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AIR QUALITY MONITORING – ESTABLISHING CRITERIA FOR STATIONS CLASSIFICATION

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ABSTRACT

According to the Council Decision 97/101/EC on Exchange of Information, stations should be classified in relation to the type of area where they are located and according to the type of dominant emission sources influencing the air pollutant concentrations at the station.

A detailed methodology was developed for the validation of the classification of Portuguese air quality monitoring stations, through objective criteria to assure a harmonized interpretation of the definitions, from region to region.

In relation to the criteria for area types, best results were found for the population density within a 1km radius in the surroundings of each station. In relation to dominant emission sources, were pointed out criteria based upon several pollutants concentrations.

Key Words: Air Quality, Monitoring, Stations Classification, Emission Sources

1. INTRODUCTION

In the Eighties and Nineties the assessment of air quality within European Members States was based on networks of air quality monitoring stations established according to their specific realities.

More recently, in the Council Directive 96/62/EC of 27 September 1996, was considered necessary to establish a procedure for the exchange of information between the Member States on air quality, in order to help combat pollution and nuisance. That Directive established the framework for assessment and management of ambient air quality on the basis of common methods and criteria. In the so-called Daughter Directives can be found other criteria related with classification and location of sampling points. The Commission Decision 97/101/EC, of 27 January 1997, brought the concept of harmonization to exchange of information and data on ambient air quality in the European Union.

The Portuguese air quality monitoring network includes 73 stations (operating in 2005) managed by regional authorities.

In 2000 and 2001 the Environmental Institute in cooperation with the Faculty of Sciences and Technology of the New University of Lisbon collected information about the meta-information of all the national network stations, in each location (available in a data base at www.qualar.org). After these visits, were performed some adjustments to the stations classification according to the specifications set in the recent legislation. For the most recent stations have been accepted the classifications given by regional authorities.

However, some issues had been raised: there is a necessity of using common criteria to uniformize the process of stations classification; the definitions established on the Commission Decision 2001/752/EC are too vague; and several doubts remained after applying the referred definitions to the existing stations.

All those issues pursuant the development of this study, that aimed to validate and clarify air quality monitoring stations classification, through objective methodologies based upon a common procedure that assure a harmonized interpretation of the definitions, from region to region, in compliance with European legislation. The stations classification must obey to a set of common rules in order to increase the compatibility and comparability of the data transmitted

According to the Annexes of Council Decision 97/101/EC on Exchange of Information, as revised by Commission Decision 2001/752/EC of 17 October 2001, air quality monitoring stations should be classified in relation to the dominant emission sources influencing the air pollutant concentrations at the station:

- Traffic - located such that its pollution level is determined predominantly by the emissions from nearby traffic (roads, motorways, highways);
- Industrial - located such that its pollution level is influenced predominantly by emissions from nearby single industrial sources or industrial areas with many sources;
- Background - located such that its pollution level is not influenced significantly by any single source or street, but rather by the integrated contribution from all sources upwind of the station;

and according to the area type where they are located:

- Urban - continuously built-up area;
- Suburban - largely built-up area: continuous settlement of detached buildings mixed with non-urbanised areas (small lakes, woods, agricultural);
- Rural - all areas that do not fulfil the criteria for urban or suburban areas are defined as rural areas.

Two distinct methodologies were identified to validate the stations classification in relation to dominant emission sources and in relation to the type of area.

2. METHODOLOGY

2.1. Validation of air quality monitoring stations by type of area

The validation of stations classification by type of area is based on criteria that allow distinguishing the Urban, Suburban and Rural classes of stations.

All the 51 monitoring stations operating in Portugal in 2003 were considered in the study.

According to the Guidance on the Annexes to Decision 97/101/EC on Exchange of Information as revised by Decision 2001/752/EC (or in short the Guidance on the Annexes), the definitions of area types are based on the distribution/density of buildings. However other elements such as population density, size of the area and land-use information can be taken into consideration when classifying the area in particular for "limit" cases (European Commission - DG Environment, 2002).

Population density in the surrounding area of the station was used as indicator. To verify the classification of the stations some indicators, related with Portuguese territorial administrative levels, were tested. The *freguesia* is the smallest Portuguese territorial administrative unit. It is divided in small statistic areas - the statistic sections and sub-sections - for demographic purposes. The statistic sub-section is the smallest homogenous area within the *freguesia* and corresponds, for example, to the block in urban areas. Thus, three indicators were tested: population density in the *freguesia* where each station is located; population density in the statistic sub-sections; and population density in the circular area of 1 km around the station, based on the smallest territorial unit the statistic sub-section (best results were found for this last indicator).

