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APICE

WP3.2 – REPORT FROM BARCELONA REGION

arpav
Agenzia Regionale per la Prevenzione e Protezione Ambientale del Veneto
Regione del Veneto
Provincia di Genova
Marseille Fos
idæa

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SUMMARY

University of West Macedonia redacted five reports for each region which participates in APICE project: Barcelona, Marseille, Venice, Genoa and Thessaloniki. In each report, there is a brief presentation of each region and port area. An analysis of the air quality in each area for the last years follows and the interest is focused on PM10. Meteorological conditions influence is also examined. With the scope of the study of the port's contribution to the air quality of each city, these reports prepare the next steps of an inter-comparison campaign and an air long monitoring campaign for a source apportionment study as also for modeling activities and socio-economic trends. The present report refers to the port of Barcelona.

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CONTENTS

1. INTRODUCTION

2. PARTNERS PRESENTATION

3. PORT PRESENTATION

4. MONITORING NETWORK

   4.1 AIR QUALITY NETWORK

   4.2 METEOROLOGY NETWORK

5. MEASUREMENTS

   5.1 POLLUTANTS

   5.2 METEOROLOGICAL PARAMETERS

6. ANALYSIS OF PM10 FOR YEAR 2009 FOR NEAR THE PORT STATION

   6.1 PM10 ANALYSIS

   6.2 WIND ROSES

7. FRAMEWORK ANALYSIS

   7.1 INTERNATIONAL

   7.2 EUROPEAN

   7.3 NATIONAL

8. EVALUATION OF AIR QUALITY IN REGION OF BARCELONA

SOURCES

ANNEX I

PROJECTS

ANNEX II

PUBLICATIONS

ANNEX III

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Project co-financed by the European Regional Development Fund

MODELING ACTIVITIES

CONTENTS OF FIGURES

Figure 1: Location of the monitoring stations in the Barcelona city. The green squares indicate those sites operated by CSIC.

Figure 2: Network of meteorological stations in Barcelona city.

Figure 3: Daily levels of PM_{10}, $PM_{2.5}$ and PM_1 recorded at Torre Girona-CSIC in 2009. African dust outbreaks are highlighted with orange rhombus (NAF).

Figure 4: Daily levels of black carbon measured at Torre Girona-CSIC in 2009.

Figure 5: Daily concentrations of particle number (5-1000 nm) registered at Torre Girona-CSIC in 2009.

Figure 6: a) Daily concentrations of NO_2 and SO_2 registered at a nearby (GOR in Figure 2) monitoring site to Torre Girona-CSIC in 2009. b) Daily patters of these gaseous pollutants.

Figure 7: Mean annual concentrations of mineral matter, sea spray, OM+EC, unaccounted mass, sulphate, nitrate, ammonium and trace elements registered in PM_{10}, $PM_{2.5}$ and PM_1 at Torre Girona-CSIC in 2009.

Figure 8: Daily concentrations of mineral matter, sea spray, OM+EC, sulphate and nitrate measured in PM_{10} at Torre Girona-CSIC in 2009. Note that OM+EC concentrations are only available in the first half of 2009.

Figure 9: Daily concentrations of some trace elements measured in PM_{10} at Torre Girona-CSIC in 2009.

Figure 10: Location of monitoring sites in the harbor area of Barcelona during 2009.

Figure 11: Daily levels of PM_{10} (top) and $PM_{2.5}$ (bottom) recorded at different sites in the harbor area of Barcelona in 2009.

Figure 12: Wind roses for SO_2, NO_2 and H_2S obtained for the Barcelona harbor area in 2009. These figures have been taken from the annual report elaborated by the harbor authorities.

Figure 13: Mean daily values of wind direction, wind velocity, ambient temperature, relative humidity, sea level pressure and precipitation recorded in Barcelona-Collserola in 2009.

Figure 14: The location of Torre Girona station which is marked with a blue arrow

Figure 15: PM10 monthly averages in 2009 (μg/m^3).

Figure 16: PM10 exceeded days in 2009 (μg/m^3).

Figure 17: PM10 daily averages in 2009 (μg/m^3).

Figure 18a: PM10 averages per day in 2009 (μg/m^3).

Figure 18b: BC averages per day in 2009 (μg/m^3).

Figure 19: Hourly PM10 averages in 2009 (μg/m^3).

Figure 20: PM10 concentration rose (μg/m^3, degrees) and wind speed rose (m/s, degrees) in 2009 – Activities in Barcelona

Figure 21: Wind speed rose in 2009 (m/s, degrees)

Figure 22: PM10 concentration rose (μg/m^3, degrees) and wind speed rose (m/s, degrees) in 2009 –Activities in Barcelona

Figure 23: MARPOL Annex VI Knox Emission Limits

Figure 24: MARPOL Annex VI Fuel Sulfur Limits

Figure 25: Special protection zone of the Atmospheric Environment for the pollutants NO_2 and PM_{10}.

Figure 26: Territorial delimitation of the Air Quality Plan for NO_2 and PM_{10}.

Figure 27: Example of SAPUSS model for the area of Barcelona city: PM10 levels, 0.5 km resolution. From Jiménez P. at http://chubasco.inf.um.es/sapuss/aq/BCN005_aqi.html

Figure 28: Example of HERMES model for the area of Barcelona city: NO levels, 1 km resolution. From Caliope project at http://www.bsc.es/caliope/?q=node/70

CONTENTS OF TABLES

Table 1: Main characteristics of the different Air Quality zones distinguished in Catalonia

Table 2: Monitoring sites constituting the Air Quality Zone 1 in which Barcelona and its harbor are located.

Table 3: Mean monthly levels of particle number concentration (> 5nm), black carbon (BC), particle mass concentrations (PM_{10}, $PM_{2.5}$ and PM_1), and number of exceedances of the daily limit value of PM_{10} (DLV) establish in 50 µg/m^3 recorded at one reference urban site of Barcelona (Torre Girona-CSIC).

Table 4: Mean annual TSP, PM_{10} and $PM_{2.5}$ levels measured at different locations in the harbor area of Barcelona in 2009.

Table 5: Mean annual levels from 2000 to 2009 of a number of atmospheric pollutants measured at different locations in the harbor area of Barcelona. This table has been taken from the annual report elaborated by the harbor authorities.

Table 6: MARPOL Annex VI NOx Emission Limits

Table 7: MARPOL Annex VI Fuel Sulfur Limits

Table 8: Air quality standards per pollutant

Table 9: Air quality standards for PM2.5 in lines of AEI

Table 10: National normative framework per pollutant

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1. INTRODUCTION

The current report has been redacted in lines of APICE program (Common Mediterranean strategy and local practical Actions for the mitigation of Port, Industries and Cities Emissions). APICE project develops its actions within 5 study areas of 4 MED space Countries belonging to the regions of Veneto and Liguria (Italy), Provence-Alpes-Côte d'Azur (France), Cataluña (Spain) and Central Macedonia (Greece) and involve some of the most important port-cities of Mediterranean space. The project areas show common features related to the port-areas systems (in terms of harbor-industrial district organization) and present the same problems of air-pollution affecting seriously not only the populated urban centers but also the whole natural ecosystems and the cultural heritage (the project territories count several Sites of Community Importance & Special Protection Areas in their surroundings, as well as UNESCO sites).

The report includes a description of the air quality and meteorology network in Barcelona's region. Furthermore, a brief analysis of the air quality during the last years is included. The interest is focused on the Port of Barcelona, which is the main transport and services infrastructure in Catalonia, the second Spanish port in terms of total goods traffic and the first in terms of value. PM10 particles monthly, daily and hourly variation was examined for the year 2009. A discussion about PM10 limit values excesses as well as the effect of meteorological parameters to PM10 levels is also included. Finally, a description of the national and international framework follows.

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2. PARTNERS PRESENTATION

EUCC Mediterranean Centre

November 2003, the EUCC Mediterranean Centre was officially inaugurated in an international event at el Far, Centre del Treballs del Mar, in Barcelona. EUCC Mediterranean Centre aims to carry out the EUCC's mission in the Mediterranean region in its widest sense, including the Atlantic regions of Spain and Portugal. EUCC Mediterranean Centre was founded with the objective of supporting EUCC's activities, EUCC members and National Branches in this geographical area, as well as developing new initiatives in cooperation with other NGOs, research institutes and government agencies. Other priorities in the Mediterranean Centre are the promotion of sustainable tourism, energy, aquaculture and fisheries and the designation and management of marine protected areas. For this aim, EUCC Mediterranean Centre will continue promoting the development of ICZM policy, strategies and plans as an instrument to achieve sustainable development along European coasts.

IDÆA-CSIC

(Institute of Environmental Assessment and Water Research, Spanish Research Council)

IDÆA is devoted to the study of the natural and anthropogenic changes occurring in the ecosystems of the geosphere using chemical and geochemical tools. IDÆA is focused on the changes related to climate and those involving toxicity increases for organisms and humans. The IDÆA research activities are based on the expertise of its personnel in environmental sciences, analytical chemistry, geochemistry, hydrology and biotechnology. These researchers have a consolidated record of publication in leading scientific journals, participation in international projects, contribution to the remediation of major environmental accidents, identification of environmental problems and study of climate and global change. Spain has specific environmental features as consequence of its climate and geographic situation. Water, either that originating from rivers or aquifers, undergoes strong reuse and intensive exploitation due to its scarcity. This aspect tends to condition the quantity and quality of water resources and requires important social and economical efforts for providing sufficient amounts of high quality water to the population. The scientific researchers of IDÆA are committed to this task. One of the main goals of the institute concerns the implementation of advanced assessment and management methods to grant the accessibility of high quality water to the population.Another specific problem is air quality which is threatened by Saharan dust episodes as well as specific problems of urban and industrial pollution. Several researchers of IDÆA are fully involved in developing chemical and geochemical methods for air analysis as well as in participating in national and international panels for air quality improvement.

The effects of diffuse pollution on organisms and humans are also a major research topic of interest for the researchers of the institute. IDÆA has 174 researchers grouped in the Departments of Geosciences and Environmental Chemistry. They are expert in handling these problems using sophisticated analytical instrumentation and innovative environmental and geochemical methods. Among other facilities the institute has the Laboratory of Dioxins, the one with highest consolidated professional tradition in Spain, and a large number of chromatographic and mass spectrometric instruments which support the high international standard profile of the institute.

3. PORT PRESENTATION

The Port of Barcelona is the main transport and services infrastructure in Catalonia, the second Spanish port in terms of total goods traffic and the first in terms of value. The 450 shipping lines operated by 118 ship owners which regularly link Barcelona with 850 ports of the five continents, set it a head and shoulders above other Spanish ports for international traffic.
The Port has nearly forty specialized and multipurpose terminals for attending to the different types of traffic generated in its hinterland - the market which it serves. In addition, the commercial port has a logistics port, the Logistics Activities Area, or ZAL, and an urban port, the Port Veil, which is open to the public. Total traffic in 2007 was in excess of 51 million tones, with 2.6 million containers, 801 406 new vehicles (it is the top Mediterranean port for car traffic) and 2.8 million passengers, of which 1.7 travelled on cruise ships (Barcelona is the top European cruiser port). The Port is growing fast in the area of short sea shipping, which offers a combined service for the transport of passengers and vehicles, aimed especially at trucks. A total of 319 144 passengers and 85 586 trucks used the short sea shipping services in 2006. This is a sustainable model of transport, providing improvements in logistics operations and is also more competitive than road transport. The Port has also helped to push forward the creation of the European School of Short Sea Shipping, the first Europe-wide institution dedicated to providing specific training in short sea shipping. Based in Barcelona, the School is a unique training model, with the courses provided on board ships sailing the regular lines between the Port of Barcelona and the ports of Genoa and Civitavecchia (Rome).
The enlarged Port will be able to handle annual traffic of 130 million tonnes and 10 million containers and will therefore require road and rail accesses with sufficient capacity to allow this huge amount of goods to leave the Port smoothly and speedily. The Port of Barcelona has opted for the railway to connect to its potential markets in the centre and north of Europe in competitive conditions in terms of costs and time, using criteria of sustainability and mobility. The Port of Barcelona's Rail and Road Accessibility Plan involves building infrastructures with the capacity to operate 180 trains a day, equivalent to 150 000 tonnes/day or 30 million tonnes/year. To channel this large amount of traffic, the Port will have rail terminals in each of the new terminals, in addition to the existing rail terminals, and a large loading and unloading station will be built in the old bed of the river Llobregat.
The enlargement and the improvement of the accesses are the foundation for the Port to be able to handle new traffic. The Port is working to attract the growing maritime traffic between Europe and Asia, especially with China. Currently only 24% of the goods flowing between Europe and Asia and passing through the Suez Canal are loaded and unloaded in the ports of Southern Europe. The Port of Barcelona, which already handles 35% of all traffic between Spain and Asia, rising to 38% in the case of China, aims to attract a large part of this potential traffic The enlargement, the increased traffic with Asia, a greater presence in European and Mediterranean markets, the creation of new road and rail accesses and the improved dynamism and efficiency of port processes are all factors that will help the Port of Barcelona to achieve its strategic aim: to become the gateway to southern Europe and the main Euro-Mediterranean logistics hub.

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4. MONITORING NETWORKS

4.1 AIR QUALITY NETWORK

The regional Air Quality network of Catalonia comprises 15 areas distinguished in function of its population, type of environment, topography and anthropogenic activities occurring in each one (Table 1 and Figure 1). The smallest and more populated zone is the “Àrea de Barcelona”, in which the Barcelona city and its harbor are located. Around 3 million people are living in this zone, which is under intense anthropogenic pressure (traffic, industry, power generation, construction activities, and harbor emissions, among others).

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Table 1: Main characteristics of the different Air Quality zones distinguished in Catalonia.

Zone number	**Name**	**Number of municipalities**	**Surface (km²)**	**Population (Inhab.)**	**Type of areas**		
					Urban	Suburban	Rural
1	Àrea de Barcelona	19	341	2654782	Yes	Yes	No
2	Vallès Baix Llobregat	61	1177	1037293	Yes	Yes	Yes
3	Penedès Garraf	70	1418	272736	Yes	Yes	Yes
4	Camp de Tarragona	49	994	315467	Yes	Yes	Yes
5	Catalunya Central	85	2764	230078	Yes	Yes	Yes
6	Plana de Vic	38	806	115313	Yes	Yes	Yes
7	Maresme	33	501	367131	Yes	Yes	Yes
8	Comarques de Girona	117	3672	291470	Yes	Yes	Yes
9	Empordà	85	1346	180334	Yes	Yes	Yes
10	Alt Llobregat	51	2090	60951	No	No	Yes
11	Pirineu Oriental	51	2794	55568	No	No	Yes
12	Pirineu Occidental	33	2918	21062	No	No	Yes
13	Prepirineu	26	2414	20932	No	No	Yes
14	Terres de Ponent	146	4710	296935	Yes	Yes	Yes
15	Terres de l'Ebre	80	3951	169988	Yes	Yes	Yes

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STATIONS

The “Àrea de Barcelona” has a dense monitoring network composed of 28 stations (Table 2) in which a number of air quality parameters are measured. Most of them (16) record automatic measurements, mainly gaseous pollutants (NOx, SO_2, O_3, CO) and particulate matter mass concentration (PM_{10}). Among these 16 sites, in 10 of them manual measurements are also recorded (PM_{10}, acid rain, metals, benzene).

Table 2: Monitoring sites constituting the Air Quality Zone 1 in which Barcelona and its harbor are located.

ZQA 1: Àrea de Barcelona			
CITY	**LOCATION**	**AUTOMATIC MEASUREMENTS**	**MANUAL MEASUREMENTS**
Badalona	Av. Marquès Mont-roig - c/ Ausiàs March	NOx, O_3, CO, SO_2	PM_{10}
Badalona	Pl. Pep Ventura	NOx, O_3, CO, SO_2,	
Badalona	Av. del Caritg		PM_{10}
Barcelona	Av. Roma-c/ Urgell (Eixample)	NOx, PM_{10}, O_3, CO, SO_2	PM_{10}, Benzene, Metals
Barcelona	Ciutadella	NOx, O_3, CO, SO_2	Benzene
Barcelona	Escullera	O_3	
Barcelona	Gràcia-St. Gervasi (Gala Placídia)	NOx, PM_{10}, O_3, CO, SO_2	PM_{10}, $PM_{2.5}$, Benzene, Metals
Barcelona	IES Goya (C/ Garriga i Roca)		PM_{10}, $PM_{2.5}$
Barcelona	Moll Pescadors (Port Vell)		PM_{10}
Barcelona	Pl. Universitat		PM_{10} , $PM_{2.5}$, Metals
Barcelona	Poblenou (Pl. Doctor Trueta)	NOx, PM10, O_3, CO, SO_2	Benzene, PM_{10},Metals

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Barcelona	Sants (Jardins de Can Mantega)	NOx, PM10, CO, SO_2	PM_{10}, Metals
Barcelona	Vall d'Hebron	NOx, O_3, CO, SO_2	PM_{10}, $PM_{2.5}$, Benzene, Metals
Barcelona	Zona universitària		PM_{10}, Metals
Barcelona	C/ Lluís Solé i Sabarís		PM_{10}, $PM_{2.5}$
Barcelona	Dàrsena Sud	Acid rain	
Barcelona	IES Verdaguer		PM_{10}, Metals
Barcelona	Torre Girona	SO_2 ,NOx,O_3, PM_{10}, $PM_{2.5}$, PM_1	
Cornellà de Llobregat	Avd. Salvador Allende-c/ Bonvei	NOx, SO_2	
El Prat de Llobregat	Pl. Església	NOx, SO_2, H_2S	Benzene, PM_{10} ,Metals
El Prat de Llobregat	Jardins de la Pau	NOx, O_3, SO_2	Benzene, PM_{10}
Esplugues de Llobregat	Escola Isidre Martí		PM_{10}
Esplugues de Llobregat	Centre La Plana		PM_{10}
Gavà	Parc de Mil·leni	NOx, O_3, SO_2	Benzene
Gavà	Parc de Mil·leni	NOx, O_3, CO, SO_2	PM_{10}, $PM_{2.5}$, Benzene, Metals
L'Hospitalet de Llobregat	Av.Torrent Gornal	NOx, O_3, CO, SO_2	PM_{10}
Molins de Rei	Ajuntament		PM_{10}
Prat Llobregat	C/ Riu Anoia	NOx, O_3, CO, SO_2	PM_{10}, $PM_{2.5}$, Benzene, Metals
St. Adrià del Besòs	C/ Olímpic	NOx, PM_{10}, O_3, CO, SO_2	PM_{10}, Metals

St. Feliu de Llobregat	C/ Eugeni d'Ors		PM_{10}, Metals
St. Vicenç dels Horts	C/ Ribot-c/ St. Miquel	NOx, O_3, PM_{10}, SO_2	
St. Vicenç dels Horts	Col·legi Verge del Rocío		PM_{10}, $PM_{2.5}$, Metals
Sta. Coloma de Gramenet	Ajuntament		PM_{10}
Sta. Coloma de Gramenet	Torre Balldovina	NOx, O_3, CO, SO_2	
Viladecans	Av. Josep Tarradellas	NOx, O_3, CO, SO_2	PM_{10}, $PM_{2.5}$, benzene, Metals

This report presents the data from one of the urban sites of Barcelona city that is operated by the CSIC (Torre Girona), formerly Luis Solé i Sabaris (see Figure 1). At the Torre Girona site, a number of parameters are being measured (PM_{10}, $PM_{2.5}$, PM_1, black carbon, number concentration, in addition to NOx, CO, SO_2, O_3). A complete chemical characterization is continuously carried out in both three PM fractions.

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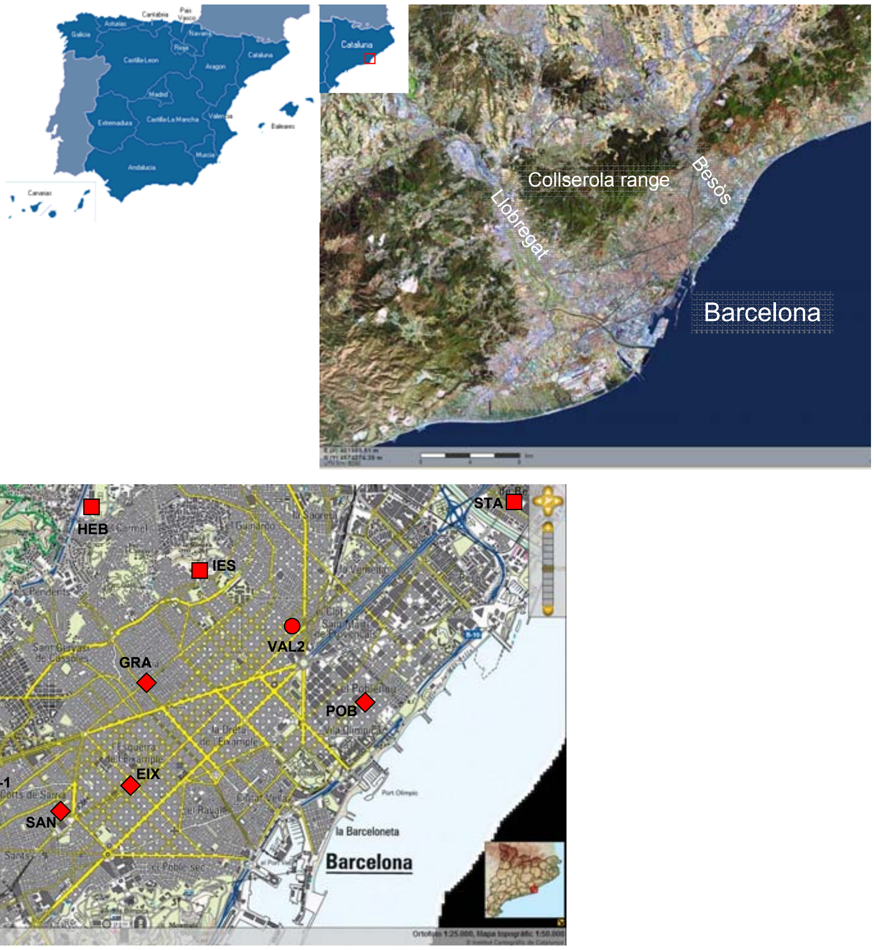

Figure 1: Location of the monitoring stations in the Barcelona city. The green squares indicate those sites operated by CSIC.

