de Lisboa - Figure 1), and close to the places where the indicative measurement with diffusion tubes was taking place.

Figure 1: Aspects of the interior and exterior of the mobile laboratory - SNIF AIRLAB and its measurement equipment

The rank of diffusion tubes at different distances of the berm and at both sides of the roadway, aimed to provide a better understanding of the dispersion pattern of the pollutants along those areas (Figure 2).

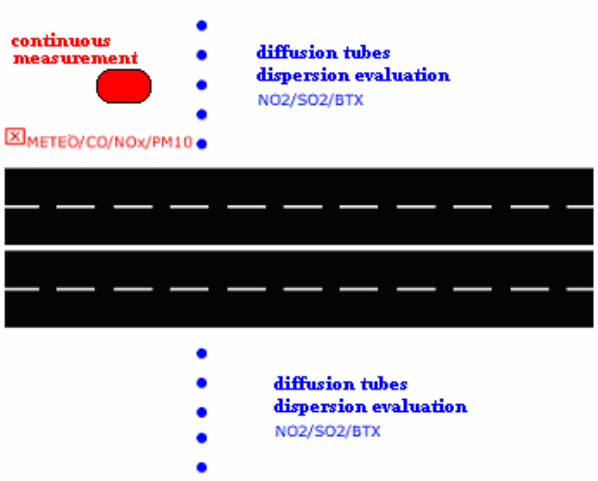

Figure 2: Project of installation of the measuring equipment and SNIF Lab.

2.1 Gases Sampling

The monitoring of pollutant gases was made using passive Radiello® diffusion tubes for the sampling of SO_2, NO_2, BTX (benzene, toluene, and xylene) and O_3. Toluene and xylene are pollutants not currently legislated in terms of air quality. This equipment allows the collection of an integrated pollutant sample for one determined period of exposure. The result corresponds to the average concentration for the chosen period of exposure. The exposure time of the diffusers in the sampling points was one week. Diffusion tubes were used in Paderne (close a major toll booth), and Gomes Aires.

CO and NO_2 were measured using a chemiluminescence continuous measurement technique with integrated average concentrations of fifteen minutes, which were compiled in hourly average values. For CO, taking into account the legislated eight-hours base averaged value, this integrated period was used to allow a comparison with the air quality limit value foreseen in the Decree-law n.º 111/2002 of April 16.

2.2 Particle Sampling

The monitoring of particles was carried through a continuous beta radiation instrument. The Decree-law n.º 111/2002, in its Annex XI (Section IV), indicates that the method of reference for sampling and measuring of particles PM_{10} is the one described in the European norm EN 12341. This norm considers the gravimetric method as the reference method. However, this legislation allows the use of other methods if demonstrated that their results are equivalent to the ones of the reference method. Therefore, a correction factor of 1.18 to the PM_{10} collected data (correction factor for traffic stations) was applied on the basis of inter-comparison studies performed by the Portuguese Institute of the Environment. Average concentrations of fifteen minutes were collected and integrated as hourly average values. Since the legislation establishes daily and annual limit values, the hourly data were then integrated on a daily basis to aim the respective comparison with the Decree-law n.º 111/2002 of April 16.

2.3 Meteorology

The meteorological conditions influence the concentration and the distribution of the atmospheric pollutants; therefore, the measurement of the meteorological parameters was performed in all sampled locations. A portable meteorological station measuringwind direction and speed, rainfall, temperature, and sun radiation, was used for this purpose.

3. RESULTS FROM CONTINUOUS AND INDICATIVE MEASUREMENTS

The results obtained were compared with the current legislation. The comparison was made with the legislative values for the year 2005 (Limit value - LV and/or Limit value + Margin of Tolerance - LV + MT), assuming different time bases (hourly, octo-hourly, daily or annual), depending on the pollutant. Measured data were compared with the designated values (in bold) in Table 1.