The following steps were applied:

- get the geographical localizations of all the stations;
- define a circular area with 1 km radius around each station;
- select the statistic sub-sections that are included (or have the majority of their area included) in the circular area with 1 km radius around the station;
- sum the populations and the areas and calculate the respective population densities within the circular area of 1 km radius around each station;

- define limits of population densities that allow distinguishing each one of the three area types (Urban, Suburban and Rural).

Once this methodology is applied it as to be verified, at last, in which of the three intervals fits the population density in 1 km radius around the station, and consequently which is the type of area of the station – Urban, Suburban or Rural.

To distinguish each typology of area types were established limits of population density:

- Rural areas were established as those with a population density less or equal to 500 inhabitants/km^2;
- Suburban areas were established as those with a population density between 500 and 2000 inhabitants/km^2 (or between 500 and 3000 inhabitants/km^2) – once an objective criterion does not exist to distinguish the Urban and Suburban typologies, those two limits were tested and were the ones that fit better to the pre-existing classifications;
- Urban areas were established as those with a population density greater then 2000 inhabitants/km^2 (or greater then 3000 inhabitants/km^2).

For the cases with population density between 2000 and 3000 inhabitants/km^2 the knowledge of the technician of the regional authorities is essential to decide which typology is the most appropriate.

The density population data was obtained from the "2001 Census – XIV Population General Census" (INE, 2001). A Geographical Information System software was used - the ArcGIS 8.3 from ESRI® Arc Map™ 9.0.

2.2. Validation of air quality monitoring stations in relation to dominant emission sources

The validation of stations classification in relation to dominant emission sources is based on criteria that allow distinguishing the classes of Traffic, Industrial and Background. The proposed methodology is based on the analysis of pollutants levels, by studying sets of data from 1995 to 2002, measured in the 43 stations, with annual efficiency grater or equal to 50%.

The data analysis was performed for the pollutants nitrogen dioxide (NO_2), nitrogen monoxide (NO), oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter (PM_{10}), sulphur dioxide (SO_2), and ozone (O_3).

According to the Guidance on the Annexes, as far as possible and in addition to the general type applying to the station as a whole, it is asked to classify the station as for each of the different pollutants that are measured at the station (at least for the pollutants covered by air quality Directives). It must be kept in mind that a station can be classified differently when considering the different pollutants.

Several statistical indicators and ratios between pollutants were tested. This approach allowed the comparison between statistical parameters and to understand their relation with stations classification. Were pointed out criteria (shown in Table 1) to verify the classification of the stations for different pollutants measured (NO_2, NO, NO_x, CO, SO_2), and criteria to apply to the station as a whole (based on the classification for each pollutant, ratios NO/NO_2, NO/O_3, NO_2/O_3, and criteria for

O_3). These criteria consist in pollutant concentrations, with which is made a comparison to verify if they are frequently exceeded by the concentrations measured in each station.

The stations classification by pollutant in one of the classes Traffic, Industrial or Background is done as it follows:

- for each year and each pollutant a station belongs to one of the two classes shown in Table 1 if in the majority of the referred parameters is shown compliance with a typology, otherwise belongs to the background typology;
- the final typology for each pollutant is the one that prevail in the majority of the years in analysis.

Table 1. Criteria to verify stations classification in relation to the dominant emission sources, by each pollutant

Pollutant	Parameter	Traffic typology if the concentration ($\mu g/m^3$) is:
NO_2	Annual average (hourly basis)	>30
	Percentile 50 (hourly basis)	>20
	Percentile 98/ Percentile 50	<3,5
NO	Annual average (hourly basis)	>25
	Annual maximum (annual average from 0 to 23 hours)	>45
	Annual average (annual average from 0 to 23 hours)	>20
	Annual minimum (annual average from 0 to 23 hours)	>5
	Annual minimum (annual average from 13 to 16 hours)	>10
NO_x	Annual average (hourly basis)	>50
CO	Annual average (8-hourly basis)	>450
	Percentile 50 (daily basis)	>500
	Annual maximum (annual average from 0 to 23 hours)	>700
	Annual average (annual average from 0 to 23 hours)	>450
	Annual minimum (annual average from 12 to 15 hours)	>300
	Maximum-Minimum (annual average from 0 to 23 hours)	>400
Pollutant	Parameter	Industrial typology if the concentration ($\mu g/m^3$) is:
SO_2	Annual maximum (hourly basis)	>400
	25º Annual maximum (hourly basis)	>175
	Annual average (hourly basis)	>13
	Percentile 98 (hourly basis)	>40
	Percentile 50 (hourly basis)	>6
	4º Annual maximum (daily basis)	>60

The global validation of stations classification as a whole is based on the classification obtained for each pollutant (defined as previously indicated, with criteria presented in Table 1), criteria based on ratios between pollutants and criteria for ozone, as shown in Table 2.