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4.2 METEOROLOGY NETWORK

STATIONS

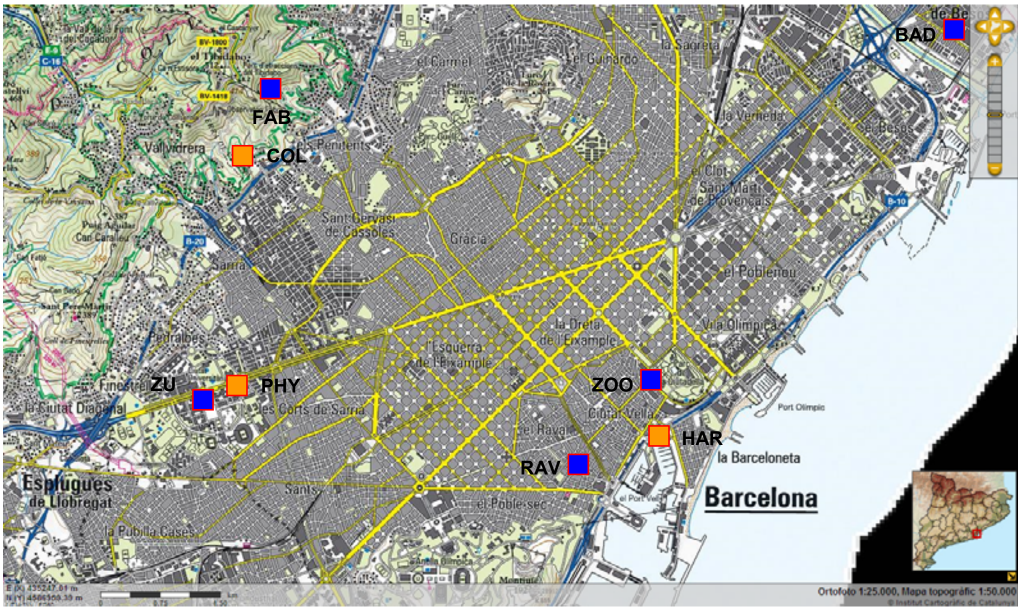

Figure 2: Network of meteorological stations in Barcelona city.

5. MEASUREMENTS

5.1 POLLUTANTS

URBAN BACKGROUND

Table 3 presents the mean monthly and annual levels of number concentration, black carbon, PM_{10}, $PM_{2.5}$, and PM_1, and the number of exceedances of the daily limit value established for PM_{10} in 50 µg m^{-3}. As regards for PM_{10} and $PM_{2.5}$ (the only regulated parameters among those measured at Torre Girona), the annual concentrations during 2009 were under the limit value (40 µg $m^{-3}$for PM_{10} and 25 µg m^{-3} for $PM_{2.5}$). Nevertheless, the daily limit value established for PM_{10} in 50 µg m^{-3} was exceeded 38 days whereas only 35 days are allowed. After quantify the contribution of African dust for each day, and subtracting this contribution to the PM_{10} concentration, 32 exceedances were computed. The contribution of African dust to PM_{10} levels in 2009 was estimated in 1.2 µg m^{-3}.

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Table 3: Mean monthly levels of particle number concentration (> 5nm), black carbon (BC), particle mass concentrations (PM_{10}, $PM_{2.5}$ and PM_1), and number of exceedances of the daily limit value of PM_{10} (DLV) establish in 50 µg/m^3 recorded at one reference urban site of Barcelona (Torre Girona-CSIC).

	Number >5nm	BC µg/m^3	PM_{10} µg/m^3	$PM_{2.5}$ µg/m^3	PM_1 µg/m^3	>DLV PM_{10}
JANUARY	25635		29	15	11	1
FEBRUARY	18595	1,9	35	23	19	7
MARCH	20666	2,1	40	24	20	9
APRIL	19276	1,7	25	17	12	0
MAY	18336	2,1	40	23	15	7
JUNE	14924	2,0	33	19	12	2
JULY	16972	1,8	41	21	13	4
AUGUST	14782	1,6	27	15	9	2
SEPTEMBER	12990	1,6	24	17	11	0
OCTOBER	17964	2,7	25	16	11	1
NOVEMBER	17203	2,6	33	17	11	5
DECEMBER	14603	2,2	18	13	9	0
Annual Mean	**17662**	**2,0**	**31**	**18**	**13**	**38**

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On a daily basis (Figure 3), PM levels and its size distribution show clear seasonal trends. The highest PM levels and finest size distribution are observed in winter (February-March, and November) as a consequence of intense pollution episodes that avoid the dispersion of the atmospheric pollutants. These episodes are usually recorded under anticyclone conditions. Relatively high PM levels and coarse particle size are observed in summer as a result of low atmospheric dispersive conditions affecting the Western Mediterranean, together with higher frequency of African dust episodes and enhanced resuspension processes. Te lowest PM levels are recorded in April, September-October and December, generally coinciding with rainy periods and intense advective conditions. As seen in Figure 3, the effect of African dust on PM_{10} levels is evident, with relatively low influence on $PM_{2.5}$ and negligible on PM_1.

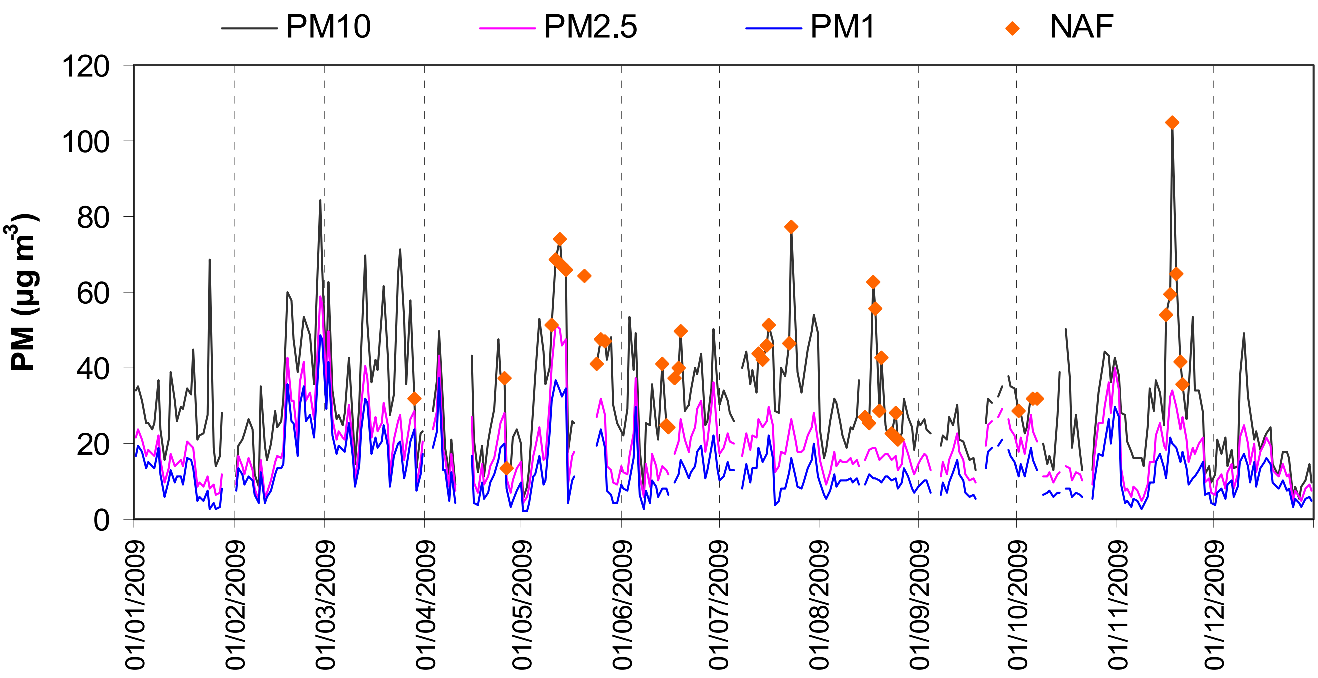

Figure 3: Daily levels of PM_{10}, $PM_{2.5}$ and PM_1 recorded at Torre Girona-CSIC in 2009. African dust outbreaks are highlighted with orange rhombus (NAF).

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When analyzing the behavior of other parameters such as black carbon or the particle number of fine and ultra-fine aerosols, other trends are observed. The black carbon concentrations are really sensible to the traffic emissions, showing little seasonal variability. Only under intense urban pollution episodes the concentrations of this parameter register significant increments with respect to previous days. These situations occur essentially in wintertime.

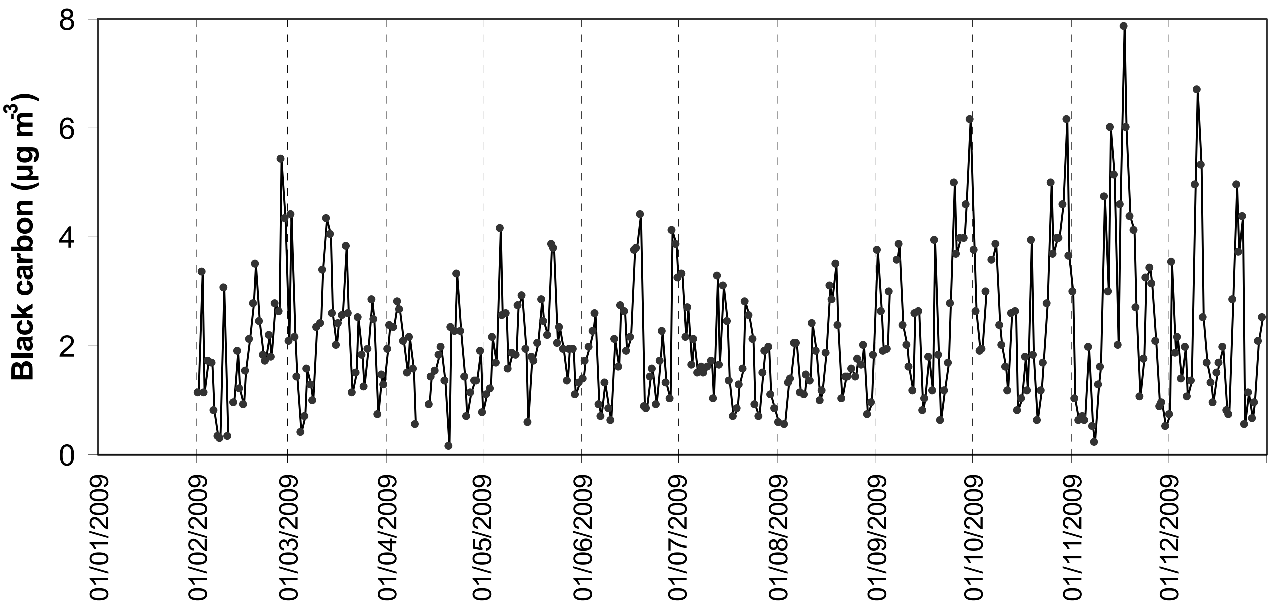

Figure 4: Daily levels of black carbon measured at Torre Girona-CSIC in 2009.

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As regards for the number concentration, different behaviors are observed. Sometimes the urban pollution episodes give significant numbers of ultra-fine particles (elevated emissions in a low-dispersive atmosphere), which are simultaneous with PM and BC peaks. Other times important number concentration peaks occur under low pollution conditions (nucleation processes). In some occasions, the urban pollution episodes are associated with low levels of number concentration which is thought as the result of coagulation and condensation processes that reduce the number concentration but not the PM mass.

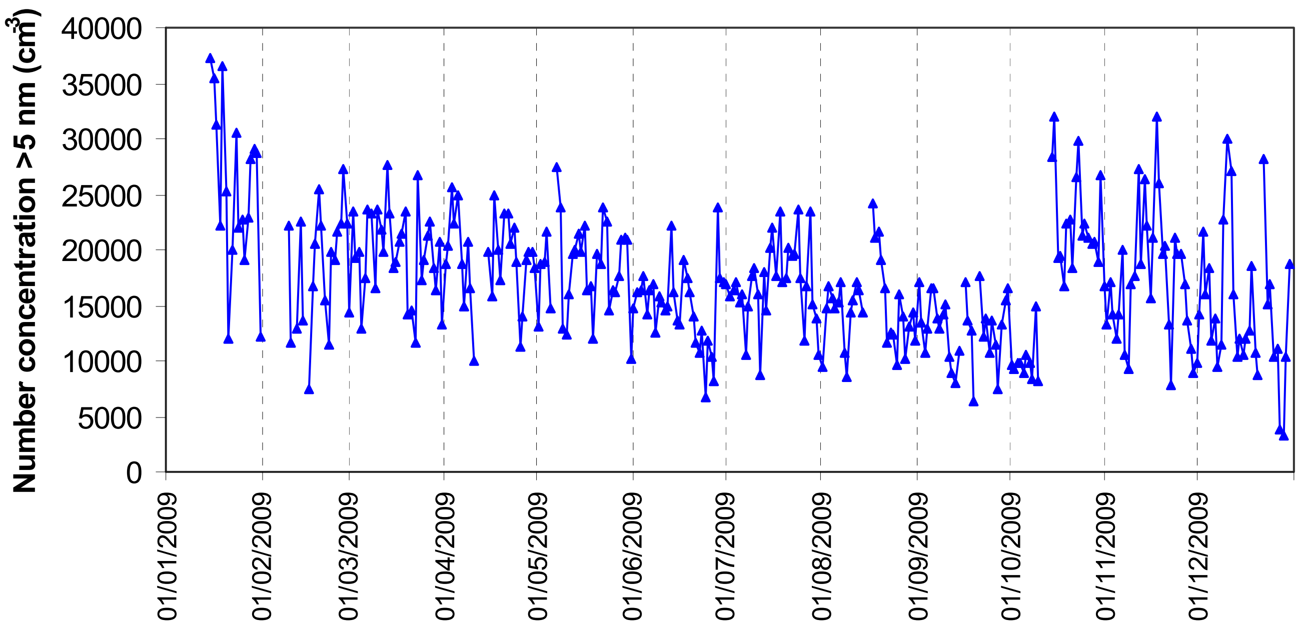

Figure 5: Daily concentrations of particle number (5-1000 nm) registered at Torre Girona-CSIC in 2009.

Regarding the seasonal evolution of NO_2 and SO_2, it is clear that both gaseous pollutants exhibit different patterns (Figure 6a). Whereas NO_2 tends to maximize in winter as a consequence of the lower dispersive conditions of the urban atmosphere, SO_2 do not show this pattern. In some episodes, NO_2 and SO_2 register simultaneous increments in a daily basis. This basically occurs under urban pollution episodes. Nevertheless, it is more frequent to observe a different behavior between NO_2 and SO_2. In fact, whereas NO_2 is highly related with traffic emissions (mainly from diesel vehicles), SO_2 concentrations in the urban area of Barcelona are more related to shipping and industrial emissions. When studying the daily patterns (Figure 6b), clear traffic dependence is observed for NO_2, with morning and vespertine peaks coinciding with the rush hours, but a midday maxima is observed in SO_2, coincident with the entrance of the sea breeze towards the city, with a typical direction from the harbor area.

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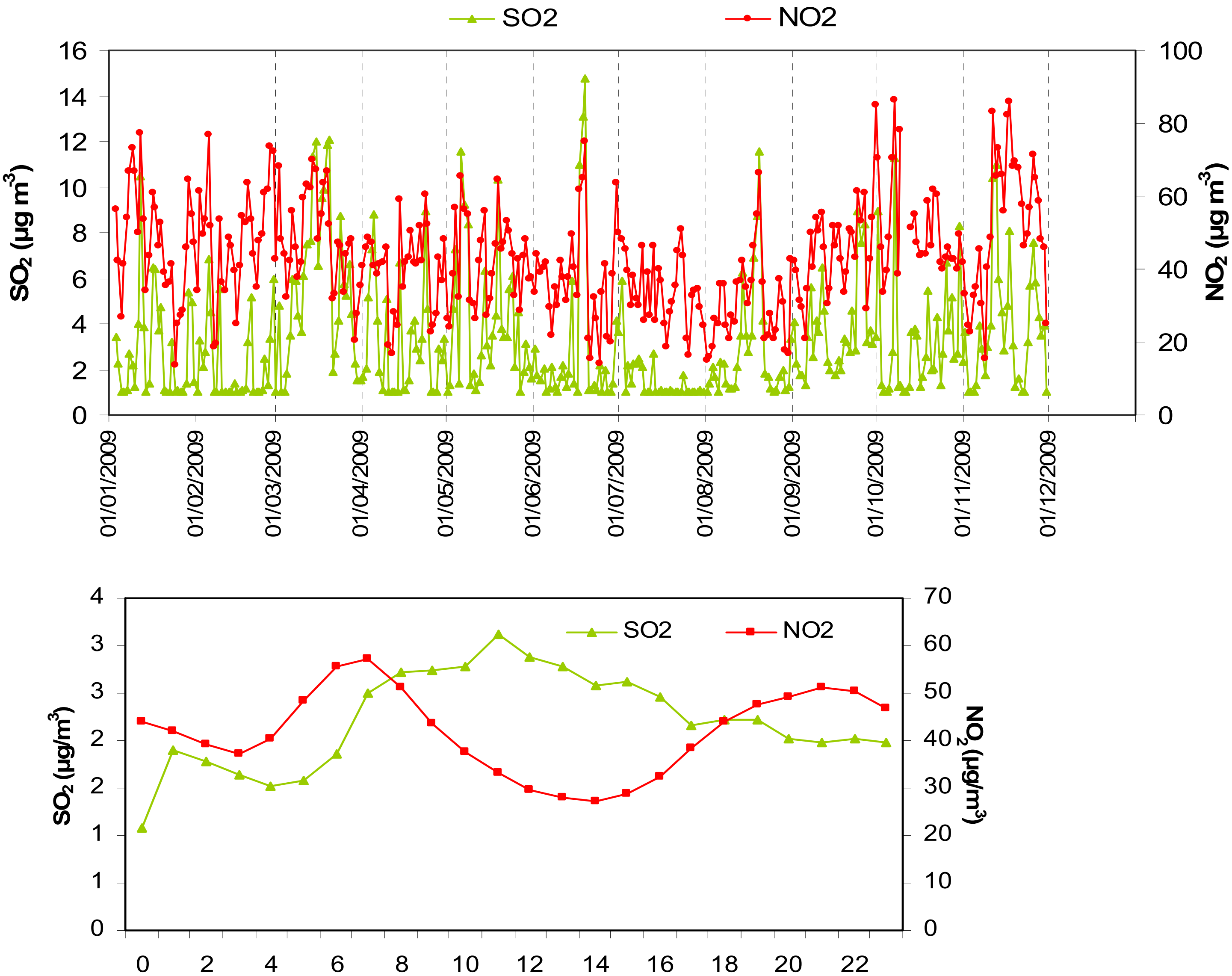

Figure 6: a) Daily concentrations of NO_2 and SO_2 registered at a nearby (GOR in Figure 2) monitoring site to Torre Girona-CSIC in 2009. b) Daily patters of these gaseous pollutants.

CHEMICAL COMPOSITION

At Torre Girona-CSIC PM_{10}, $PM_{2.5}$ and PM_1 chemical composition is determined. In this report we only present extended results for PM_{10}, and only the mean partitioning recorded for the major components as an annual mean in 2009. As seen in Figure 7, some atmospheric components have a preference for the coarse sizes such as mineral matter, sea spray and nitrate. Other components such as organic matter and elemental carbon (OM+EC), ammonium and in less proportion sulphate are mostly fine. It is important to remark that the amount of coarse components (PM_{1-10}) in the atmosphere of Barcelona is very significant (around 7 µg m^{-3} of mineral matter, around 2 µg m^{-3} of sea spray and nitrate, and about 5 µg m^{-3} of unaccounted mass). The study of the PM_{10} fraction is consequently necessary. It is expected that in the harbor area, where some dusty materials are handled, construction activities are always ongoing, and intense traffic of trucks occur, the importance of the coarse PM may be even higher than in the urban background.