Table 1: Limit-values or Limit-values + Margin of Tolerance used for comparison of results

polutant	temporal base	limit value (µg/m3)	tolerance value 2005	final value 2005
PM_{10}	µg/m³ (Diário)	50µg/m³*	-	50µg/m³
PM_{10}	µg/m³ (Anual)	40µg/m³*	-	40µg/m³
NO_2	µg/m³ (Horária)	200µg/m³**	50µg/m³	250µg/m³
NO_2	µg/m³ (anual)	40µg/m³**	10µg/m³	50µg/m³
CO	mg/m³ (Octo-horária)	10 mg/m³	-	10 mg/m³
SO_2	µg/m³ (Diária)	125 µg/m³*	-	125 µg/m³
C_6H_6	µg/m³ (Semanal)	5µg/m³**	5µg/m³	10µg/m³

*2005
** 2010

Figures 3 and 4 present the measured PM_{10} values in Paderne and Castro Verde locations.

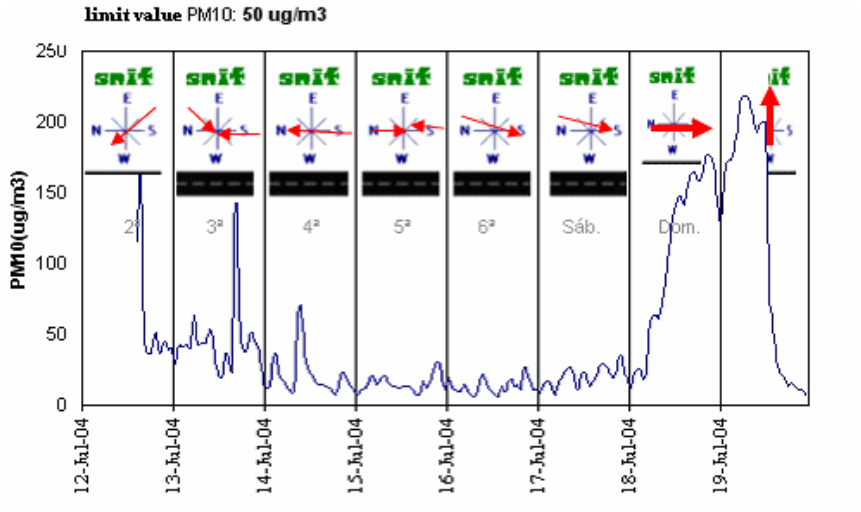

Figure 3: PM_{10} concentrations - Paderne (2nd campaign)

It was verified that PM_{10} concentrations measured during the 2nd campaign rose significantly during a weekend period. In order to evaluate the results, PM_{10} data from the two closest background monitoring stations were used. A natural event due to the wind transport of particles from the Sahara desert was identified as the cause for such high levels.

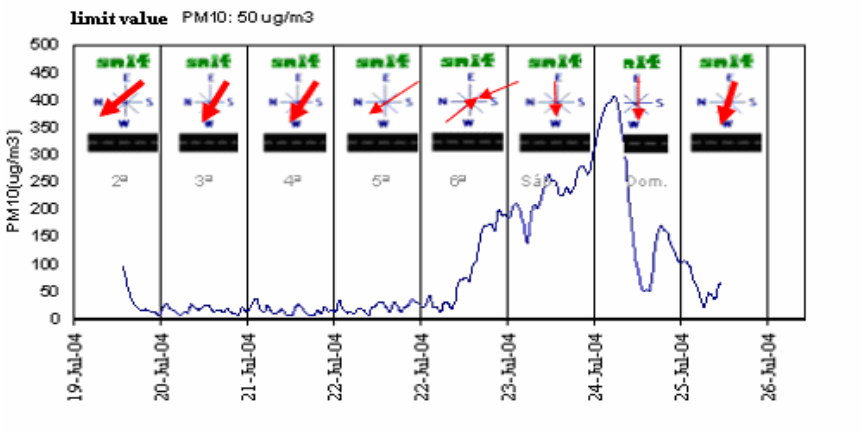

Figure 4: PM_{10} concentrations - Castro Verde (2nd campaign)

The air quality monitoring stations chosen to make the comparison were Pontal (background urban station - Portimão) and Chamusca (backgroung rural station - Chamusca). Figure 5 presents the hourly-averaged PM_{10} values for these three monitoring sites.