Table 2. Criteria to verify the global classification of stations in relation to the dominant emission sources

Pollutant	Parameter	Traffic typology if the concentration (expressed in μg/m^3) is:
O_3	Annual average (hourly basis)	<35
	Percentile 50 (hourly basis)	<35
	Summer annual average (hourly basis)	<45
Ratios between pollutants	Annual average NO/ Annual average NO_2	>0,8
	Annual average NO/ Annual average O_3	>0,6
	Annual average NO_2/ Annual average O_3	>0,8

A station as a whole is globally classified as Traffic if the concentrations measured show compliance with that typology criteria (based on the classification for each pollutant, ratios between pollutants, and criteria for O_3, as shown before), otherwise that station would be classified as Background. In the cases where some doubts still remaining, a more detailed analysis is necessary (including localization criteria). The Industrial typology depends only on the classification obtained for SO_2.

If a station has simultaneously traffic and industrial influence is necessary to get more information to decide, once the different station types are mutually exclusive as they reflect the influence of the predominant or prevailing emissions.

3. RESULTS AND DISCUSSION

3.1. Validation of air quality monitoring stations by type of area

In Table 3 is shown the current stations classification, the values of population density in the circular area of 1km in the surroundings of the station, and at last the classifications obtained after applying, to this indicator, the limits defined in the methodology. This methodology was applied to the 51 monitoring stations operating in Portugal in 2003, however, to resume the Table 3 contents, are only shown the stations for which were obtained a different classification from the current one.

The application of the developed methodologies pointed out several potentially wrong classified stations in terms of type of area:

- for six of the 51 stations considered were obtained different classifications from those that are in use (their current classification doesn't fulfil the criteria for their area type, for what, another classification is better applied);
- for other five, some doubts remain on the classification between the typologies Urban and Suburban (their population densities are between the 2000 and 3000 inhab./km^2; in these cases the knowledge of the technicians from the regional authorities is essential to determine the most correct classification);
- for all the other stations were obtained the same classifications as the current ones.

Table 3. Results obtained for stations classification by type of area

Zone	Station name	Current classification by area type	Population density in the circular area of 1km radius (inhab./ km^2)	Proposed classification according to the circular area of 1 km radius around the station	
				Case A	Case B
Porto Litoral	Ermesinde	Suburban	7573	Urban	Urban
Porto Litoral	Custóias	Suburban	2353	Urban	Suburban
Porto Litoral	Baguim	Suburban	3034	Urban	Urban
Vale do Ave	Santo Tirso	Urban	2209	Urban	Suburban
Z. I. Estarreja	Avanca	Rural	685	Suburban	Suburban
Coimbra	Av. Fernão Magalhães	Urban	2029	Urban	Suburban
AML Norte	Alfragide	Suburban	6337	Urban	Urban
AML Norte	Loures	Urban	2452	Urban	Suburban
AML Sul	Paio Pires	Urban	2652	Urban	Suburban
Alentejo Litoral	Monte Chãos	Suburban	4	Rural	Rural
Alentejo Litoral	Santiago do Cacém	Urban	1094	Suburban	Suburban
Legend: Limits for typologies intervals: Case A - Rural ≤500, Suburban]500;2000], Urban >2000 (inhab./km^2) Case B - Rural ≤500, Suburban]500;3000], Urban >3000 (inhab./km^2)					

3.2.Validation of air quality monitoring stations in relation to dominant emission sources

Trough the application of the methodology exposed in the previous section (for each of the 43 stations in analysis and for each of the years with data) is obtained the classification for each pollutant (NO_2, NO_x, NO, CO and SO_2) and for the station as a whole. Those classifications are obtained in an annual basis, i. e. for each year in analysis, and in the end is made an aggregation of information, resulting the final evaluation for each station.

In Table 4 can be found the results for global stations classification, only for all the cases where some doubts were raised in relation to the current typology, i. e. for the cases for which the global classification can be different from the current one. In order to resume the Table 4 contents, only that short list of the main results is presented (instead of the results obtained for all the stations). The results obtained for each station are aggregated for all the years with data.