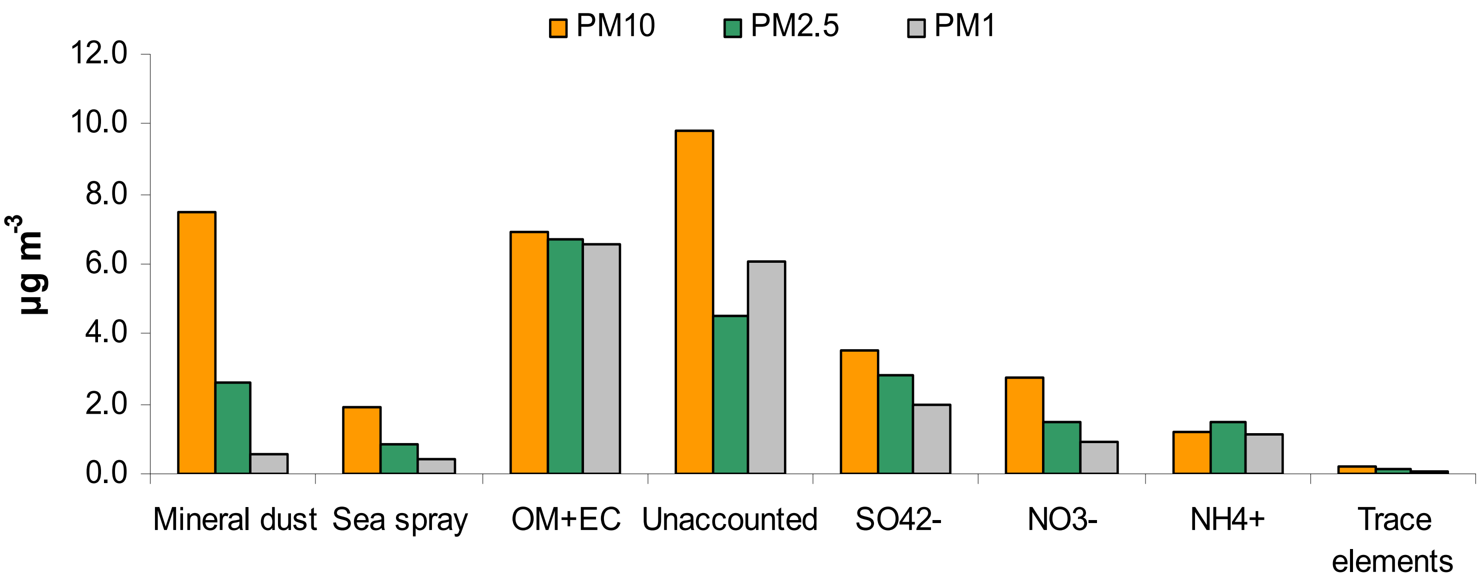

Figure 7: Mean annual concentrations of mineral matter, sea spray, OM+EC, unaccounted mass, sulphate, nitrate, ammonium and trace elements registered in PM_{10}, $PM_{2.5}$ and PM_1 at Torre Girona-CSIC in 2009.

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When studying the daily variability of the major components measured in PM_{10}, a number of characteristics may be deduced.

- Mineral matter tends to increase in summer, probably due to the enhanced resuspension processes. Nevertheless, sporadic and intense peaks are observed, coinciding with African dust outbreaks.
- Nitrate concentrations are clearly higher in winter, when a high frequency of urban pollution episodes is registered over the study area. In those cases, ammonium nitrate is the commonest inorganic secondary PM component.
- OM+EC concentrations are also higher in winter, again due to the accumulation of PM pollutants during urban pollution episodes.

Sulphate generally increases in summer, when the photochemical reactions are enhanced. In addition, the typical summer recirculation of air masses over the Western Mediterranean favors the accumulation of secondary pollutants over the region (mainly ammonium sulphate, organics and ozone).

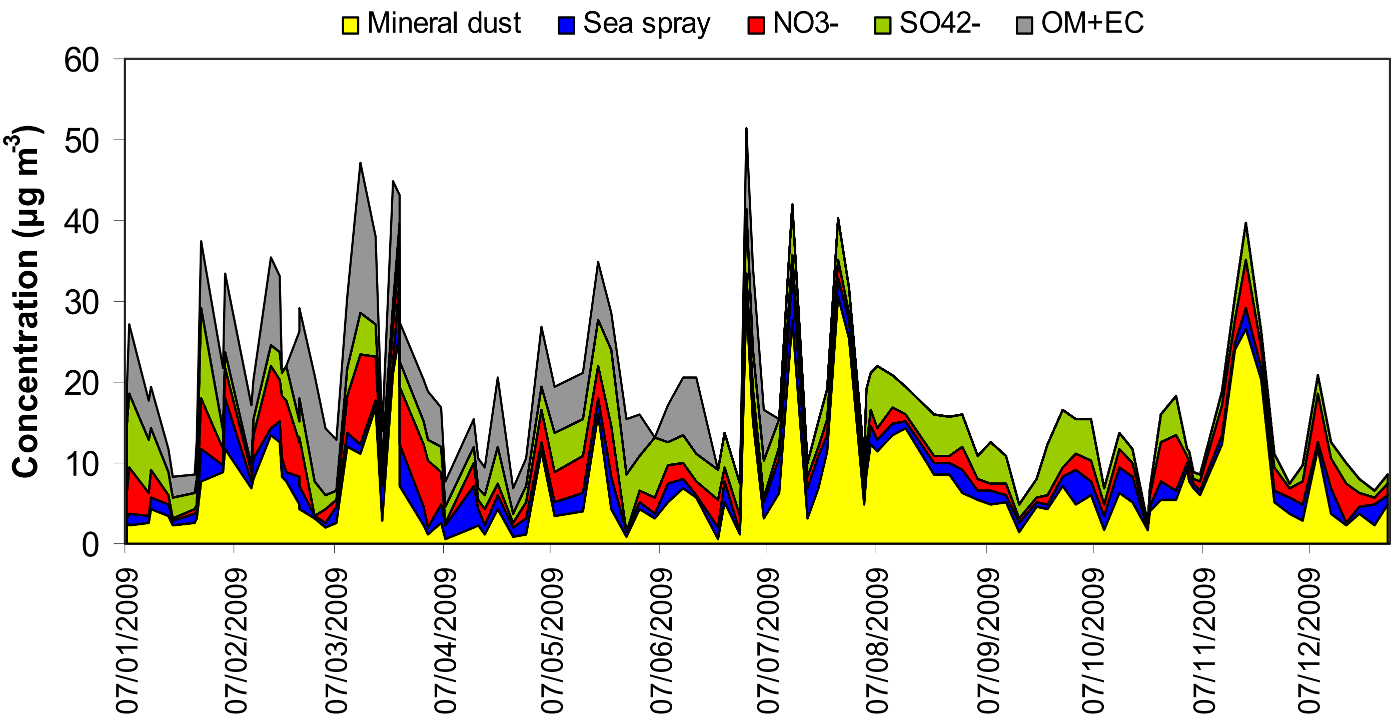

Figure 8: Daily concentrations of mineral matter, sea spray, OM+EC, sulphate and nitrate measured in PM_{10} at Torre Girona-CSIC in 2009. Note that OM+EC concentrations are only available in the first half of 2009.

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When looking to the evolution of different trace elements, a number of processes may be identified. This is due because some trace elements are typical of specific sources such as fuel-oil combustion (V and Ni), industrial emissions (Pb and Zn), and road traffic (Cu and Sb).

- Vanadium and nickel show a clear seasonal trend with higher concentrations in summer, and sporadic peaks out of this period. In the study area the harbor emissions and some industrial activities are to be the major sources of these trace elements.
- Lead and Zinc register an inverse seasonal evolution when compared to the previous two, showing higher winter concentrations. It is interesting to note that the study of the Pb-Zn episodes points out to the industrial area located in the Llobregat Basin as the source of these pollution episodes. Over this area large metallurgical activities occur.
- Copper and antimony are the best tracers of traffic emissions. In this case they show a typical winter maximum originated by the higher frequency of urban pollution episodes.

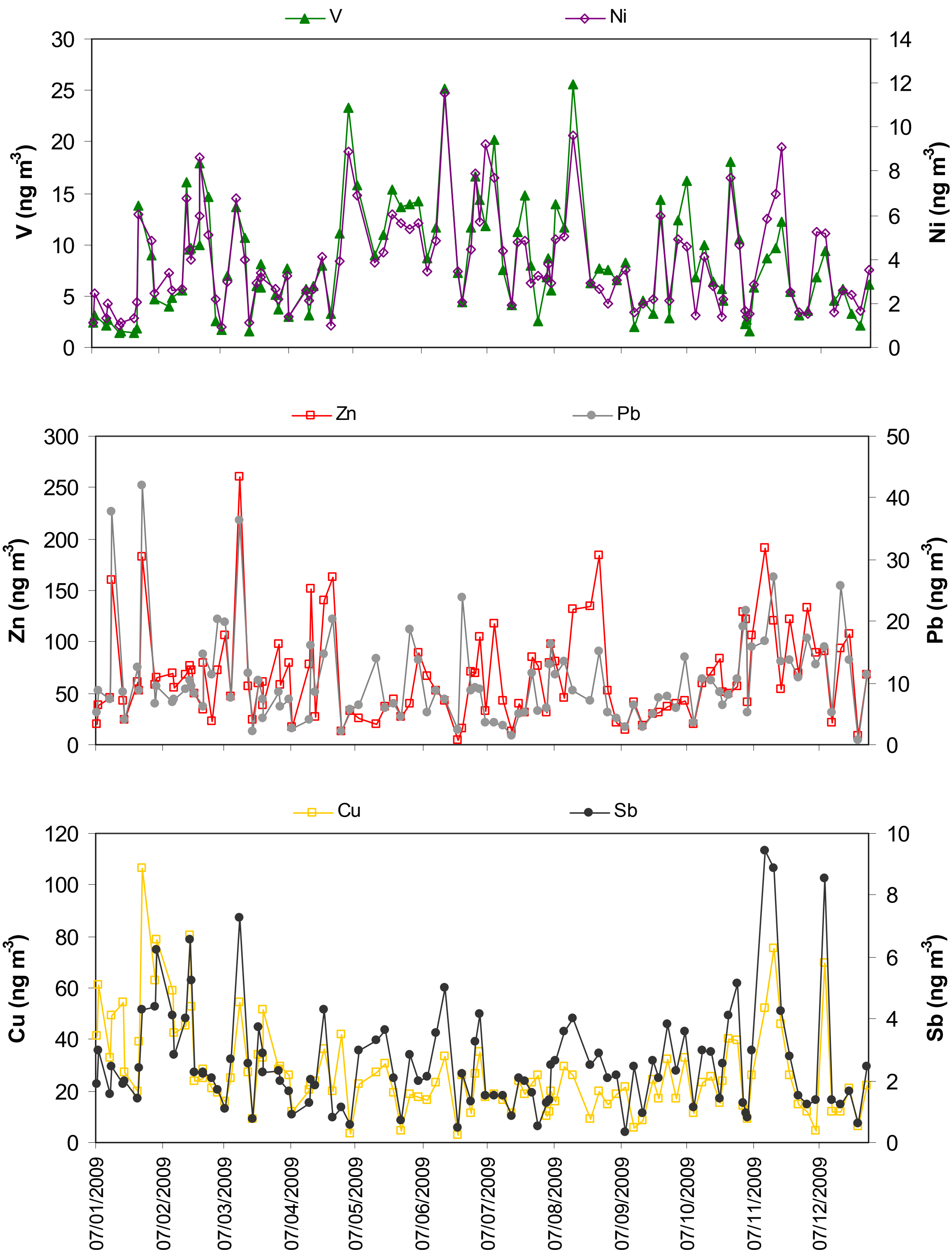

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Figure 9: Daily concentrations of some trace elements measured in PM_{10} at Torre Girona-CSIC in 2009.

HARBOR AREA

At the moment of delivering this report, the harbor authorities only supplied us levels of particulate matter concentration measured at different locations in the harbor area. The information referred to gaseous pollutants presented here has been taken from the annual report elaborated by the harbor authorities. The harbor area of Barcelona (Figure 10) has currently 3 monitoring sites with automatic, manual and meteorological instrumentation to asses on the air quality status. Furthermore, a mobile unit is continuously operative over the harbor area, being in 2009 located in the vicinity of a new power generation plant. Complementarily, 3 sites are equipped with high volume samplers to collect different fractions of PM. Finally, 3 locations are exclusively measuring meteorological parameters.

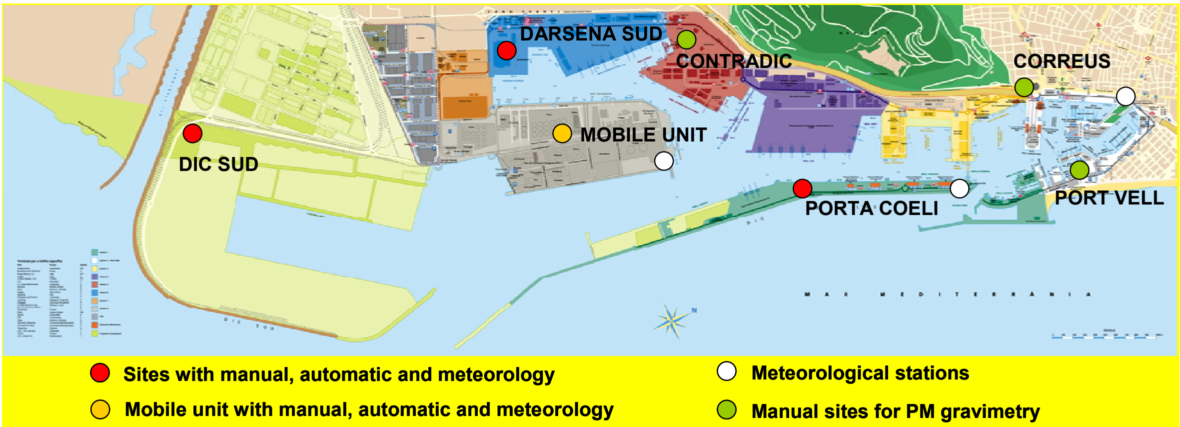

Figure 10: Location of monitoring sites in the harbour area of Barcelona during 2009.

Mean annual levels of PM_{10} and $PM_{2.5}$ in the harbor area during 2009 were generally under the limit values (Table 4) with the exception of some areas affected by construction activities (Porta Coeli and Dic Sud). Slightly higher concentrations than the annual limit value of PM_{10} (fixed in 40 µg m^{-3}) were recorded in Darsena Sud, probably as a consequence of the heavy traffic of trucks in the vicinity of this site. Mean annual levels of $PM_{2.5}$ are under the annual limit value of 25 µg m^{-3} at the two sites in which this parameter has been measured.

Table 4: Mean annual TSP, PM_{10} and $PM_{2.5}$ levels measured at different locations in the harbor area of Barcelona in 2009.

µg m^{-3}	**Correus**	**Dàrsena Sud**	**Dic Sud**	**Estibarna**	**Port Vell**	**Porta Coeli**	**Unitat Mobil**
TSP	79		465			285	
PM_{10}	33	43	83	40	34	60	34
$PM_{2.5}$		20			16		

Attending to the seasonal evolution of the PM_{10} and $PM_{2.5}$ concentrations (Figure 11), it is clear that the highest levels have been measured in wintertime, as observed in the urban background. Once again the stagnation of air masses over the area favors the accumulation of pollutants at an urban and regional scale. The higher intensity of the sea breezes in summer is evident in the lowering of the PM levels in the harbor area, more evident than in the urban background.

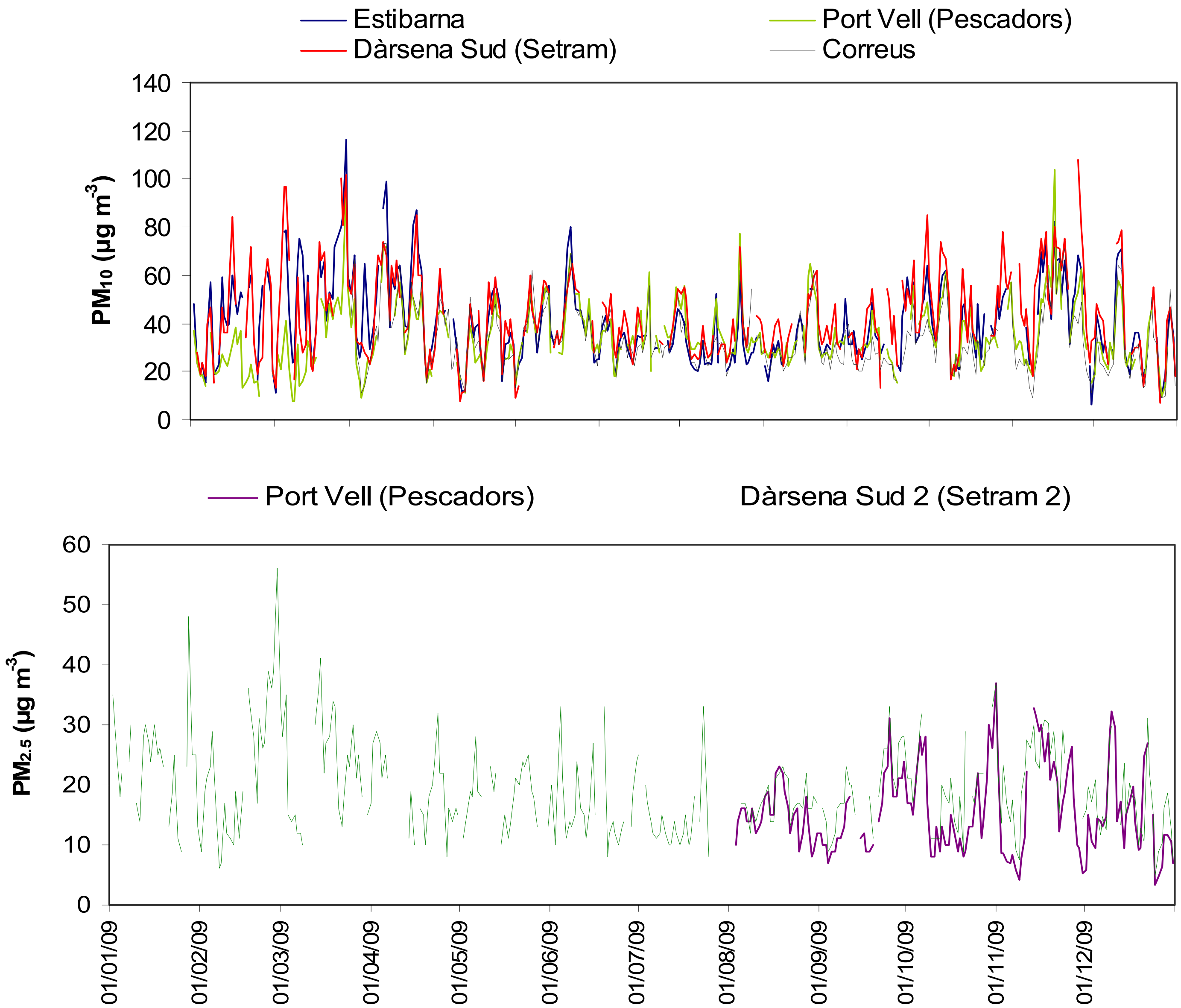

Figure 11: Daily levels of PM_{10} (top) and $PM_{2.5}$ (bottom) recorded at different sites in the harbor area of Barcelona in 2009.

As regards for the gaseous pollutants, nice figures (Figure 12) have been obtained from the annual report available online (http://www.portdebarcelona.es/). They have studied the dependence of the concentrations of different gaseous pollutants together with the wind direction. The results selected here correspond to SO_2 and H_2S (both measured at Darsena Sud), and NO_2 (measured at Mobile unit). In the case of SO_2, a clear NE and SSE origin may be deduced, just from the shipping areas. Concerning the NO_2 concentrations, an evident W-NW origin may be seen, pointing to the city, local roads and ring-roads as the major emission sources of this pollutant in the harbor area. Finally, H_2S concentrations clearly have a south origin, just from a factory using sulfur products.

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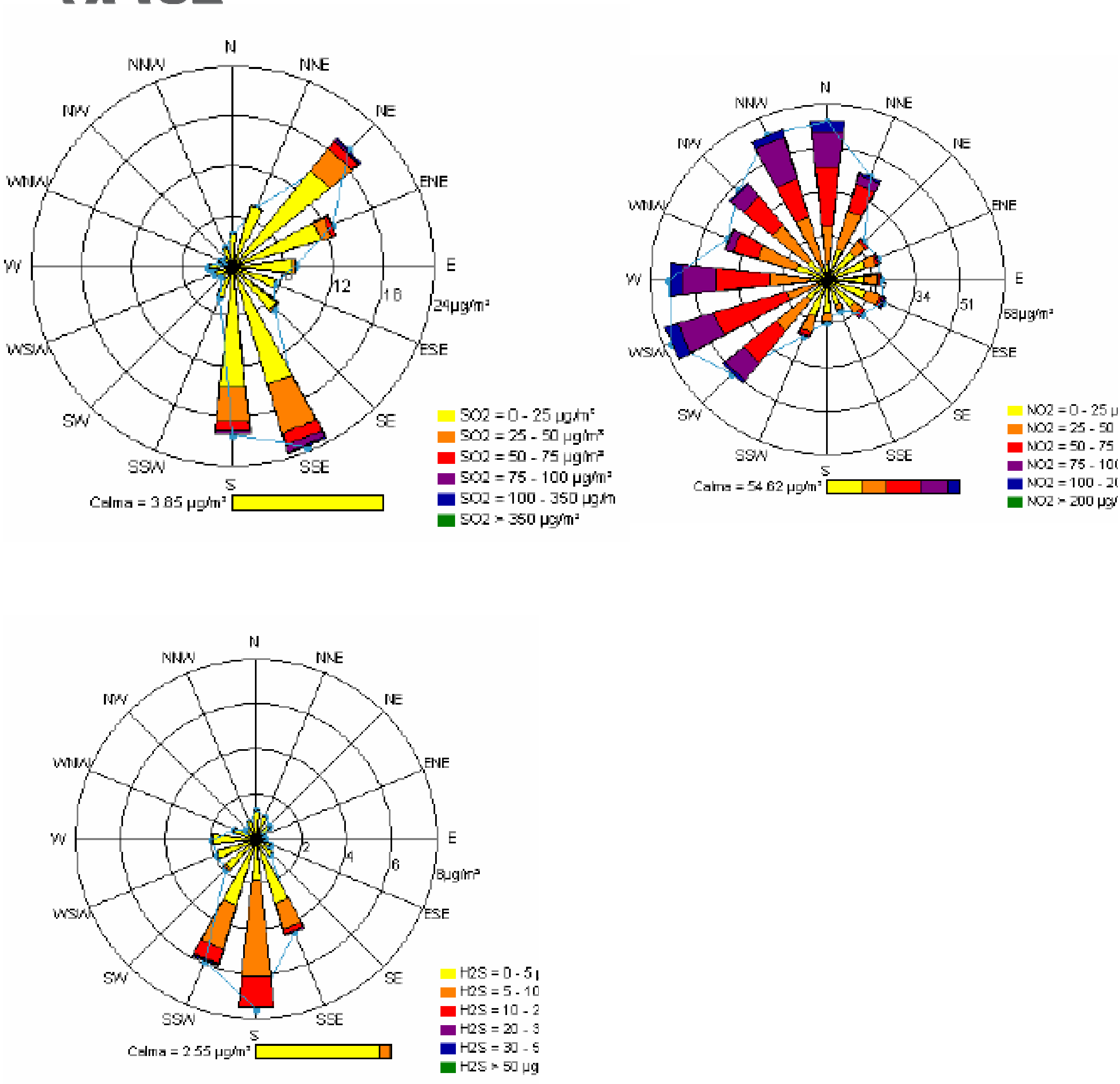

Figure 12: Wind roses for SO_2, NO_2 and H_2S obtained for the Barcelona harbor area in 2009. These figures have been taken from the annual report elaborated by the harbor authorities.