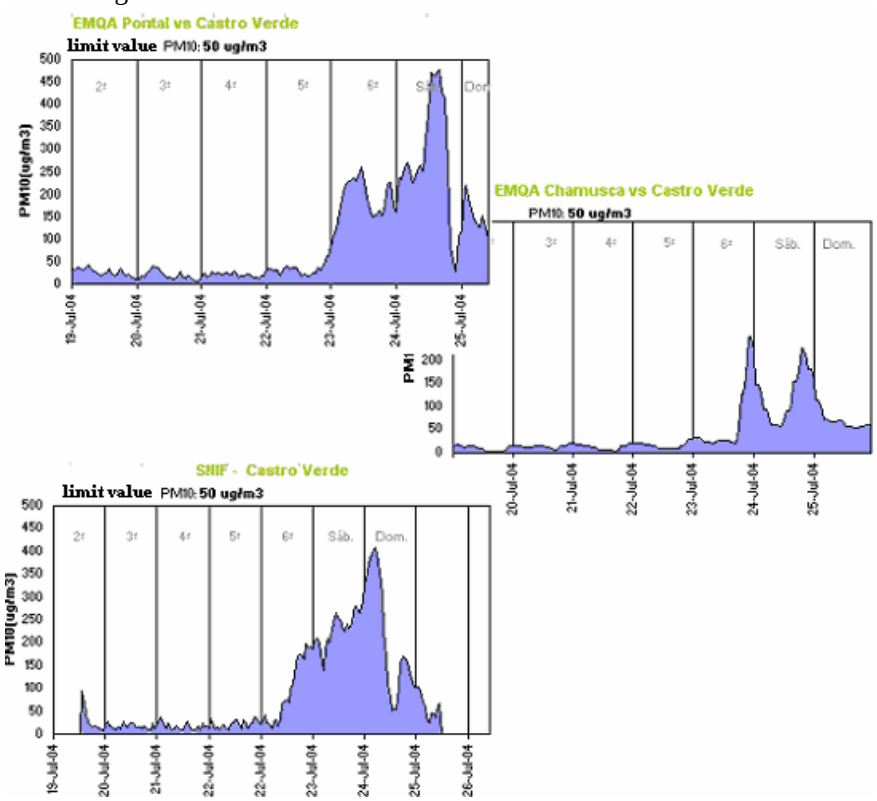

Figure 5: Hourly averaged concentrations of PM_{10} in the Pontal, Chamusca andCastro Verde monitoring sites (2nd campaign)

By the analysis of the data, it can be concluded that the high concentrations during the sampling period (through the AIRLAB) were mainly due to a particles event, given the similar levels and trends found in these monitoring stations (Figure 5).

However, by the analysis of traffic data during the peak dates, traffic hourly average values (TMH) were very high (maximum TMH of 2290 vehicles - Saturday) and that should have also contributed to the higher particle's level.

The C_6H_6 weekly averaged concentrations, in both campaigns, can be observed in Figure 6.

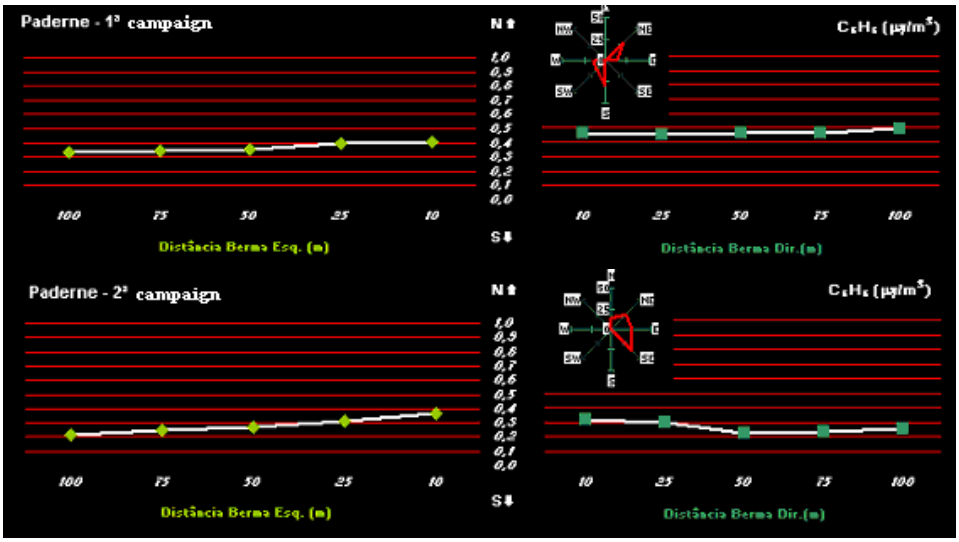

Figure 6: C_6H_6 weekly averaged concentrations in Paderne.