The application of the developed methodologies pointed out several potentially wrong classifications in terms of dominant emission sources:

- in relation to the classification per pollutant, some stations were classified differently for different pollutants;
- in relation to the global classification of stations as a whole, doubts were raised in thirteen situations:
  - in four Background stations was detected traffic influence for some pollutants, however, it is not sufficient to determine the change of the global classification into Traffic typology;
  - two of the Industrial stations didn't validate, for more then a half of the years in analysis, the criteria defined for this typology;
  - one Industrial station has some traffic influence, however, the dominant emission source is still the industrial one;
  - in three Traffic stations the SO_2 levels shown industrial influence, however, traffic is the dominant emission source;
  - three of the Traffic stations measured low concentrations of pollutants associated to traffic influence.

Table 4. Results obtained for global stations classification in relation to dominant emission sources

Current classification	Station name	Classification by pollutant					Other criteria				Reached global class.
		NO_2	NO_x	NO	CO	SO_2	Ratio NO/NO_2	Ratio NO/O_3	Ratio NO_2/O_3	O_3	
Background	Ermesinde	T	T	B	-	B	B	B	T	T	Back./ Traffic
	Leça do Bailio	T	T	B	B	B	B	B	B	B	
	Chelas	T	T	B	B	B	B	-	-	-	
	Alfragide	T	T	B	T	B	B	B	B	B	
Industrial	Lavradio	T	T	B	B	I	B	T	T	B	Ind./ Traffic
	Monte Chãos	B	B	B	-	B	B	B	B	B	Ind./ Back.
	Santiago do Cacém	B	B	B	-	B	B	B	B	B	
Traffic	Rua dos Bragas	T	T	T	T	I	B	T	T	T	Traffic/ Ind.
	Entrecampos	T	T	T	T	I	T	T	T	T	
	Hospital Velho	B	T	B	T	I	B	T	T	T	
	Câmara Municipal	B	B	B	B	-	B	-	-	-	Traffic/ Back.
	Quebedo	T	B	B	B	B	B	-	-	-	
	Afonso III	B	B	B	T	B	B	B	B	B	

Legend: abbreviations of stations classification: T–Traffic; I–Industrial; B–Background;
abbreviations of global classification: class.–classification, Ind.-Industrial, Back.-Background.

4. CONCLUSIONS

This study aimed to develop objective methodologies that allowed the validation of air quality monitoring stations classification, according to the requirements of Council Decision 97/101/EC. Those common procedures assure a harmonized interpretation of the definitions of European legislation, from region to region.

Regarding the developed methodology for stations classification by type of area the following relevant aspects should be highlighted:

- the definitions of area types are based on the distribution/density of buildings. However, once that information is not available, was used instead the population density as indicator;
- after testing some indicators the selected one was population density in the circular area of 1 km radius around each station;
- to distinguish each typology of area types were established limits of population density (Rural $\leq$500 inhabitants/km^2, Suburban]500;2000] or]500;3000] inhabitants/km^2, Urban >2000 or >3000 inhabitants/km^2);
- the application of the developed methodologies pointed out several potentially wrong classified stations in terms of type of area: for six of the 51 stations were obtained different classifications from those that are currently in use; for other five, some doubts remain on the classification between the typologies Urban and Suburban;
- the proposed changes of stations classification must be assessed by the technician of environmental regional authorities that know well the stations surroundings.

Regarding the developed methodology for stations classification in relation to dominant emission sources the following relevant aspects should be highlighted:

- to define the criteria that allow to set a station typology, was taken into account the trend of pollutant levels measured since 1995 to 2002 and the current stations typology;
- several statistical indicators were tested and were pointed out criteria to verify the classification of the station for the different pollutants measured (NO_2, NO, NO_x, CO, SO_2), and criteria to apply to the station as a whole (based on the classification for each pollutant, ratios NO/NO_2, NO/O_3, NO_2/O_3, and criteria for O_3);
- the developed methodology was applied to sets of data measured at the stations, from 1995 to 2002, to verify stations classification (global and per pollutant);
- a station as a whole is globally classified as Traffic if the criteria for this typology are validated. Otherwise the global classification will be Background. In the cases were some doubts remain, it will be necessary to perform a more detailed analysis. The Industrial typology depends only on the classification obtained for SO_2. If a station has simultaneously traffic and industrial influence, it is necessary to get more information to decide which of the emission sources is dominant;
- in relation to the classification of the 43 air quality monitoring stations by dominant emission sources, per pollutant, some stations were classified differently for

different pollutants. For the global classification of stations, doubts were raised in thirteen situations.

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