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Finally, in the annual report we have found some interesting results about the time evolution of different atmospheric pollutants in the harbor area of Barcelona since 2000 (Table 5). In general, most of the parameters show a decreasing trend from 2000 to 2009, especially evident in 2009. These trends are probably related to the economic crisis rather than abatement strategies carried out in the last years. Only a slight proportion of these decreasing trends may be related to the mitigation strategies taken at the moment.

Table 5: Mean annual levels from 2000 to 2009 of a number of atmospheric pollutants measured at different locations in the harbor area of Barcelona. This table has been taken from the annual report elaborated by the harbor authorities.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Correus (PST)	86	93	88	95	83	85	99	87	81	79
Dàrsena Sud (PM10)	-----	-----	47	54	56	57	60	53	46	43
Estibarna (PM10)	55	60	46	51	47	52	55	52	40	40
Unitat mòbil (PM10)	74	70	50	50	44	52	61	38	39	32
Port Vell (PM10)	-----	-----	-----	37	36	37	43	40	37	34
Dàrsena Sud (PM2.5)	-----	-----	29	29	27	28	32	32	29	20
SO_2	13	24	15	13	12	6.1	7.1	8.8	10.6	6.2
NO_2	55	63	67	71	55	67	72	48	37	39
H_2S	3.6	8.3	3.8	3.6	4.3	2.8	2.4	2.4	2.7	2.2
CO	0.6	0.6	0.5	0.5	0.3	0.4	0.4	0.2	0.2	0.1
HCT	0.4	0.6	0.5	0.6	0.3	0.5	0.5	0.9	0.3	0.4
O_3	40	41	32	44	43	46	43	45	52	

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5.2 METEOROLOGICAL PARAMETERS

URBAN BACKGROUND

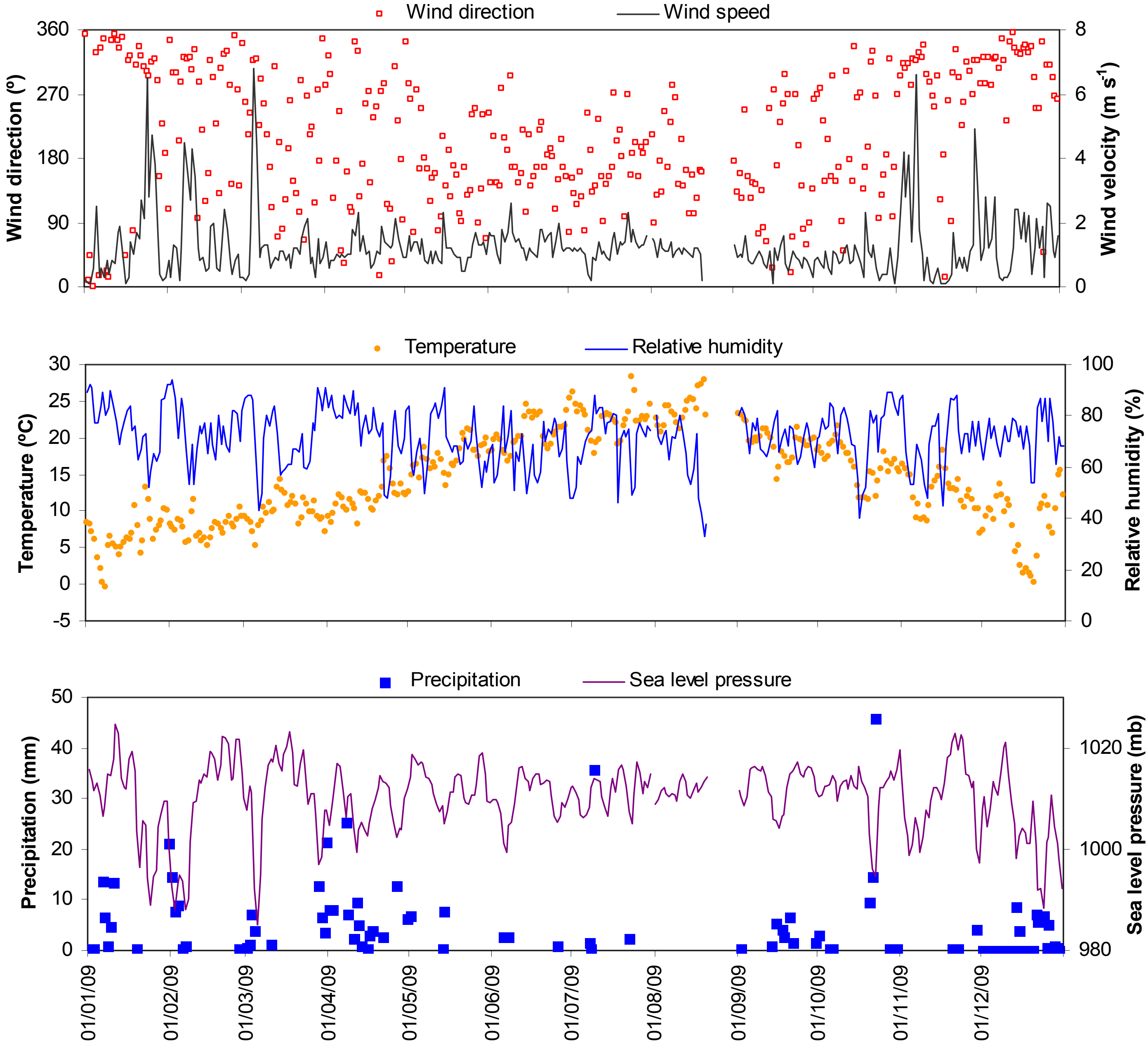

Figure 13: Mean daily values of wind direction, wind velocity, ambient temperature, relative humidity, sea level pressure and precipitation recorded in Barcelona-Collserola in 2009.

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6. ANALYSIS OF PM10 FOR YEAR 2009 FOR NEAR THE PORT STATION

In this section, an analysis of the air quality at “Torre Girona” station is presented. This station was selected because of its direct affection by the port air pollution and due to the immediate access to data. The location of is marked with a blue arrow (Figure 14). The available data from this station are shown in table 1 in paragraph 4.1. The analysis is focused on PM10 particles which is one of the major pollutants that attract the scientific interest, as there is a proven connection with adverse health problems.

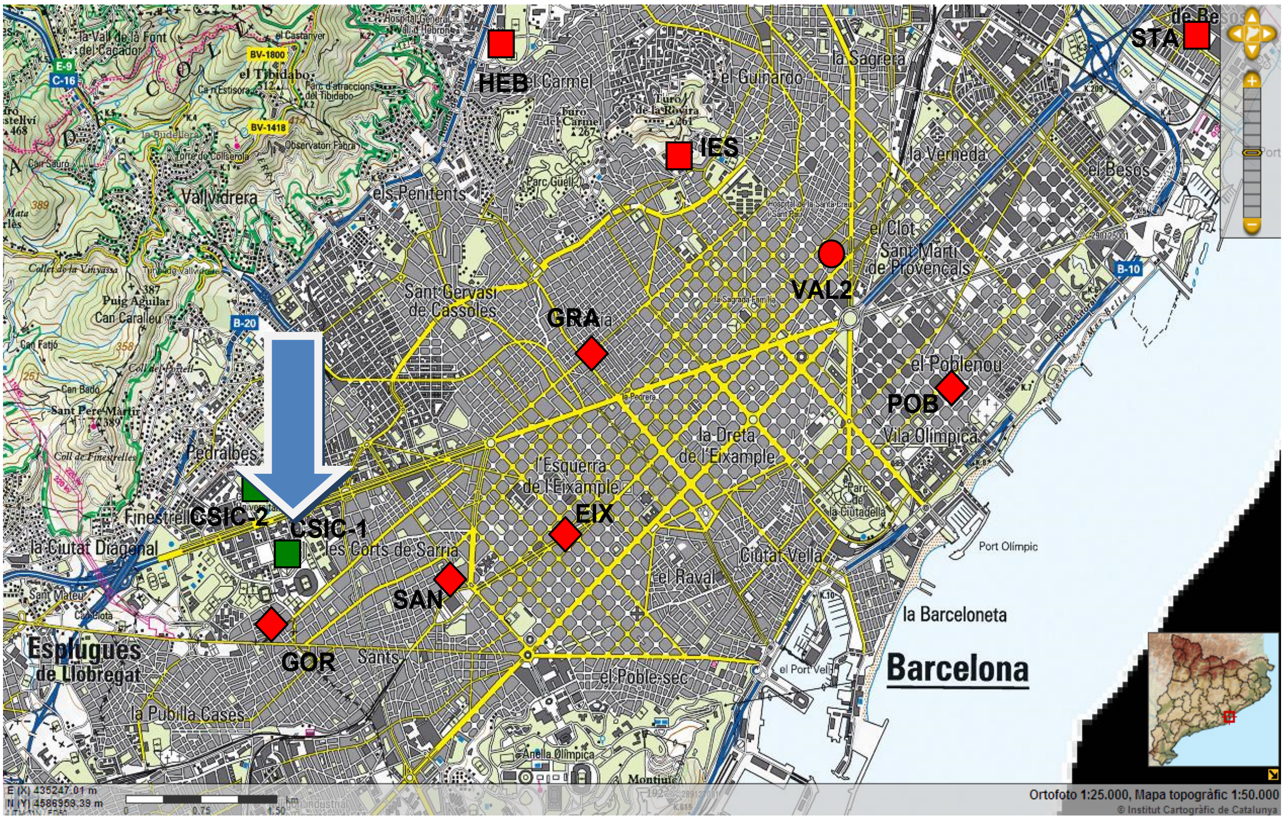

Figure 14: The location of Torre Girona station which is marked with a white arrow

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6.1 PM10 ANALYSIS

A discussion for monthly, daily, hourly variation of PM_{10} during 2009 follows. Furthermore, the correlation between meteorological conditions and PM_{10} levels is examined as well as the contribution of port activities to the air quality of Barcelona.

MONTHLY AVERAGES

The monthly variation of PM_{10} concentration for the year 2009 is presented in the Figure 15. The maximum values correspond to February, March, May and July. As mentioned previously, in winter intense pollution episodes that avoid the dispersion of the atmospheric pollutants are observed. In summer as a result of low atmospheric dispersive conditions affecting the Western Mediterranean, together with higher frequency of African dust episodes and enhanced resuspension processes. The lowest PM levels were recorded in rainy periods (April and September-October), vacation period (August) and windy months (December).

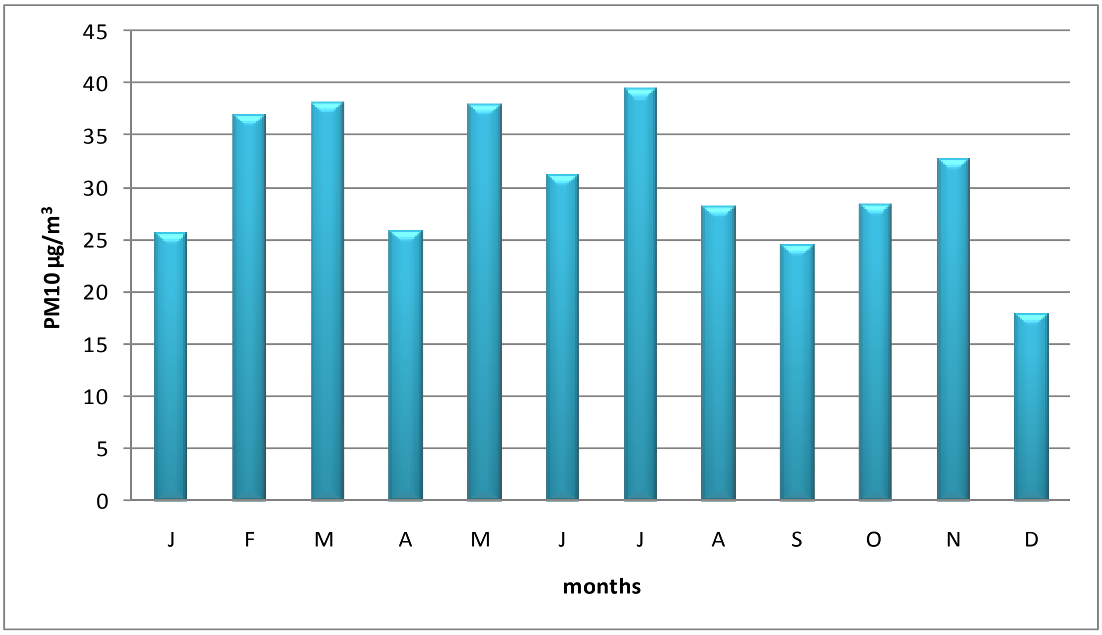

Figure 15: PM10 monthly averages in 2009 (µg/m³).

EXCEEDED DAYS

The new Directive 2008/50/EC highlights that the PM_{10} limit of 50µg/m^3 should not be exceeded for more than 35 times per calendar year. As noticed in Figure 16, the measured concentration exceeded the limit in 38 days, some of theme coinciding with African dust outbreaks but mostly having a dominant anthropogenic origin.

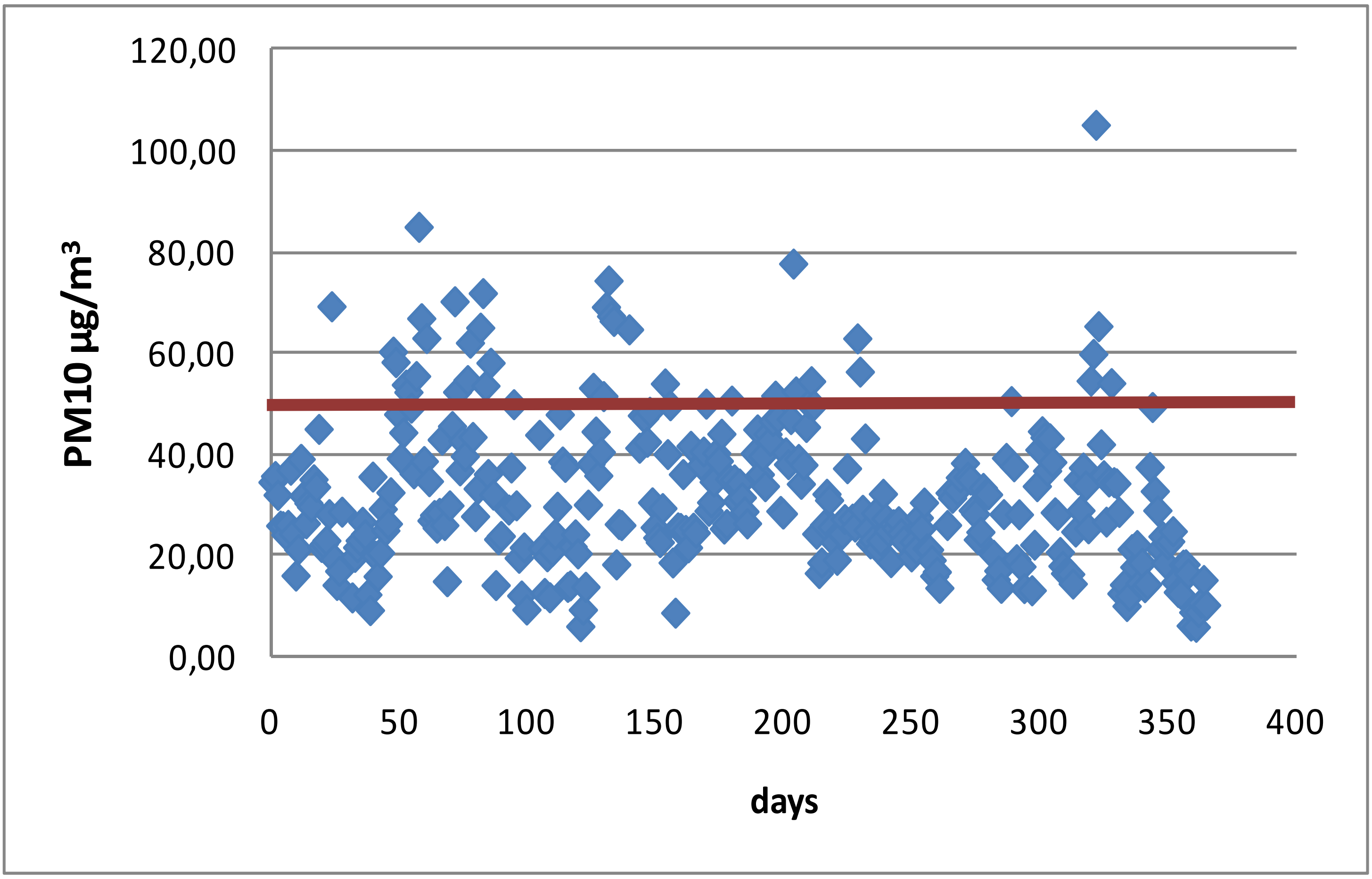

Figure 16: PM10 exceeded days in 2009 (µg/m^3).

DAILY AVERAGES

The daily variation of PM_{10} concentration during 2009 is presented in the Figure 17. The highest values are noticed during both warm and cold period, as discussed in previous paragraph. Important weekly cycles are evidenced, with highest PM levels in the middle of the week and clearly lower on Sundays. The highest PM records are mostly recorded under winter stagnating conditions and/or under African dust influence.

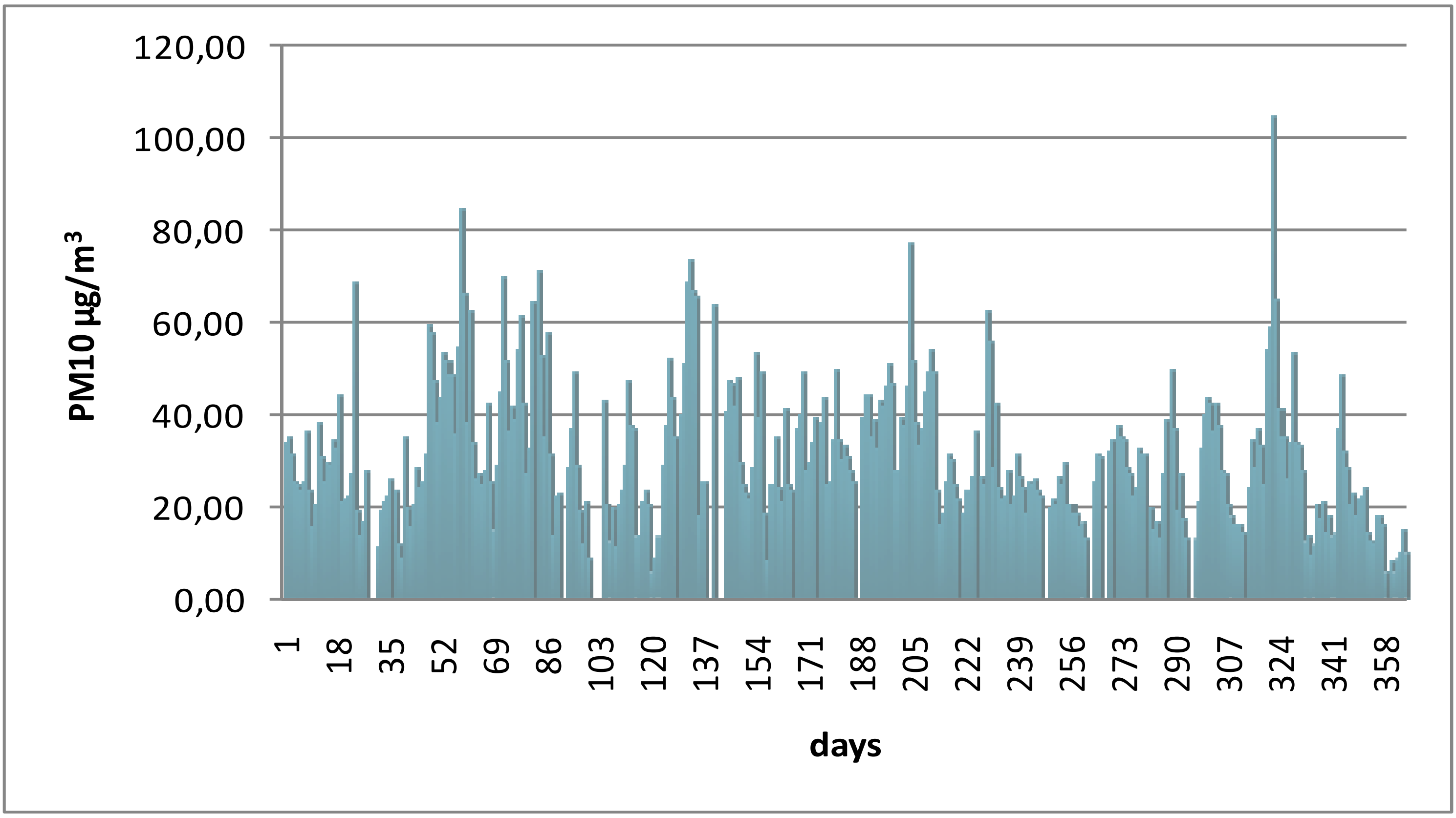

Figure 17: PM10 daily averages in 2009 (µg/m³).