The values collected for C_6H_6 remained low and are similar for the two campaigns, although slightly higher in the 1st campaign. Tendentially, a decreasing pattern is verified from the road to both sides, with exception of one point. A direct comparison with the legislation is not possible because benzene concentrations correspond to weekly averages and not annual averages.

4. DISCUSSION

In general, the values obtained along the two campaigns for all the pollutants were low. For the SO_2, NO_2, O_3, and C_6H_6 gases referring to weekly averages (through indicative measurement - diffusion tubes), it was confirmed that during the accomplishment of the two campaigns in the four monitored points, the measured concentrations were very low. The NO_2 and CO continuous monitoring also registered low values of concentration.

Relatively to the obtained results through the diffusion tubes, for NO_2 and SO_2, it was not possible to obtain a linear pollutant dispersion behaviour with the distance

to the road. The reduced measured concentrations of pollutants and the wind variable conditions can explain this not linear trend.

The C_6H_6 values presented a decreasing linear dispersion behaviour and larger expression until 50m distance from the road.
By the application of different methodologies involving a detailed analysis of the evolution of the pollutants concentration and their relationship with background stations located in other locations of the region, two critical points (Paderne and Castro Verde) were identified with higher levels of PM_{10}. These occurrences were directly related with the increase of the vehicles traffic circulating in those sections and with a natural event that brought Sahara dust to the monitored area. Meteorological conditions marked by major occurrences of calm situations during the respective sampling periods also determined the levels found.

Results gave evidence that diffusive samplers may overestimate the concentration values when compared with continuous measurement. This occurs when very low concentrations are measured. Knowledge about the traffic counts for the campaign periods allowed a better explanation of the motorway impact in terms of air quality, through the relationship established with certain observed peaks.

For particles, an analysis of the ratio between the number of daily excedances of the limit-value and the number of sampling days during both campaigns, allowed to extrapolate that the 35-excedance days permitted annually would be probably overtaken.

Regarding the measurements of CO in the four points of sampling and for both campaigns, very low concentrations values, in 0.2 $mg.m^{-3}$ order (octo-hourly secular base), were observed, with little significant variations in the different cited points. The behavior of this pollutant to the level of its secular distribution, presents in general, a common profile in relation to the increase of its values during the period of weekend, in particular, Friday and Sunday night, probabily because of the addition of traffic typically associated to these days of the week in this roadway.

In relation to NO_2, very low values of concentration had also been observed, with a maximum of 18.0 $\mu g.m^{-3}$, as an average of the measured concentrations in the point of the VLA (countinuous monitoring), quite below the threshold value for the protection of human health (250 $\mu g.m^{-3}$ - hourly base). Concerning the weekly averages of this pollutant (passive sampling monitoring), measured values in general were higher than those acquired through the continuous measurement. When compared with the respective legislated annual value base (50 $\mu g.m^{-3}$ for year 2005) all values are below the legislated targets.

The highest weekly average concentration of SO_2 occurred at Castro Verde, reaching 9.1 $\mu g.m^{-3}$, which should be considered as an outlier when compared with the other collected data, but still well below the daily limit-value of 125 $\mu g.m^{-3}$. It was mentioned that the variations in the concentrations between sampling campaigns are not significant. However, distinct orders of magnitude are observed considering the

two sampling locations (Paderne and Castro Verde). The concentrations of SO_2 in the Paderne point are similar to the background concentrations existing in the region.

In respect to ozone, this pollutant was measured only in places 100 m far from the road (in locations Paderne and Castro Verde). The existence of this pollutant near the roadway is not directely associated with the traffic road circulation: its formation is dependent on other factors such as the solar radiation or the existence of precursor pollutants that may have distinct sources. Therefore, it is probable that the concentrations registed are in fact background concentrations characteristic of this region for that time of the year.

5. CONCLUSION

The monitoring air quality data of the *A2 South*, only indicates potentials problems of particulate atmospheric pollution, because the high level concentrations measuredclose to the motorway toll booths that should be associated, more than to the PM_{10} direct emission through the vehicles exaustion, to the ressuspension related with the vehicles circulation and to the occurrence of natural events, namely the long distance transport of particles from North of Africa. Benzene seems to be the best descriptor to evaluate the impact on air pollution.

6. ACKNOWLEDGMENTS

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