AVERAGES PER DAY

The average PM_{10} concentration for each day of the week for the year 2009 is shown in figure 18. As expected, PM_{10} levels increase progressively during the week to reach the maximum on Thursdays. On Sundays, minimum concentrations of PM_{10} are recorded, which is correlated with the lower traffic displacements.

A similar trend may be observed in the levels of Black Carbon, typically tracing the traffic emissions.

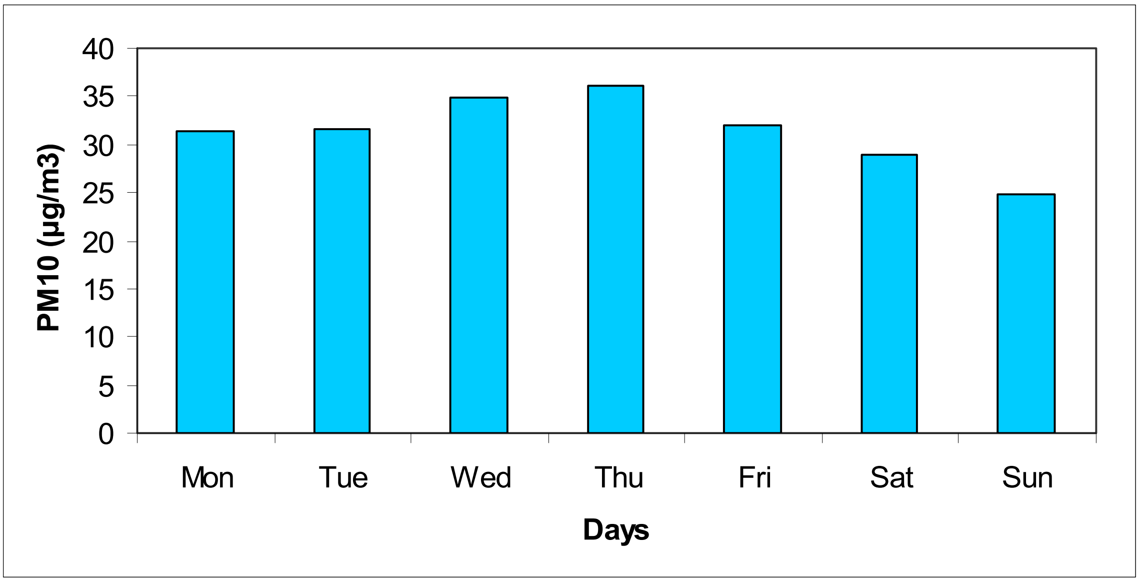

Figure 18a: PM10 averages per day in 2009 (µg/m^3).

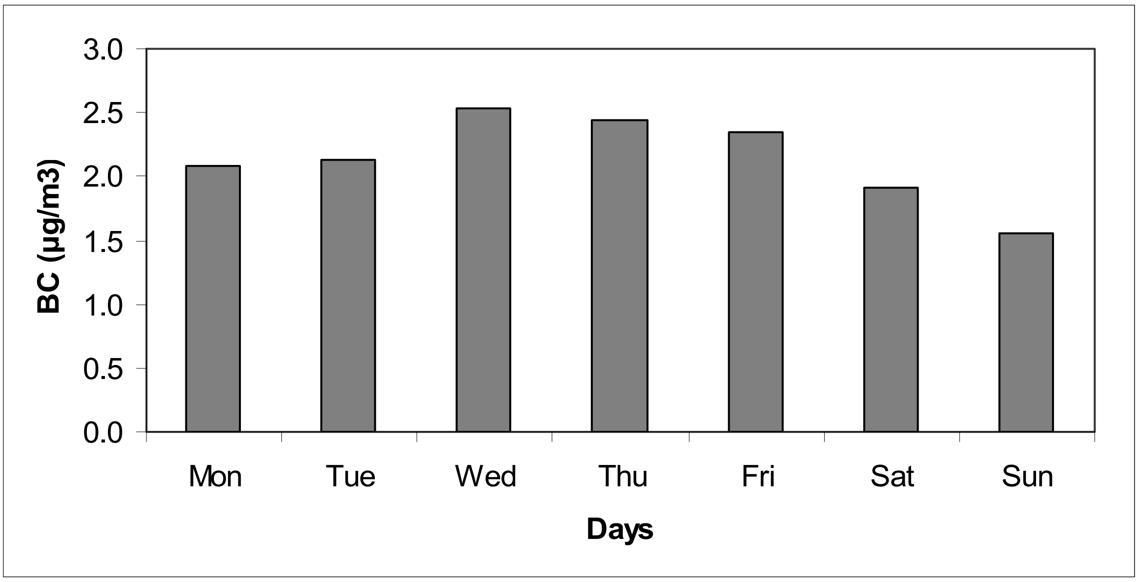

Figure 18b: BC averages per day in 2009 (µg/m^3).

HOURLY AVERAGES

Figure 19 presents the mean hourly (from 01:00 to 24:00) variation of PM_{10} in 2009. As it can be noticed, concentration levels increase during early morning hours owing to the intense vehicles circulation starting at that time. Nevertheless the maximum concentrations are recorded between 12-14 p.m. This behavior is due to the enhanced resuspension processes as a consequence of the increase in wind velocity. Concentration levels during afternoon remain elevated while following a decreasing trend during night, when the road traffic activity decreases in parallel to the lowering in the wind velocity.

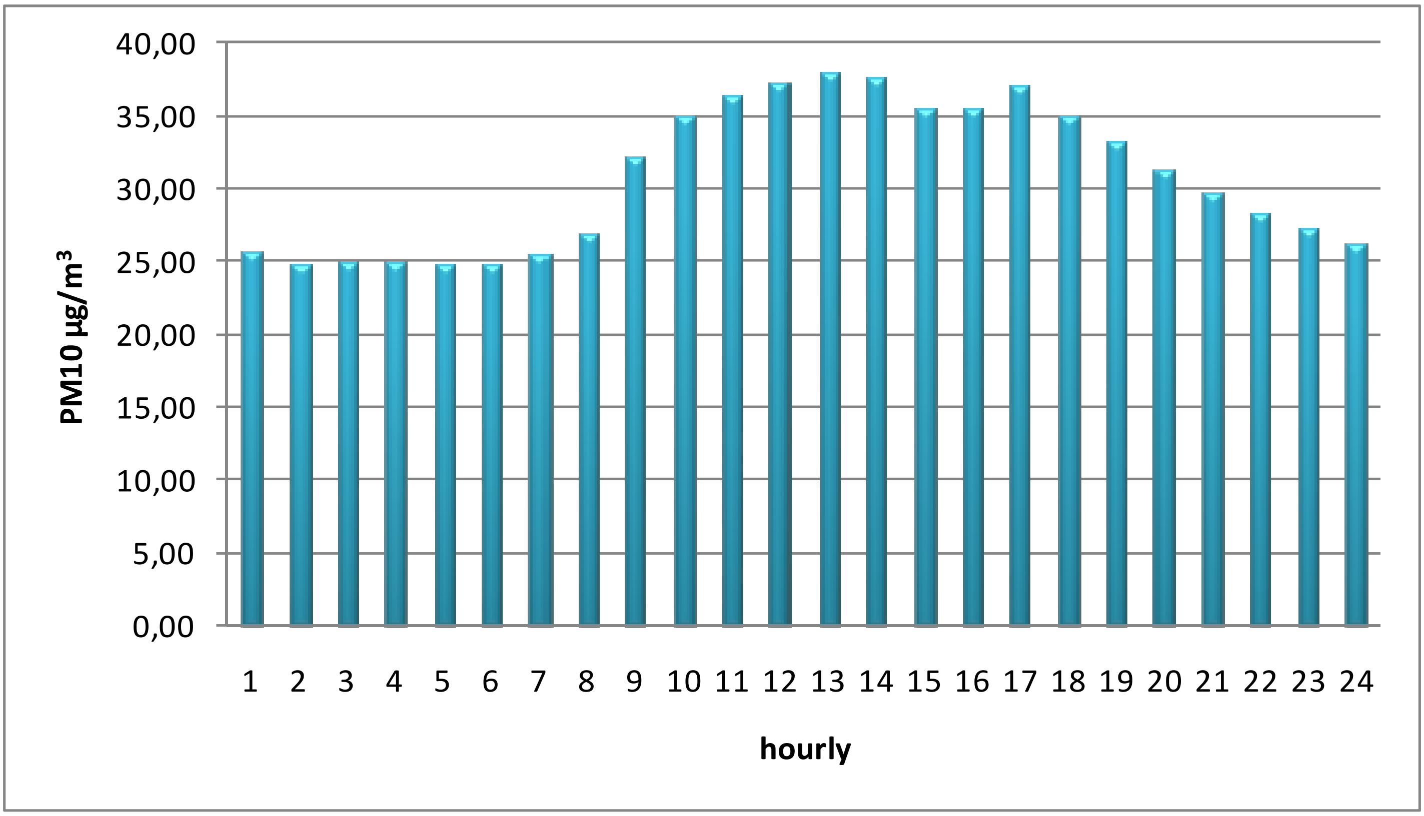

Figure 19: Hourly PM10 averages in 2009 (μg/m³).

6.2 WIND ROSES

The meteorological parameters which can affect pollutants' levels in atmosphere are:

- Wind speed
- Wind direction
- Atmospheric stability
- Solar radiation
- Precipitation
- Humidity
- Temperature

WIND SPEED ROSE

Figure 20 presents the daily *wind-speed direction* rose-diagram for 2009. The diagram axis presents the frequency of the observed values of wind speed in % values. Daily data (in m/s and degrees respectively) were provided by "Torre Girona" station. As shown, maximum daily values (up to 7m/s) for wind speed were observed mainly during periods with prevailing north-western wind, coinciding with strong Atlantic air masses advections.

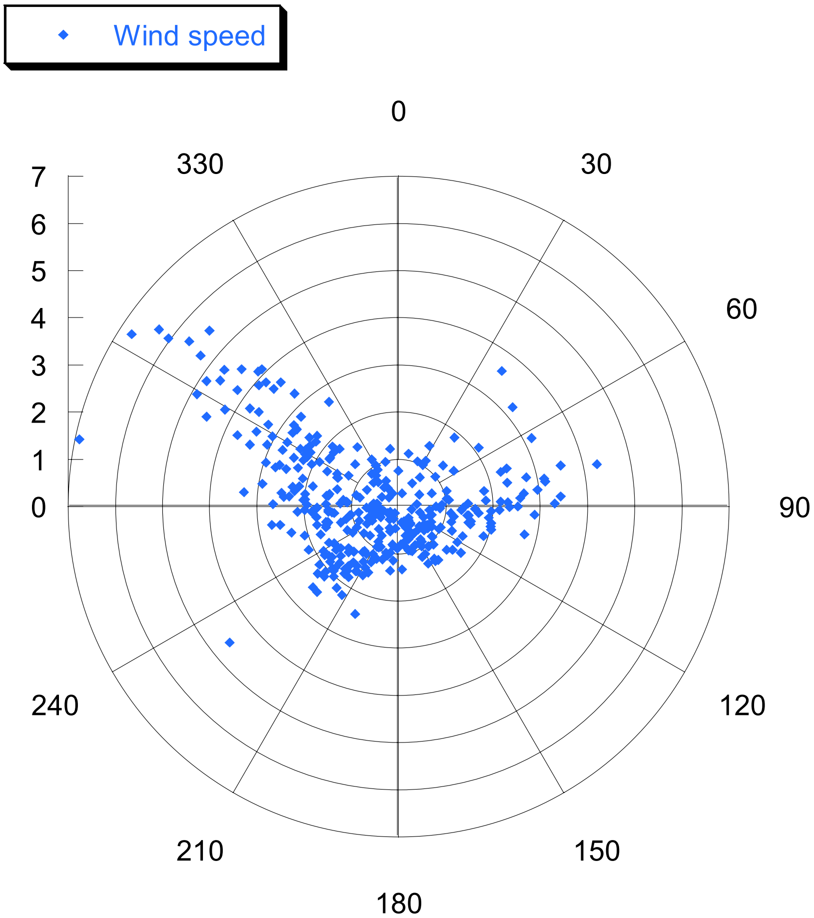

Figure 20: PM10 concentration rose (µg/m³, degrees) and wind speed rose (m/s, degrees) in 2009 – Activities in Barcelona

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WIND DIRECTION ROSE

Figure 21 presents the PM_{10} concentration (in μg/m^3)-*wind direction* (in degrees) rose-diagram in 2009. The diagram axis presents the frequency of the observed values of PM_{10} concentration in %values. As observed, there is not a clear relation between wind direction and PM_{10} concentrations which siuggest that most of the PM_{10} in the urban background of Barcelona is of a local origin. The North direction appears to be the cleanest.

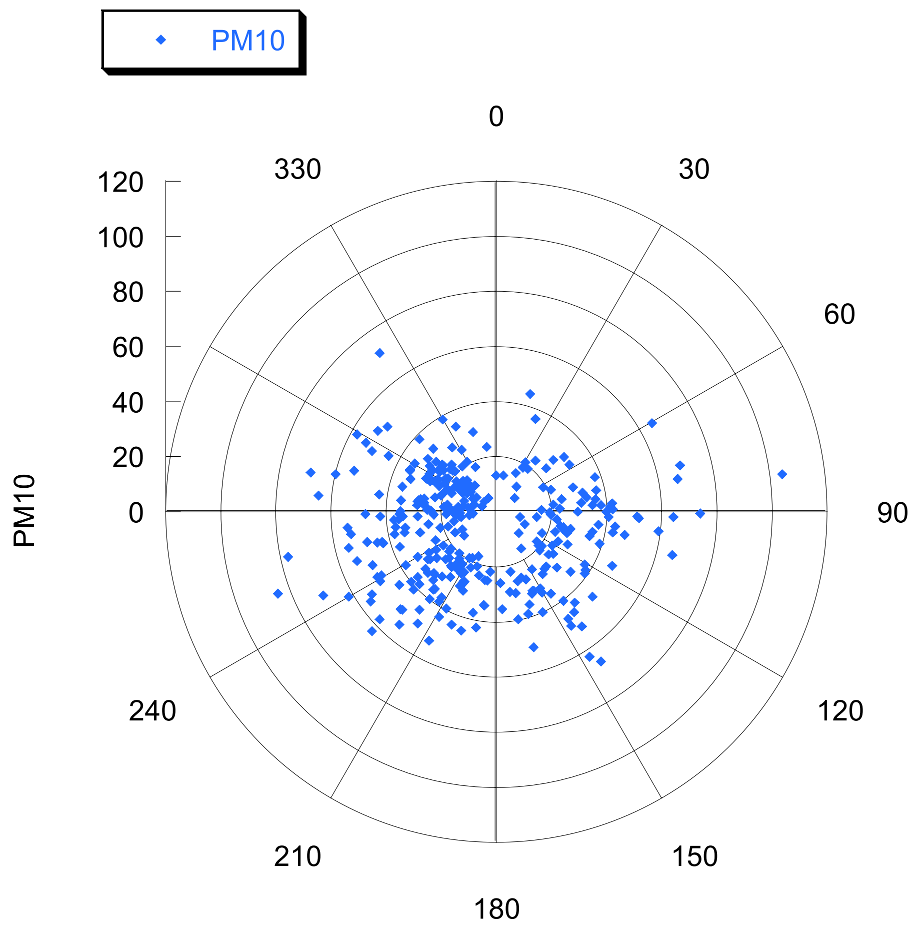
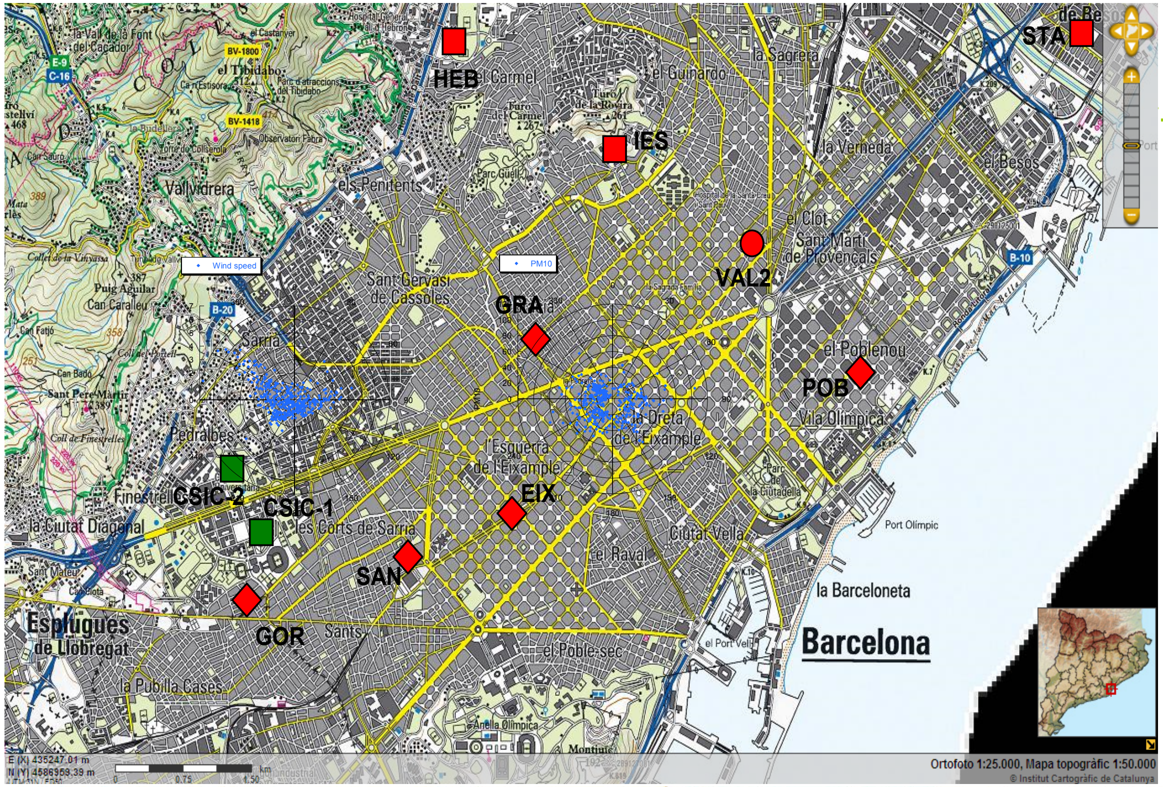


Figure 21: Wind speed rose in 2009 (m/s, degrees)



INTERCOMPARISON OF ROSES

Highest winds are associated with NW wind directions but they are related to low PM levels. The highest PM levels are usually recorded during SW winds, coinciding with the evolution of the sea breeze during the day (from approximately 90º to about 240º).

Figure 22: PM10 concentration rose (µg/m³, degrees) and wind speed rose (m/s, degrees) for year 2009 –Activities in Barcelona

7. FRAMEWORK ANALYSIS

7.1 INTRODUCTION

By itself, technology is as likely to harm the environment as to help it. That's why laws and regulations have been such an important part of tackling the problem of pollution. Many once-polluted cities now have relatively clean air and water, largely thanks to anti-pollution laws introduced during the mid-20th century. In England, following the 1952 smog tragedy that killed thousands of people in the capital city of London, the government introduced its Clean Air Act of 1956, which restricted how and where coal could be burned and where furnaces could be sited and forced people to build smokestacks higher to disperse pollution. In the United States, a series of Clean Air Acts were passed between the 1960s and 1990s. The 1990 Pollution Prevention Act went even further, shifting the emphasis from cleaning up pollution to preventing it ever happening in the first place.

National laws are of little help in tackling trans-boundary pollution (when air pollution from one country affects neighboring countries or continents), but that doesn't mean the law is useless in such cases. The creation of the European Union (now comprising around 30 different countries) has led to many Europe-wide environmental acts, called directives. These force the member countries to introduce their own, broadly similar, national environmental laws that ultimately cover the entire European region. For example, the 1976 European Bathing Water Directive tried to enforce minimum standards of water quality for beaches and coastal areas across Europe to reduce pollution from sewage disposal, while the 1996 European Directive on Integrated Pollution Prevention and Control (IPPC) attempted to limit air and water pollution from industry. Other successful international laws include the Convention on Long-Range Trans-boundary Air Pollution (1979), which has helped to reduce sulfur dioxide emissions from power plants and, of course, the Montreal Protocol, which successfully brought 196 countries together to target ozone depletion. Unfortunately, attempts to control global warming through international laws and agreements have so far proved less successful.

Any effective program regulating maritime emissions will need to take account of the legal circumstances that govern maritime activity. Indeed, the international nature of shipping means that international regulations need to be accounted for in considering the legal context. To that end, the following section provides a very brief discussion of the existing international legal framework and its relevance for shipping.

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7.2 INTERNATIONAL FRAMEWORK

INTRODUCTION

Exhaust emissions from ships are considered to be a significant source of air pollution, with 18-30% of all nitrogen oxide and 9% of sulphur oxide pollution. The 15 biggest ships emit about as much sulphur oxide pollution as all cars combined. Sulfur in the air creates acid rain which damages crops and buildings. When inhaled the sulfur is known to cause respiratory problems and even increase the risk of a heart attack. According to Irene Blooming, a spokeswoman for the European environmental coalition Seas at Risk, the fuel used in oil tankers and container ships is high in sulfur and cheaper to buy compared to the fuel used for domestic land use. "A ship lets out around 50 times more sulfur than a lorry per metric ton of cargo carried." Cities in the U.S. like Long Beach, Los Angeles, Houston, Galveston, and Pittsburgh see some of the heaviest shipping traffic in the nation and have left local officials desperately trying to clean up the air. The increasing trade between the U.S. and China is helping to increase the number of vessels navigating the Pacific and exacerbating many of the environmental problems. To maintain the level of growth China is currently experiencing, large amounts of grain are being shipped to China by the boat load. The number of voyages is expected to continue increasing. 3.5% to 4% of all climate change emissions are caused by shipping.

Although international regulation in other environmental areas is long standing, international efforts to reduce air emissions from ships are relatively new. The need for measures to reduce air pollutant emissions from international shipping has been on the agenda since the late 1980s. After years of negotiation, a first agreement – the Annex VI to the IMO's MARPOL Convention – was adopted in 1997. But even at the time of adoption it was widely recognized as being insufficient.

LEGISLATION AUTHORITIES

There are some common elements that an emissions policy for ships must include; one of them is an appropriate legal basis, which is also related to an effective monitoring and enforcement regime. Any new policy to control emissions would have to be in conformity with international and EU law. The United Nations Convention on the Law of the Sea ("UNCLOS") sets out the basic legal framework that governs international shipping. The Convention gives some support for the control of air emissions (Article 212), but this is balanced against the right of ships to innocent passage without being subject to any charges, except for services received. Relevant are also the current international environmental regulations, notably the International Maritime Organization's ("IMO's"), International Convention on the Prevention of Pollution from Ships ("MARPOL"), which sets a global limit on fuel sulphur content, and also designates Sulphur Oxide Emission Control Areas ("SECAs") in the North Sea and the Baltic Sea. MARPOL also sets NOx emissions standards via the IMO "NOx curve". (The 2005 EU Sulphur Directive imposes additional requirements to limit fuel sulphur content in SECAs, imposes restrictions on passenger vessels throughout the EU, and requires ships at berth to use 0.1 percent sulphur fuel or better from 2010 onward. The considered policies must be consistent with the existing legal framework for addressing emissions from shipping, although it is likely that certain details need to be worked out for each one.

The mentioned authorities are based on studies of emissions from ships. This is complicated by the fact that fuel consumption and emission factors are highly variable, depending on engine size, age, and load, on existing emission control technologies, on fuel composition, and on ambient conditions. In general, monitoring can be divided into periodic and continuous monitoring (periodic monitoring is cheaper but less accurate than continuous monitoring) and into monitoring of the fuel used or direct measurement of exhaust emissions (fuel-based is cheaper but less accurate than the monitoring of exhaust emissions). The appropriate trade-off between cost and accuracy is likely to depend on the instrument used, as requirements differ between different approaches. Additional considerations include the ability to keep track of emissions within a specific geographical area, which poses significant challenges without continuous monitoring.

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UNITED NATIONS CONVENTION ON THE LAW OF SEA (UNCLOS)

The United Nations Convention on the Law of the Sea ("UNCLOS"), formally codified in 1982, is the basic legal framework that governs international shipping. As noted in Davies et al. (BMT 2000), states operate in three capacities: as flag, port, and coastal states. UNCLOS gives flag states the primary authority to impose environmental regulations (including those related to air emissions) on marine sources through their responsibility to enforce international laws. The roles of other jurisdictions—i.e., port and coastal states— "have traditionally been more limited" (BMT 2000). However, the language in UNCLOS suggests that non-flag states do have some authority to regulate marine emissions.

UNCLOS guarantees port states the right to "establish particular requirements for the prevention, reduction and control of pollution of the marine environment as a condition for the entry of foreign vessels into their ports or internal waters" (Article 211, paragraph 2). In addition, UNCLOS gives each coastal state the authority to control in-port emissions through its right to "exclude vessels from its ports or place conditions upon their entry" (BMT 2000). Although coastal states have limited authority to regulate general pollution under UNCLOS, they appear to have greater power in the regulation of air emissions. Articles 212 and 222 of UNCLOS, which govern air emissions from marine vessels, are somewhat vague with respect to the jurisdictional limits of coastal states. Indeed, when it comes to air emissions, a state's jurisdiction is defined with respect to infringement upon its airspace. Article 212 allows states to "adopt laws and regulations to prevent, reduce and control pollution of the marine environment from or through the atmosphere, applicable to the air space under their sovereignty." While UNCLOS gives some jurisdiction to port and coastal states in the control of marine air emissions, the Convention professes a clear preference for international regulations wherever possible. IMO would manage any such international regulations. Though IMO is explicitly mentioned only once in UNCLOS (Article 2 of Annex VIII), UNCLOS frequently refers to the "competent international organization" in connection with the adoption of international shipping safety and pollution standards; in most cases, this phrasing (i.e., "the competent international organization") has been interpreted to refer exclusively to IMO. IMO is generally responsible for the oversight of international shipping activity. In particular, IMO's charter explicitly charges it with the oversight of safety and antipollution efforts in international shipping. Since its creation in 1948, IMO has established a variety of measures to enforce increased safety and reduced pollution from international shipping. A major limitation affecting any jurisdictional authority relates to the right of innocent passage, which is also codified in UNCLOS. UNCLOS Part 2, Section 3 guarantees innocent right of passage for foreign-flag vessels in the territorial sea without being subject to any charges, except for services received. This restriction is clearly relevant to the control of emissions from shipping, since under a strict reading of this requirement, payments or charges related to reducing emissions from foreign-flag vessels would have to be embodied in a framework of providing services to those vessels. In addition, one aspect of the right of innocent passage, articulated in Article 21 of UNCLOS, precludes coastal states from enforcing any regulations that apply to the design, construction, manning or equipment of foreign vessels. This could be interpreted as restricting the ability of coastal states to require pollution abatement equipment or engine modifications on foreign vessels. A reason for considering market-based approaches to emissions regulations is that they offer a flexible means of complying with environmental regulations, and therefore may make it easier to promote the use of low-emissions technologies in certain sea areas, without impinging upon ships' right of innocent passage.

INTERNATIONAL MARITIME ORGANIZATION (IMO)

International Maritime Organization (IMO) is an agency of the United Nations which has been formed to promote maritime safety. It was formally established by an international conference in Geneva in 1948, and became active in 1958 when the IMO Convention entered into force (the original name was the Inter-Governmental Maritime Consultative Organization, or IMCO, but the name was changed in 1982 to IMO). IMO currently groups 167 Member States and 3 Associate Members.

IMO ship pollution rules are contained in the "International Convention on the Prevention of Pollution from Ships", known as MARPOL 73/78. On 27 September 1997, the MARPOL Convention has been amended by the "1997 Protocol", which includes Annex VI titled "Regulations for the Prevention of Air Pollution from Ships". MARPOL Annex VI sets limits on NOx and SOx emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances.

The IMO emission standards are commonly referred to as Tier I...III standards. The Tier I standards were defined in the 1997 version of Annex VI, while the Tier II/III standards were introduced by Annex VI amendments adopted in 2008, as follows:

1997 Protocol (Tier I)—The "1997 Protocol" to MARPOL, which includes Annex VI, becomes effective 12 months after being accepted by 15 States with not less than 50% of world merchant shipping tonnage. On 18 May 2004, Samoa deposited its ratification as the 15th State (joining Bahamas, Bangladesh, Barbados, Denmark, Germany, Greece, Liberia, Marshal Islands, Norway, Panama, Singapore, Spain, Sweden, and Vanuatu). At that date, Annex VI was ratified by States with 54.57% of world merchant shipping tonnage.

Accordingly, Annex VI entered into force on 19 May 2005. It applies retroactively to new engines greater than 130 kW installed on vessels constructed on or after January 1, 2000, or which undergo a major conversion after that date. The regulation also applies to fixed and floating rigs and to drilling platforms (except for emissions associated directly with exploration and/or handling of sea-bed minerals). In anticipation of the Annex VI ratification, most marine engine manufacturers have been building engines compliant with the above standards since 2000.

2008 Amendments (Tier II/III)—Annex VI amendments adopted in October 2008 introduced (1) new fuel quality requirements beginning from July 2010, (2) Tier II and III NOx emission standards for new engines, and (3) Tier I NOx requirements for existing pre-2000 engines.

The revised Annex VI enters into force on 1 July 2010. By October 2008, Annex VI was ratified by 53 countries (including the Unites States), representing 81.88% of tonnage.

EMISSION CONTROL AREAS

Two sets of emission and fuel quality requirements are defined by Annex VI: (1) global requirements, and (2) more stringent requirements applicable to ships in Emission Control Areas (ECA). An Emission Control Area can be designated for SOx and PM, or NOx, or all three types of emissions from ships, subject to a proposal from a Party to Annex VI.

Existing Emission Control Areas include:

- Baltic Sea (SOx, adopted: 1997 / entered into force: 2005)
- North Sea (SOx, 2005/2006)
- North American ECA, including most of US and Canadian coast (NOx & SOx, 2010/2012).

EMISSION STANDARTS

NOx

NOx emission limits are set for diesel engines depending on the engine maximum operating speed (n, rpm), as shown in Table 6 and presented graphically in Figure 23. Tier I and Tier II limits are global, while the Tier III standards apply only in NOx Emission Control Areas.

Table 6: MARPOL Annex VI NOx Emission Limits

Tier	Date	NOx Limit, g/kWh		
		n < 130	**130 ≤ n < 2000**	**n ≥ 2000**
Tier I	2000	17.0	$45 \cdot n^{-0.2}$	9.8
Tier II	2011	14.4	$44 \cdot n^{-0.23}$	7.7
Tier III	2016†	3.4	$9 \cdot n^{-0.2}$	1.96

† In NOx Emission Control Areas (Tier II standards apply outside ECAs).

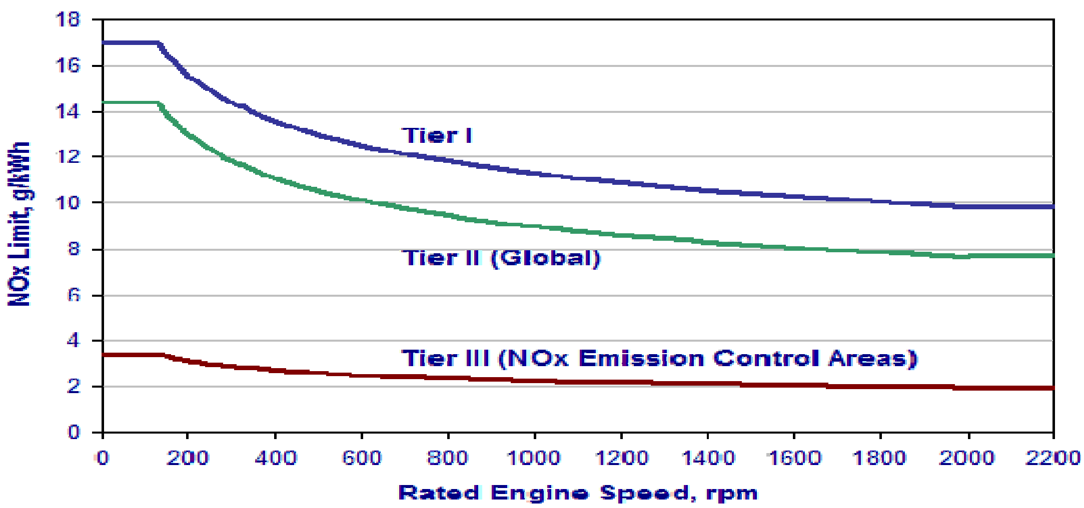

Figure 23: MARPOL Annex VI NOx Emission Limits

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Tier II standards are expected to be met by combustion process optimization. The parameters examined by engine manufacturers include fuel injection timing, pressure, and rate (rate shaping), fuel nozzle flow area; exhaust valve timing, and cylinder compression volume.

Tier III standards are expected to require dedicated NOx emission control technologies such as various forms of water induction into the combustion process (with fuel, scavenging air, or in-cylinder), exhaust gas recirculation, or selective catalytic reduction.

Pre-2000 Engines. Under the 2008 Annex VI amendments, Tier I standards become applicable to existing engines installed on ships built between 1st January 1990 to 31st December 1999, with a displacement ≥ 90 liters per cylinder and rated output ≥ 5000 kW, subject to availability of approved engine upgrade kit.

Testing. Engine emissions are tested on various ISO 8178 cycles (E2, E3 cycles for various types of propulsion engines, D2 for constant speed auxiliary engines, C1 for variable speed and load auxiliary engines). Addition of not-to-exceed (NTE) testing requirements to the Tier III standards is being debated. NTE limits with a multiplier of 1.5 would be applicable to NOx emissions at any individual load point in the E2/E3 cycle. Engines are tested using distillate diesel fuels, even though residual fuels are usually used in real life operation.

Further technical details pertaining to NOx emissions, such as emission control methods, are included in the mandatory “NOx Technical Code”, which has been adopted under the cover of “Resolution 2”.

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SULFUR

Annex VI regulations include caps on sulfur content of fuel oil as a measure to control SOx emissions and, indirectly, PM emissions (there are no explicit PM emission limits). Special fuel quality provisions exist for SOx Emission Control Areas (SOx ECA or SECA). The sulfur limits and implementation dates are listed in Table 19 and illustrated in Figure 24.

Table 7: MARPOL Annex VI Fuel Sulfur Limits

<table>
<tr><th rowspan="2">Date</th><th colspan="2">Sulfur Limit in Fuel (% m/m)</th></tr>
<tr><th>SOx ECA</th><th>Global</th></tr>
<tr><td>2000</td><td>1.5%</td><td rowspan="2">4.5%</td></tr>
<tr><td>2010.07</td><td rowspan="2">1.0%</td></tr>
<tr><td>2012</td><td rowspan="2">3.5%</td></tr>
<tr><td>2015</td><td rowspan="2">0.1%</td></tr>
<tr><td>2020[a]</td><td>0.5%</td></tr>
</table>

a - alternative date is 2025, to be decided by a review in 2018

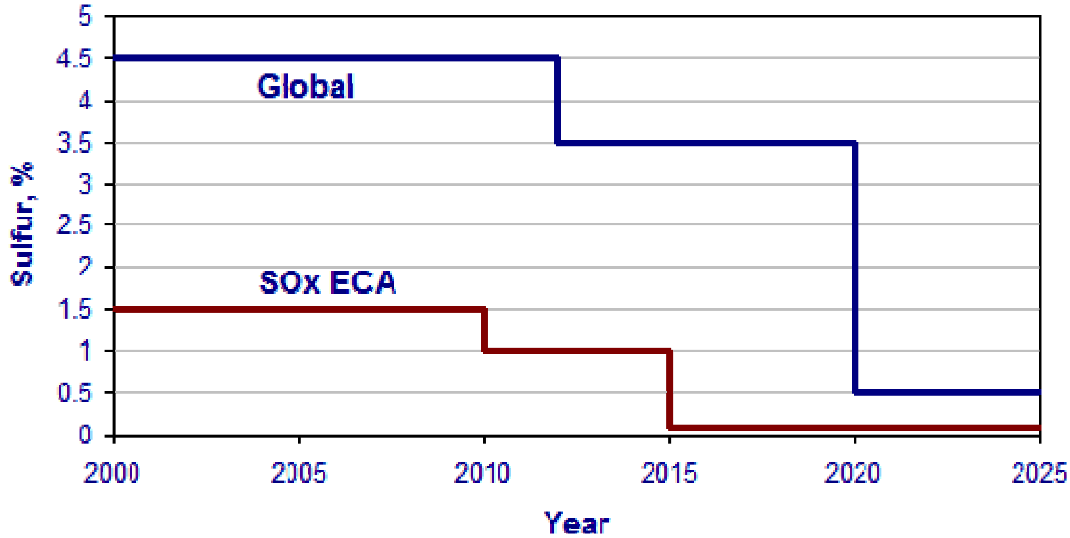

Figure 24: MARPOL Annex VI Fuel Sulfur Limits

Heavy fuel oil (HFO) is allowed provided that it meets the applicable sulfur limit (i.e., there is no mandate to use distillate fuels).

Alternative measures are also allowed (in the SOx ECAs and globally) to reduce sulfur emissions, such as through the use of scrubbers. For example, in lieu of using the 1.5% S fuel in SOx ECAs, ships can fit an exhaust gas cleaning system or use any other technological method to limit SOx emissions to ≤ 6 g/kWh (as SO_2).

OTHER PROVISIONS

Ozone Depleting Substances. Annex VI prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

Annex VI also prohibits the incineration on board ships of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Compliance. Compliance with the provisions of Annex VI is determined by periodic inspections and surveys. Upon passing the surveys, the ship is issued an "International Air Pollution Prevention Certificate", which is valid for up to 5 years. Under the "NOx Technical Code", the ship operator (not the engine manufacturer) is responsible for in-use compliance.

Greenhouse Gas Emissions. Annex VI does not cover the emission of greenhouse gases from ships. In November 2003, the IMO adopted resolution A.963(23) on IMO Policies and Practices related to the Reduction of Greenhouse Gas Emissions from Ships.

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7.3 EUROPEAN

INTRODUCTION

Most European ports are free to determine their own dues and therefore also free to introduce dues differentiation. Indeed, dues are already commonly differentiated according to vessel class or particular vessel characteristics. The addition of environmental criteria is not likely to require new institutions, provided that ports can easily verify the status of ships with respect to the differentiation criteria it has in place. In the absence of existing institutions to carry out certification of ships according to the desired criteria, this may require that procedures be put in place.

AIR QUALITY STANDARTS

Humans can be adversely affected by exposure to air pollutants in ambient air. In response, the European Union has developed an extensive body of legislation which establishes health based standards and objectives for a number of pollutants in air. These standards and objectives are summarized in the table below. These apply over differing periods of time because the observed health impacts associated with the various pollutants occur over different exposure times.

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Table 8: Air quality standards per pollutant

Pollutant	Concentration	Averaging period	Legal nature	Permitted exceedences each year
Fine articles (PM2.5)	25 µg/m3***	1 year	Target value enters into force 1.1.2010 Limit value enters into force 1.1.2015	n/a
PM10	50 µg/m3	24 hours	Limit value enters into force 1.1.2005**	35
	40 µg/m3	1 year	Limit value enters into force 1.1.2005**	n/a
Sulphur dioxide (SO2)	350 µg/m3	1 hour	Limit value enters into force 1.1.2005	24
	125 µg/m3	24 hours	Limit value enters into force 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m3	1 hour	Limit value enters into force 1.1.2010	18
	40 µg/m3	1 year	Limit value enters into force 1.1.2010*	n/a
Lead (Pb)	0.5 µg/m3	1 year	Limit value enters into force 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applies from 1.1.2005 to 31.12.2009)	n/a
Carbon	10 mg/m3	Maximum daily 8 hour	Limit value enters	n/a

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monoxide (CO)		mean	into force 1.1.2005	
Benzene	5 µg/m3	1 year	Limit value enters into force 1.1.2010**	n/a
Ozone	120 µg/m3	Maximum daily 8 hour mean	Target value enters into force 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m3	1 year	Target value enters into force 1.1.2012	n/a
Cadmium (Cd)	5 ng/m3	1 year	Target value enters into force 1.1.2012	n/a
Nickel (Ni)	20 ng/m3	1 year	Target value enters into force 1.1.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m3 (expressed as concentration of Benzo(a)pyrene)	1 year	Target value enters into force 1.1.2012	n/a

**Under the new Directive the Member State can apply for an extension of up to five years (i.e. maximum up to 2015) in a specific zone. Request is subject to assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (48µg/m3 for annual NO2 limit value).*

***Under the new Directive the Member State can apply for an extension until three years after the date of entry into force of the new Directive (i.e. May 20011) in a specific zone. Request is subject to assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (35 days at 75µg/m3 for daily PM10 limit value, 48µg/m3 for annual PM10 limit value).*

****Standard introduced by the new Directive 2008/50/EC*

Under EU law a limit value is legally binding from the date it enters into force subject to any exceedences permitted by the legislation. A target value is to be attained as far as possible by the attainment date and so is less strict than a limit value.

The new Directive is introducing additional PM2.5 objectives targeting the **exposure** of the population to fine particles. These objectives are set at the national level and are based on the average exposure indicator (AEI).

AEI is determined as a 3-year running annual mean PM2.5 concentration averaged over the selected monitoring stations in agglomerations and larger urban areas, set in urban background locations to best assess the PM2.5 exposure to the general population.

Table 9: Air quality standards for PM2.5 in lines of AEI

Title	**Metric**	**Averaging period**	**Legal nature**	**Permitted exceedences each year**
PM2.5 Exposure concentration obligation	20 µg/m3 (AEI)	Based on 3 year average	Legally binding in 2015 (years 2013,2014,2015)	n/a
PM2.5 Exposure reduction target	Percentage reduction* + all measures to reach 18 µg/m3 (AEI)	Based on 3 year average	Reduction to be attained where possible in 2020, determined on the basis of the value of exposure indicator in 2010	n/a

** Depending on the value of AEI in 2010, a percentage reduction requirement (0, 10, 15, or 20%) is set in the Directive. If AEI in 2010 is assessed to be over 22 µg/m3, all appropriate measures need to be taken to achieve 18µg/m^3 by 2020.*

PRINCIPLES

European legislation on air quality is built on certain principles. The first of these is that the Member States divide their territory into a number of zones and agglomerations. In these zones and agglomerations, the Member States should undertake assessments of air pollution levels using measurements and modeling and other empirical techniques. When levels are elevated, the Member States should prepare an air quality plan or program to ensure compliance with the limit value before the date when the limit value formally enters into force. In addition, information on air quality should be disseminated to the public.

CLEAN AIR FOR EUROPE (CAFE)

In May 2001, the European Commission formally adopted the Clean Air For Europe (CAFE) program. The program is aimed at integrating the various strands of air pollution policy under the 6th Environmental Action Program and includes the preparation of a thematic strategy on air pollution – one of seven covering various areas of EU environmental policy. The CAFE process has therefore effectively become the focal point for the EU's air quality work, providing a framework within which air pollution measures, such as the Auto Oil program, national emissions ceilings Directive and the air quality Daughter Directives can be coordinated.

In September 2005, the Commission published its Thematic Strategy on Air Pollution; its aim being to cut the annual number of premature deaths caused by air pollution by 40% by 2020 from the 2000 level and to reduce the continuing damage to Europe's ecosystems. To do this the Strategy says that emissions of sulphur dioxide will need to be reduced by 82%, nitrogen oxides by 60%, volatile organic compounds by 51%, ammonia by 27% and fine particulate matter by 59% (compared to their 2000 levels).

The Strategy proposes streamlining European air quality legislation and to this end includes a proposal for a Directive on Ambient Air Quality and Cleaner Air for Europe (COM (2005) 447) which will replace the Air Quality Framework Directive and three of its Daughter Directives (on sulphur dioxide, oxides of nitrogen, particulate matter and lead; on carbon monoxide & benzene; and that on monitoring & information on ozone).

The Strategy also outlines proposals for reviewing the National Emission Ceilings Directive, and for consideration to be given to the feasibility of tighter (Euro 5) emission limits for cars and Euro VI for heavy goods vehicles. Consideration is also to be given to extending the Integrated Pollution Prevention Control Directive to cover small combustion plant, a new Directive reducing VOC emissions from fuel stations, setting NOx emission limit values for ships, and reducing nitrogen use for animal feedstuffs and fertilizers.

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EUROPEAN QUALITY LIMIT VALUES

European Limit Values are legally binding, and exceedences can result in the European Commission taking legal action against the country at fault. In 1996, the European Union adopted the Air Quality Framework Directive (96/62/EC), which in turn gave rise to a series of "Daughter" Directives containing Limit Values for seven pollutants. In June 2008, a new Air Quality Directive (2008/50/EC) came into force and must have been implemented by member states by 11 June 2010. This merges the former framework Directive and the first three Daughter Directives into a single Directive with no change to existing air quality objectives. It also introduces new air quality objectives for $PM_{2.5}$ (fine particles) including a limit value and exposure related objectives – exposure concentration obligation and exposure reduction target. The new Directive also introduced several new features that weaken the previous legislation, including the possibility to discount natural sources of particles (e.g. sea salt) when assessing compliance against limit values, and the possibility (with EU approval) of time extensions of three years (PM_{10}) or up to five years (NO_2, benzene) for complying with limit values.

EU MARINE SULPHUR DIRECTIVE

In 2002, the European Commission presented a proposal to amend Directive 1999/32 as regards the sulphur content of marine fuels (henceforth, the “marine fuel sulphur directive”) The European Parliament and Council finalized the marine fuel sulphur directive in April 2005 with a second reading agreement. At the time of writing, the directive had not yet been published in the EU Official Journal, but it had been formally signed and given the directive reference number 2005/33. The directive includes the following provisions: Ships in IMO Sulphur Emission Control Areas must use 1.5 percent sulphur fuel or better – starting with the Baltic Sea in May 2006, then extending to the North Sea and Channel in autumn 2007. All passenger vessels on regular services to or from Community ports must use 1.5 percent sulphur fuel or better from May 2006 onward. Ships at berth in ports must use 0.1 percent sulphur fuel or better from 2010 onward.

These provisions should apply to all marine fuels and replace the current regulations on marine gas oil, thereby establishing a similar regime for marine fuels as for heavy fuels and gas oils used by land-based sources, which are limited to 1.0 percent and 0.1 percent sulphur content, respectively. The Directive also allows ships to use other technical abatement technologies that achieve the same or greater levels of emission reductions, provided it can be demonstrated that these technologies do not adversely affect the marine environment. (The most often mentioned acceptable abatement technology is the desulphurization of exhaust gases via “seawater scrubbing.”)

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EU CONTEXT- SUBSIDIES AND STATE AID RULES

The Commission has adopted the following three sets of state aid guidelines that define the context with regard to possible state subsidies for ship emissions reductions.

1. Community guidelines on state aid for environmental protection (2001/C37/03) allow aid where it serves as an incentive to firms to achieve levels of protection that are higher than those required by Community standards, or where no Community standards exist—as is the case for NOX emissions from seagoing ships. Investment aid can be given for plant and equipment intended to reduce or eliminate pollution, but may not exceed 30 percent gross of the eligible investment costs.

2. Community guidelines on state aid to maritime transport (1997/C205/05) allow investment aid in certain circumstances to promote the use of clean ships, such as providing incentives to upgrade Community registered ships to standards which exceed mandatory environmental standards laid down in international conventions.

3. Finally, the most recent Commission framework on state aid to shipbuilding (2003/C317/O6) allows aid for research and development and allows aid up to 20 percent of gross expenditure for innovation, i.e. technologically new or substantially improved products and processes compared to the state of the art referring to industry. Thus, it appears to be legally possible for Member States to provide subsidies for emissions reductions generated through the development and use of emissions abatement technologies for ships, either for new vessels or for retrofits.

MARKET BASED APPROACHES TO AIR EMISSIONS POLICY

Once a primarily theoretical approach to environmental policy, economic instruments have gained wide acceptance over the last three decades. Indeed, virtually all environmental policy initiatives that have been developed recently in the US include a market-based component. Market-based approaches have recently gained wider acceptance in Europe as well. The EU Emissions Trading Scheme (the "EU ETS") represents perhaps the most prominent example of Europe's use of market-based approaches. Under the EU ETS, Member States are permitted to trade CO2 emissions reduction credits among one another, as part of an EU-wide initiative to meet anticipated obligations under the Kyoto Protocol. The Commission has recognized that market-based instruments might be used to deal with various environmental issues. Experience suggests that well-designed market based approaches can reduce the costs and increase the likelihood of achieving environmental targets (see, e.g., Ellerman, Joskow and Harrison 2003). This experience also indicates, however, that the market-based approaches need to be carefully thought out in order to achieve these and other objectives. Moreover, it is important to include all interested parties in this process, particularly since the approach is relatively new for shipping.

7.4 NATIONAL FRAMEWORK

Spanish legislative and normative framework regarding air quality and port management

<u>Spanish legislative and normative framework regarding air quality</u>

In Spain, the Law 34/2007 adopts provisions concerning air quality and environmental protection. This law aims at establishing the basis concerning prevention, control and reduction of emission of atmospheric pollution in order to avoid, and when this is not possible, diminish the damage to people, the environment and other goods originated by this pollution. The text of the law contains: object of the Law; extent of application; definitions; guiding principles; authority of public administrations; inter-administrative cooperation; obligations of persons responsible for facilities involved in activities potentially pollutant of the atmosphere; information to the public; evaluation and management of the air quality; prevention and control of emissions; planning; instruments of promotion of protection of the atmosphere; control, inspection, vigilance and follow-up; system of sanctions. It repeals the regulation of unhealthy, harmful and dangerous activities, approved by Decree 2414/1961 of 30 November 1961; Law 38/1972 of 22 December 1972, and annexes II and III of Decree 833/1975 of 6 February 1975.

The institution in charge of air quality is the General Direction of Environmental Quality and Evaluation within the Ministry of Environment. In particular, it is the National Authority for the National Inventory System of Pollutant Emissions to the Atmosphere.

Air quality legislated values

After the adoption of the Directive 2008/50/EC on Ambient Air Quality and Cleaner Air for Europe, Spain is working on a new royal decree to integrate the new regulations on new pollutants, such as the particulate matter with diameter ≤2,5 μm (PM2,5), and new requirements related to assessment and management of air environment quality. Although the directive should be incorporated into the Spanish legislation by 11th June 2010, the royal decree is still not passed.

Thus, the main legal instrument to establish the pollutants values is the Royal Decree 1073/2002 on the evaluation and management of the air environment quality concerning sulphur dioxide, nitrogen dioxide, oxides of nitrogen, particulate matter, lead, benzene and carbon monoxide, which incorporates into national legislation the

Directive 96/62/EC, 1999/30/EC and 2000/69/EC. Further details on normative is provided at the following tables which summarize the air quality objectives by pollutant:

Table 10: National normative framework per pollutant

- Sulphur dioxide (SO_2)

Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Hourly limit value for human health protection	1 hour	350 µg/m^3 Not possible to exceed more than 24 times per civil year
Daily limit value for human health protection	24 hours	125 µg/m^3 Not possible to exceed more than 3 times per civil year
Limit value for ecosystems protection	1 civil year and winter period	20 µg/m^3
Threshold warning	1 hour	500 µg/m^3

- Nitrogen dioxide and oxides of nitrogen (NO_2 and NOx)

Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Hourly limit value for human health protection	1 hour	200 µg/m^3 of NO_2 Not possible to exceed more than 18 times per civil year
Annual limit value for human health protection	1 civil year	40 µg/m^3 of NO_2
Limit value for vegetation	1 civil year	30 µg/m^3 of NOx

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protection		
Threshold warning	1 hour	400 µg/m^3

- Particulate matter with diameter ≤10 µm (PM_{10})

Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Daily limit value for human health protection	24 hour	50 µg/m^3 Not possible to exceed more than 35 times per civil year
Annual limit value for human health protection	1 civil year	40 µg/m^3

- Benzene

Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Annual limit value for human health protection	1 civil year	5 µg/m^3

- Lead

Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Annual limit value for human health protection	1 civil year	0,5 µg/m^3

- Carbon monoxide (CO)

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Reference values according to Royal Decree 1073/2002		
	Period	Limit value
Limit value for human health protection	Maximum daily 8 hours	10 mg/m^3

- Ozone (O_3)

Reference values according to Royal Decree 1796/2003		
	Period	Limit value
Objective value for human health protection	Maximum daily 8 hours mean	120 $\mu g/m^3$ which can't be exceeded more than 25 days average every civil year within a 3 years period
Objective value for vegetation protection	AOT40	18000 $\mu g/h{\cdot}m^3$ Average within a 5 years period
Long-term objective for human health protection	Maximum daily 8 hours mean within a year	120 $\mu g/m^3$
Long-term objective for vegetation protection	AOT40	6000 $\mu g/h{\cdot}m^3$
Threshold warning	Hourly average	240 $\mu g/m^3$
Threshold to inform population	Hourly average	180 $\mu g/m^3$

- Hydrogen sulphide (H_2S)

Reference values according to Decree 833/75		
	Period	Limit value
Semi-hourly limit value	Semi-hourly average	100 $\mu g/m^3$

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Daily limit value	Daily average	40 µg/m^3

- Chlorine (Cl2) and hydrogen chloride (HCl)

Reference values according to Decree 833/75		
	Period	Limit value
Semi-hourly limit value	Semi-hourly average	300 µg/m^3
Daily limit value	Daily average	50 µg/m^3

- Arsenic (As), cadmium (Cd), nickel (Ni) and benzo(a)pyrene

Reference values according to Directive 2004/107/EC from 31st December 2012	
Pollutant	Objective value
Arsenic	6 ng/m^3
Cadmium	5 ng/m^3
Nickel	20 ng/m^3
Benzo(a)pyrene	1 ng/m^3

National emission ceilings

The Directive 2001/81/EC on national emission ceilings for certain atmospheric pollutants aims at limiting emissions of acidifying and eutrophying pollutants and ozone precursors in order to improve the protection in the Community of the environment and human health against risks of adverse effects from acidification, soil eutrophication and ground-level ozone and to move towards the long-term objectives of not exceeding critical levels and loads and of effective protection of all people against recognized health risks from air pollution by establishing national emission ceilings, taking the years 2010 and 2020 as benchmarks, and by means of successive reviews as set out in Articles 4 and 10 of this directive. To this aim, it sets national emissions ceilings (the maximum amount of a substance expressed in kilotonnes, which may be emitted from a Member State in a calendar year) by 2010 for certain pollutants; in particular, for Spain, these are the ceilings:

- NOx: 847 Kilotonnes
- COV: 662 Kilotonnes
- SOx: 746 Kilotonnes
- NH_3: 353 Kilotonnes

In order to fulfill these ceilings, Member States must elaborate, revise and update national programs for progressive emissions reduction. Spain elaborated in 2003 its first National Program and later on the second National Program for Emissions Reduction (Resolution of 14th January 2008, of the General Secretariat for the Prevention of Pollution and Climate Change (BOE nº 25, 29.01.08). This plan includes a number of policies and measures related to port activity, such as the Strategic Plan of Infrastructures and Transport 2005-2020.

Spanish legislation on port and navigation management and air emissions

In Spain there are two institutions in charge of navigation and ports which are regulated by the Law 27/1992 and could play a role on air emissions management: the General Direction of the Merchant Navy of the Ministry of Public Works and State Ports of Spain.

The General Direction of the Merchant Navy

It is the competent body for general planning of maritime navigation and the Spanish civil fleet. In the light of the APICE project, two of its functions must be highlighted:

a) The prevention and fight against marine pollution from ships, boats and fixed platforms, as well as marine waters cleansing
b) The elaboration and proposal of sartorial normative, especially that coming from commentary regulations or from international organizations, internal legal advice and processing sanction proceedings. The coordination of the international activity of the General Direction of the Merchant Navy, especially related to the European Union and the International Maritime Organization.

For these functions, there are two General Sub directions concerned:

- General Sub direction for Safety, Pollution and Maritime Inspection
- General Sub direction for Maritime Normative and International Cooperation

Therefore, in terms of the APICE project, these sub directions have an important role to play.

State Ports of Spain

It is a Public Body dependent of the Ministry of Public Works with global responsibilities on the state ports system, in charge of the execution of the governmental port policy and the coordination and efficiency control of the port system made up of 28 Port Authorities (Port Authority of Barcelona, among them). The principal aim of State Ports of Spain is to ensure that the ports contribute efficiently to the economic development of the country. Supporting initiatives, ensuring the smooth functioning of procedures, drawing up plans and designing strategies of combined action and optimizing management efficiency are just a few of the functions carried out by the State Ports of Spain. This implies revising the port policy of the government and serving as intermediary between the ports and the central administration.

Regarding environment, takes responsibility in the environment protection through:

- Controlling the compliance with environment legislation.
- Promoting the development and review of the current Environment Policy of the port authorities through the implementation of Environment Management Systems and clean technologies in order to achieve the environment purposes established. Involvement in a continuous enhancement.
- Increasing State Ports and port authority staff's awareness of environment problems through environmental programs.
- Developing prevention strategies to face the pollution originated by operations and activities of State Ports. Analyze and promote the actions required to reduce the impact of these agents on the environment.

The Barcelona Port Authority, though working at a local level, has a character of national body since it is part of State Ports of Spain. Its mission consists in leading the development of the Port of Barcelona, to generate and manage infrastructures and to guarantee reliable services in order to contribute to clients' competitiveness and create value for society at large.

The Environment Service (Servei de Medi Ambient–SMA), as a part of the Barcelona Port Authority structure, is made up of a team of professionals prepared to offer a series of services related with the environmental vigilance. The objective of this vigilance is to contribute to the protection of the environment, with regard to the atmospheric environment (air), the aquatic environment (water) and the edaphic environment (land).

Other important objective is to offer to the concessionaire companies of the Port an advice service about the environmental subjects (licenses, ISO 14000, emissions control, etc.) in order to collaborate in the compliance of the requirements specified by the competent administration.

For the development of its objectives, the Environment Service (SMA) has its own resources (weather stations, automatic and manual pollutant analyzers, marine multiparametrical sound (CTD), water cleaner boats, antipollution barriers, etc.) and, in some cases, supervises the task of the contracted external companies.

The Environment Service of the Port of Barcelona has two different performances. On one hand, it offers to the port companies and to the different public entities the information related to the environmental data which are processed in the measuring stations of the Port of Barcelona, and on the other hand, it offers to the port companies an advice service on environmental subjects.

The vigilance of the air quality in the port environment is carried out through the measurement of the pollutants concentrations in the air and the study of its diffusion on the atmosphere.

In order to achieve this objective, the Environment Service (SMA) of the Port of Barcelona has been equipped with its own infrastructure which turns the Port of Barcelona into a territory with one of the densest atmospheric networks existing nowadays. This infrastructure is made up of a weather stations network, two measuring stations networks of environmental concentration, one manual and the other automatic, and a mobile unit.

The atmospheric problems in the Port have an additional importance because of its closeness to the city; there is a synergy between the two systems which causes that the vigilance of the air quality arouses too the interest of the local entities of public health and environment.

Specific national legislation regarding air emissions in ports and navigation

Spain deposited the Adhesion Instrument to 1997 Protocol to Marpol 73/78 Convention in 2004 (BOE núm. 251, 18th October 2004[1]). This protocol contains the regulations for prevention of air pollution from ships, and it is included as Annex VI of the Convention. The revised Annex VI entered into force on 1st July 2010.

[1] http://www.puertos.es/export/download/puertos/1115208118104.pdf

BARCELONA

Air Quality Plan in the Metropolitan Area of Barcelona

At the regional level, the competence on air quality is hold by the General Subdirection for Prevention and Control of the Atmospheric Pollution, within the General Direction of Environment Quality, Generalitat of Catalonia. In particular, it aims at:

1) Assessing air quality parameters through the Network of Vigilance and Prevision of Atmospheric Pollution
2) Reducing and preventing pollutants emissions
3) Elaborating plans when the air quality is not appropriated

In the light of the APICE project, it is of utmost importance to take into account the current air quality plan in the metropolitan area of Barcelona.

The Decree 322/1987, which develops the Law 22/1983, regarding protection of atmospheric environment, establishes that the zones where the admissible limit values are exceeded must be declared special protected zones, and medium and long term measures are needed in order to restore the air quality. Once the special protection zone has been declared, the Executive Board must pass an Action Plan that comprises the specific needed actions to restore the air quality.

In this context, the Decree 226/2006, of 23rd May, established Special Protected Zones of the Atmospheric Environment for the pollutants NO_2 and PM_{10} (see Figure 18 and 19). The Action plan for the air quality improvement, passed by Decree 152/2007, has been extended by Decree 203/2009 since many measures have not implemented, and the preliminary assessment of the air quality shows that EU objectives by 2009 will not be met.

The plan comprises 73 measures structured in the following areas: prevention (10), industrial (27), energy (4), road transport (6), maritime transport (8), air transport (3), domestic sector (4) and public awareness (11). The selection of the measures of the action plan has been done by the Interdepartmental Commission (promoted by the Department of Environment and Housing and composed by the departments of Territorial Policy and Public Works; Health; Innovation, Universities and Enterprise; and Interior and Institutional Relations and Participation, besides the Catalan Energy Institute and the Metropolitan Transport Authority) keeping in mind, in addition to the environmental efficiency criteria, the social impact, economic costs and whichever other factor that could has an impact on the measure, giving priority to the measures involving public administrations.

Concerning the port, the objective was to reduce 20% NO_2 and 10% PM_{10} through these measures:

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- Actions over the containers lorries fleet (environmental requirements)
- Promotion of rail transport of goods
- Electric supply for ships
- Inner float ships renewal
- Modification of Port taxes
- Renewal of auxiliary loading and unloading machinery
- Handling of dusty material improvement
- Strategic plan for the reduction of the emissions in the port

The Environment Service of the Barcelona Port Authority is the main responsible for the implementation of these measures and has reported yearly to the Generalitat on the progress. The degree of implementation varies from one measure to other, but remarkable achievements have been met.

The action plan includes the establishment of the Technical Office for the Plan Monitoring, attached to the General Subdirection for Prevention and Control of the Atmospheric Pollution. Its function is to follow-up the schedule and implementation degree of the measures regarding the emissions reduction and the impact on the air quality levels, through indicators, as well as to report about the Plan evolution and to prepare measures or actions proposal to fine-tune the initial measures.

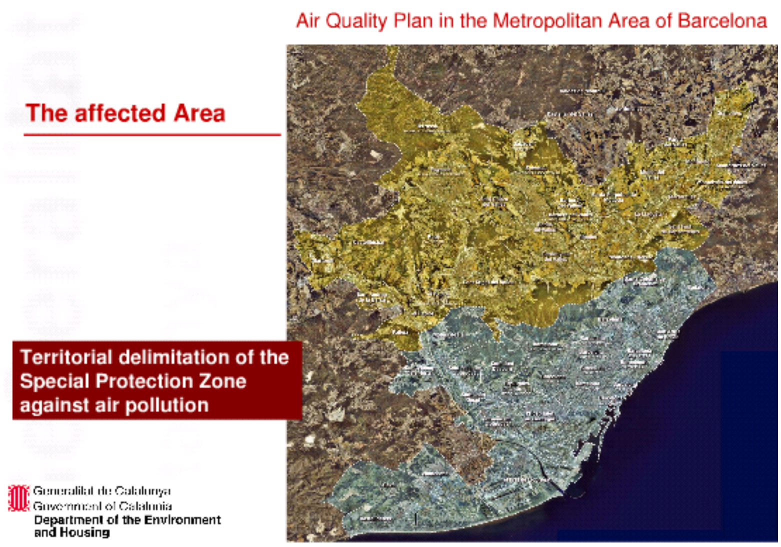

Figure 25: Special protection zone of the Atmospheric Environment for the pollutants NO_2 and PM_{10}.

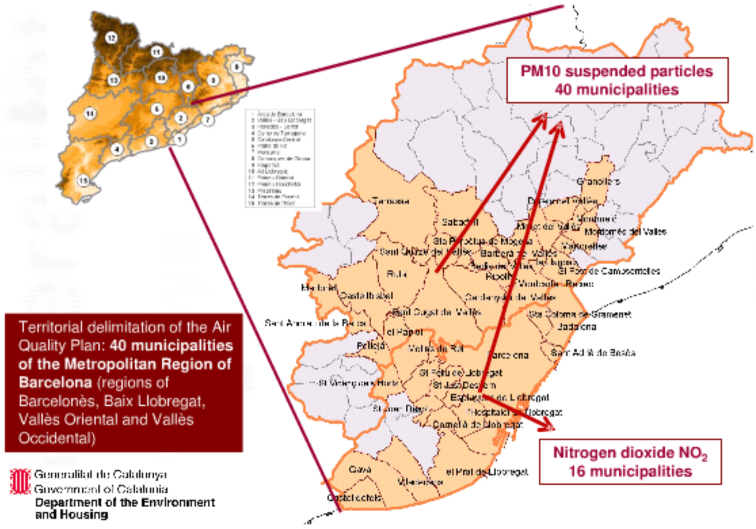

Figure 26: Territorial delimitation of the Air Quality Plan for NO_2 and PM_{10}.

8. EVALUATION OF AIR QUALITY IN REGION OF BARCELONA

The current report has been redacted in lines of APICE program (Common Mediterranean strategy and local practical Actions for the mitigation of Port, Industries and Cities Emissions). The report includes a brief analysis of the air quality of the area during the last years. The interest is focused on the Port of Barcelona, which is the main transport and services infrastructure in Catalonia, the second Spanish port in terms of total goods traffic and the first in terms of value

The "Àrea de Barcelona" has a dense monitoring network composed of 28 stations in which a number of air quality parameters are measured: NOx, CO, SO_2, O_3, CO, PM_{10}, $PM_{2.5}$ particles number concentration, acid rain, metals, benzene, and black carbon. Data of meteorological parameters (wind speed, wind direction, temperature and relative humidity) are also available from the national meteorological network.

In general, most of the parameters show a decreasing trend from 2000 to 2009, especially evident in 2009. These trends are probably related to the economic crisis rather than abatement strategies carried out in the last years. Only a slight proportion of these decreasing trends may be related to the mitigation strategies taken at the moment.

The main conclusions of the analysis of the air quality in Barcelona's region for the year 2009 are:

- Regarding PM_{10} and $PM_{2.5}$ (the only regulated parameters among those measured at Torre Girona); the annual concentrations during 2009 were under the limit value (40 µg $m^{-3}$for PM_{10} and 25 µg m^{-3} for $PM_{2.5}$). Nevertheless, the daily limit value established for PM_{10} in 50 µg m^{-3} was exceeded 38 days whereas only 35 days are allowed. *After quantify the contribution of African dust for each day, and subtracting this contribution to the PM_{10} concentration, 32 exceedances were computed.* On a daily basis, PM levels and its size distribution show clear seasonal trends. The highest PM levels and finest size distribution are observed in winter (February-March, and November) *as a consequence of intense pollution episodes that avoid the dispersion of the atmospheric pollutants. These episodes are usually recorded under anticyclone conditions.* Relatively high PM levels and coarse particle size are observed in summer *as a result of low atmospheric dispersive conditions affecting the Western Mediterranean, together with higher frequency of African dust episodes and enhanced resuspension processes.* The lowest PM levels are recorded in April, September-October and December, generally *coinciding with rainy periods and intense advective conditions.* The effect of African dust on PM_{10} levels is evident, with relatively low influence on $PM_{2.5}$ and negligible on PM_1.

- The black carbon concentrations are *really sensible to the traffic emissions*, showing little seasonal variability. As regards for the number concentration, sometimes the urban pollution episodes give significant numbers of ultra-fine particles *(elevated emissions in a low-dispersive atmosphere)*, which are simultaneous with PM and BC peaks. Other times important number concentration peaks occur *under low pollution conditions (nucleation processes).* In some occasions, the urban pollution episodes are associated with low levels of number concentration which is thought as *the result of coagulation and condensation processes that reduce the number concentration but not the PM mass.*

- Regarding the seasonal evolution of NO_2 and SO_2, it is clear that both gaseous pollutants exhibit different patterns. Whereas NO_2 *tends to maximize in winter as a consequence of the lower dispersive conditions of the urban atmosphere*, SO_2 do not show this pattern. In some episodes, NO_2 and SO_2 register simultaneous increments in a daily basis. This basically occurs *under urban pollution episodes*. Nevertheless, it is more frequent to observe a different behavior between NO_2 and SO_2. In fact, whereas NO_2 is highly *related with traffic emissions (mainly from diesel vehicles)*, SO_2 concentrations in the urban area of Barcelona are more *related to shipping and industrial emissions*. Clear traffic dependence is observed for NO_2, with morning and vespertine peaks coinciding with *the rush hours*, but a midday maxima is observed in SO_2, *coincident with the entrance of the sea breeze towards the city, with a typical direction from the harbor area.*

- Regarding the chemical composition of particles, some atmospheric components have a preference for the coarse sizes such as mineral matter, sea spray and nitrate. Other components such as organic matter and elemental carbon (OM+EC), ammonium and in less proportion sulphate are mostly fine. It is important to remark that the amount of coarse components (PM_{1-10}) in the atmosphere of Barcelona is very significant. It is expected that in the harbor area, where some dusty materials are handled, *construction activities are always ongoing, and intense traffic of trucks occur*, the importance of the coarse PM may be even higher than in the urban background. Furthermore,

  ✓ Mineral matter tends to increase in summer, *probably due to the enhanced resuspension processes.* Nevertheless, sporadic and intense peaks are observed, *coinciding with African dust outbreaks.*

- ✓ Nitrate concentrations are clearly higher in winter, *when a high frequency of urban pollution episodes* is registered over the study area. In those cases, ammonium nitrate is the commonest inorganic secondary PM component.
- ✓ OM+EC concentrations are also higher in winter, again *due to the accumulation of PM pollutants during urban pollution episodes.*
- ✓ Sulphate generally increases in summer, *when the photochemical reactions are enhanced. In addition, the typical summer recirculation of air masses over the Western Mediterranean favors the accumulation of secondary pollutants over the region* (mainly ammonium sulphate, organics and ozone).
- ✓ Vanadium and nickel show a clear seasonal trend with higher concentrations in summer, and sporadic peaks out of this period. In the study area *the harbor emissions and some industrial activities are to be the major sources of these trace elements.*
- ✓ Lead and Zinc register an inverse seasonal evolution when compared to the previous two, showing higher winter concentrations. *It is interesting to note that the study of the BP-Zn episodes points out to the industrial area located in the Llobregat Basin as the source of these pollution episodes. Over this area large metallurgical activities occur.*
- ✓ Copper and antimony are the best tracers of traffic emissions. In this case they show a typical winter maximum originated by the *higher frequency of urban pollution episodes.*

The present report has focused on the study of PM10 levels in the port area during 2009. Thus,

- Mean annual levels of PM_{10} and $PM_{2.5}$ in the harbor area during 2009 were generally under the limit values with the exception of some areas affected by *construction activities* (Porta Coeli and Dic Sud). Slightly higher concentrations than the annual limit value of PM_{10} (fixed in 40 µg m^{-3}) were recorded in Darsena Sud, probably as a consequence of *the heavy traffic of trucks in the vicinity of this site*. Attending to the seasonal evolution of the PM_{10} and $PM_{2.5}$ concentrations, it is clear that the highest levels have been measured in wintertime, as observed in the urban background. *Once again the stagnation of air masses over the area favors the accumulation of pollutants at an urban and regional scale. The higher intensity of the sea breezes in summer is evident in the lowering of the PM levels in the harbor area, more evident than in the urban background.*

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- As regards for the gaseous pollutants, in the case of SO_2, a clear NE and SSE origin may be deduced, *just from the shipping areas*. Concerning the NO_2 concentrations, an evident W-NW origin may be seen, *pointing to the city*, *local roads and ring-roads as the major emission sources of this pollutant in the harbor area.* Finally, H_2S concentrations clearly have a south origin, just from a *factory using sulfur products*.

In conclusion, as mentioned previously, the aim of the present report was to briefly describe the air quality conditions in the region of Barcelona, based on the data collected from the air quality and meteorological networks. A source apportionment study which will follow in the frame of APICE project will lead to focused conclusions on the main sources contributing to PM levels. The role of the ports emissions, in combination with the meteorological pattern of each area will be extensively examined.

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ANNEX I

PUBLICATIONS

SCI JOURNALS BY TOPIC

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ANNEX II

PROJECTS

EUROPEAN PROJECTS

- Integrated assessment of health risks of environmental stressors in Europe (INTARESE). 161.701E. 2004-2007.
- European Super-sites for Atmospheric Aerosol Research (EUSAAR) RII3-CT-2006- 026140. 99.449E. 2006-2010
- Climate Change and Impact Research: the Mediterranean Environment (CIRCE). 55754 E. 2007-2011.

NATIONAL PROJECTS

- Estudio y evaluación de la contaminación atmosférica por material particulado y metales en España. 795.000 E. 2006-2009.
- Interpretación de series temporales de niveles de partículas en las estaciones de la red EMEP-CAMP-VAG de España y para la ejecución de analítica química en muestras de aerosoles de la estación VAG de Izaña. 452.900 E. 2007-2010
- CALIOPE: sistema de calidad del aire operativo para España. 44.600 E. 2006.
- CALIOPE: sistema de calidad del aire operativo para España. 44.600 E. 2007.
- CALIOPE: sistema de calidad del aire operativo para España. 44.600 E. 2008.
- CALIOPE: sistema de calidad del aire operativo para España. 38.351 E. 2009.
- Evaluación integral del impacto de las emisiones de partículas de los automóviles en la calidad del aire urbano. 194.575 E. 2004-2007.
- Multidisciplinary Research Consortium on GRadual and Abrupt Climate Changes, and their Impacts on the Environment (GRACCIE). 460.000 E. 2007-2012.
- Sistema de Evaluación de Riesgos por Contaminación Atmosférica (SERCA). 230.757 E. 2008-2011.
- CAMPAÑAS DE MEDIDAS PARA LA DETERMINACION DE ORIGENES DEL AEROSOL ATMOSFERICO EN AMBIENTE URBANO Y RURAL DE ESPAÑA (DAURE). 43.000 E. 2008-2010.
- Caracterización integral de aerosoles troposféricos de fondo continental en el NE de Iberia (CARIATI). 173.000 E. 2009-2012.
- Acuerdo de encomienda de gestión entre el Ministerio de Medio Ambiente, y Medio Rural y Marino- y la Agencia Estatal Consejo Superior de Investigaciones Científicas para la realización de trabajos relacionados con el estudio y evaluación de la contaminación atmosférica por material particulado y metales en España. 1.203.585 E. 2010-2013.

ANNEX III

MODELING ACTIVITIES

Model used and main characteristics

Neither CSIC nor EUCC has performed modelling activities in the area of Barcelona. In this section, we explain some models that have been applied by other institutions and researchers.

Modelling activities by the Generalitat de Catalunya

In the framework of the air quality improvement plan in force in the metropolitan area in Barcelona, it was assessed the potential impact of emission sources on the air quality. For this, different methodologies have been applied according to the different sources.

- *modelling of emissions generated by terrestrial transport and household*

In order to estimate the air quality levels gemerated by terrestrial transport and household, a boxes model (Jacob 1999) has been used. This model is a simplification of the continuity equation (mass conservation) for a closed volume. The model simulates that emission sources are confined within a box (in this case, a mesh 500 x 500 metres long) with a height equivalent to the layer of atmospheric mix.

- *modelling of emissions generated by industry and energy activities*

It has been used the Gaussian model ISCST (Industrial Source Complex Short Term) of the Environmental Protection Agency (EPA).

- modelling of emissions generated by the Port of Barcelona activities

The ISCST model has been used as well, considering the emissions inventory an emission surface where the inner terrestrial transport as well as the pollutants emissions by vessels.

- modelling of emissions generated by the Airport of El Prat de Llobregat activity

The ISCST model has been used as well, from the emissions inventory by areas which include the air and terrestrial transport, as well as the equipment associated to support activities.

Solving Aerosol Problems Using Synergistic Strategies (SAPUSS)

The campaign SAPUSS, "Solving Aerosol Problems by Using Synergistic Strategies" is supported by the Marie Curie Programme of the EC PF7 Programme. The Iberian Peninsula (10 km resolution), the Metropolitan area of Barcelona (2 km resolution), and the city of Barcelona (0.5 km resolution) are the geographical scope of this initiative. The model is available at: http://chubasco.inf.um.es/sapuss/inicio.html

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This website gives access to:

1) Meteorological forecast of the three geographical scales: temperatures, precipitation, geopotential at 500 and 700, relative humidity, wind (intensity and flow directions)
2) Air quality: concentration of O3, NO2, SO2, PM1, PM10, PM2.5 and CO
3) Aerosols chemical composition: SO4, NO3, NH4, OM+EC, dust and sea salt

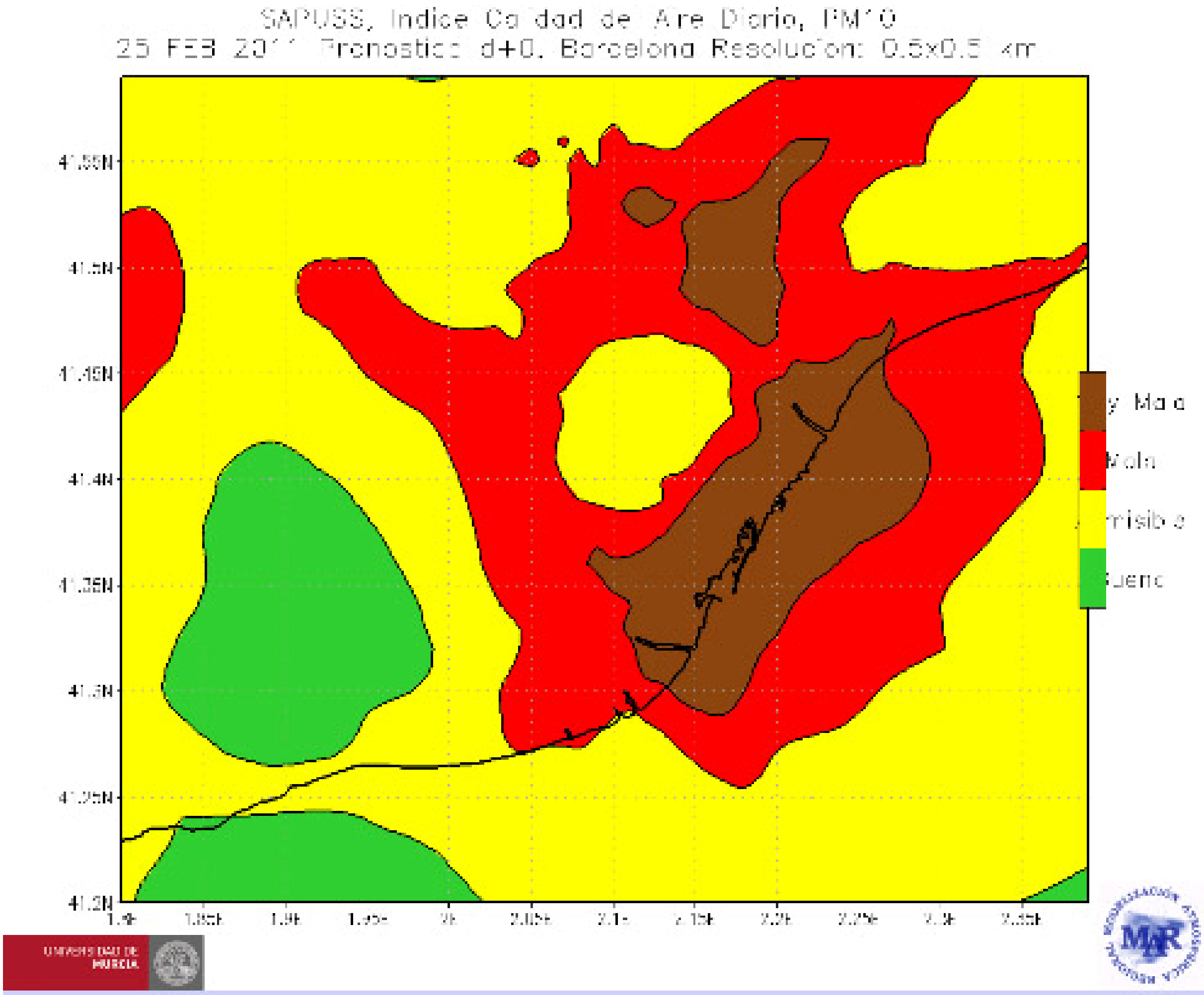

Figure 27: Example of SAPUSS model for the area of Barcelona city: PM10 levels, 0.5 km resolution. From Jiménez P. at http://chubasco.inf.um.es/sapuss/aq/BCN005_aqi.html

The High-Elective Resolution Modelling Emissions System (HERMES)

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HERMES, developed by the Barcelona Supercomputing Centre (BSC) generates the emissions for Spain needed for the application of high-resolution chemistry transport models, taking the year 2004 as reference with a temporal resolution of 1 h and a spatial resolution of 1 km^2 considering both anthropogenic (power generation, industrial activities, or-road traffic, ports, airports, solvent use, domestic and commercial fossil fuel use) and biogenic sources (vegetation), using a bottom-up approach, up-to-date information and state-of-the-art methodologies for emission estimation. HERMES is capable of calculating emissions by sector-specific sources or by individual installations and stacks. The inventory generated with HERMES emission model has been successfully integrated within the Spanish Ministry of the Environment's air quality forecasting system (Caliope project), being the emission core for the validation and assessment of air quality simulations in Spain. +

The application of the model in Barcelona is available at: http://www.bsc.es/caliope/?q=node/70

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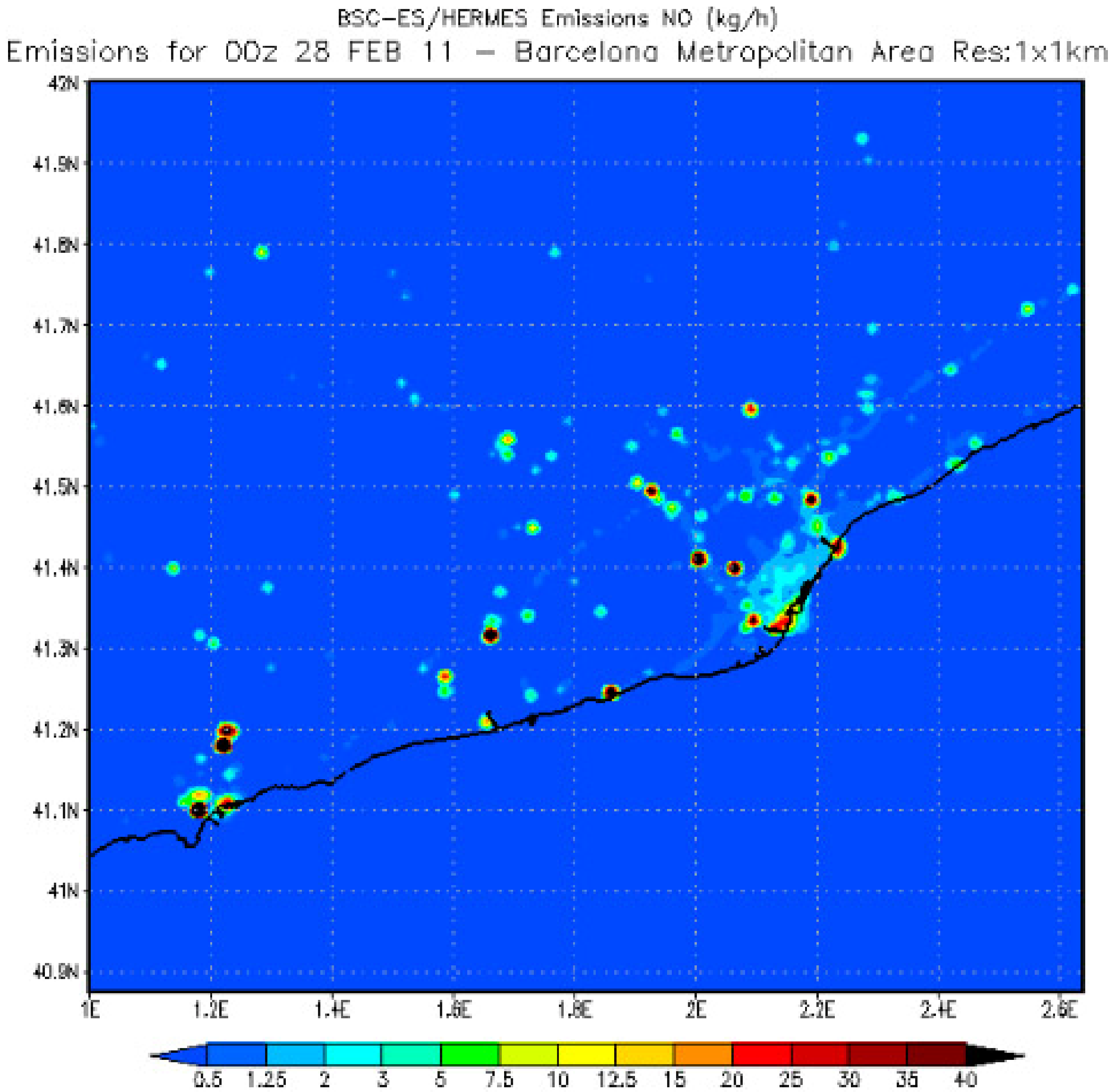

Figure 28: Example of HERMES model for the area of Barcelona city: NO levels, 1 km resolution. From Caliope project at http://www.bsc.es/caliope/?q=node/70