iMONITRAF! WP 5

Monitoring Campaigns

Activity 5.5

ARPA Friuli Venezia Giulia, ARPA Valle d'Aosta, ARPA Piemonte, Cantone Ticino

Udine

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CONTENT

1 Project iMONITRAF!: Monitoring Campaigns

In the frame of the iMONITRAF! Project, several monitoring campaigns were carried out with the aim to characterize the impacts of transports on the delicate alpine environment, in particular by way of noise and atmospheric pollution. The final goal of these campaigns was that to present a uniform benchmark for the comparison of the impacts over the different corridors, suited for the development of future scenarios and mitigation actions. The first obstacle for the creation of such a benchmark was that of the differences in the meteorological determinants that could affect the monitoring campaigns. These campaigns, in fact, had to be carried out in different climatic areas and during different meteorological conditions because of the physical distance among the different corridors. To overcome this difficulty, the choice was that to carry out these campaigns during four different characteristic periods coinciding with the four seasons.

THE IMONITRAF CORRIDORS

Figure 1: *Map of the corridors hosting monitoring campaigns carried out in the frame of ETC-Alpine Space EU project iMONITRAF!.*

The second problem encountered was that to figure out a protocol to assure the homogeneity and comparability of the measurements. In fact, even if air quality sensors have to comply to tight requirements, the way in which measures are taken can change the final measurement values, then affect interpretation. As an example, one for may, air quality measurements result particularly sensitive to the distance from pollutants sources, roads in case of transports. For this reason, the decision taken at the beginning of the monitoring campaigns was that to carry out the measurements according to the EU Directive 2008/50/CE, but positioning the sensitive element at the border of the highways (within 4 m from the edge of the most external lane). In one case (Tarvisio Corridor) this was not possible and for this reason the idea was that to estimate the pollution levels at the edge of the most external highway lane through the use of numerical modelling.

The third problem encountered was that to figure out indicators to be used for the comparisons among different corridors. In fact, because of the intrinsic limited duration of the monitoring campaign, which had to last less than one year, all the indicators fixed by the EU Directive 2008/50/CE could not be applied. For this reason, the solution adopted was that to determine, for the main pollutants related to transports (PM10 and NO2), the average diurnal and weekly cycle associated to the four seasons. The reasons of this choice were both that to permit a comparison among the state of different corridors and that to see which were the time periods (of the day and of the week) with the highest impacts on air quality.

2 The monitoring sites

2.1 Valle d'Aosta

The measurement station is located at one side of the road that links the highway to the Mont-Blanc Tunnel. The structure is owned by GEIE-TMB. ARPA VDA, that valiadates the data.
The site is equipped with:

- A meteorological station
- A PM10 concentration measurer
- An NOx, NO2 and NO analyzer
- A PM2.5 sampler
- A PM10 and Benzopyrene sampler

General site data:

City: Courmayeur, Entrèves

Activation date: 01/11/2006

Longitude: 06.58.24

Latitude: 45.47.31

Altitude: 1338

StationType: Traffic – Suburban

VALLE D'AOSTA SITE

Figure 2: *Valle d'Aosta site*

2.2 Ticino – Bioggio Airport

City: Bioggio

Activation date: 04/01/1991

Longitude: WGS84 8.9127

Latitude: WGS84 46.0106

Altitude: 285

Station Type: permanent air quality monitoring station.

Station Type: averagely populated town, suburban. Presence of industries.

Description: the Bioggio monitoring station is located in the industrial zone next to the Agno airport. The emissions generated from air and A2 highway traffic adds to the ones of the factories in the proximity of the station.

TICINO SITE

Figure 3: *Ticino site*

2.3 Piemonte

Site: Campaigns to measure air quality next to A32 highway were carried out in Susa, frazione San Giuliano, Piedmont, Italy

The mobile laboratory coordinates are: 45° 8'13.42"N, 7° 4'32.67"E

Monitoring periods:

Summer: 1/9/2010-29/9/2010

Winter: 1/12/2010-30/12/2010

Spring: 8/4/2011-9/5/2011

Autumn: 11/10/2011 – 8/11/2011 (for PM10 : 11/10/2011-9/11/2011, for PM2.5 11/10/2011-13/11/2011)

Instruments: SO2 Fluorescence analyzer API 100 E, NOx chemiluminescence analyzer

MONITOR EUROPE ML 9841B, Ozone ultraviolet rays analyzer MONITOR EUROPE ML 9810B, CO infrared rays absorption analyzer API 300 A, PM10 – PM2.5 gravimetric reference method instruments TCR TECORA, High volume sampler for sampling of PM10 particles with 1.27 m3/min suction flow in accordance with norm UNI-EN 12341, equipped with Multi-Stage Particulate Size Fractionator Analitica Strumenti, gaschromatographic BTX analyzer SINTECH SPECTRAS CG 855 series 600, meteorological station LSI LASTEM

Measured parameters: ozone (O3), nitrogen oxides (NO, NO2), carbon monoxide (CO), sulphur dioxide (SO2), benzene, toluene, xylenes, PM10-PM2.5 (particulate), Polycyclic aromatic hydrocarbons (on PM10 and PM2.5), metals (on PM10 and PM2.5), ammonium, chlorides, nitrates, sulphates, calcium, sodium, potassium, magnesium on particular matter (various fractions), meteorological parameters

Site description: the monitoring site is located in frazione San Giuliano, Susa, in Susa valley, about 2 km far from the main town of the valley, Susa (6700 inhabitants), and 50 km far from Turin, capital of Piedmont Region (about 900.000 inhabitants)

PIEMONTE SITE

Figure 4: *Piemonte site*

2.4 Friuli Venezia Giulia

City: Tarvisio

Longitude: 13°33'43"E

Latitude: 46°30'25"N

Altitude: 1070 meters.

Station Type: mobile laboratory.

Station Type: averagely populated town, suburban. Presence of industries.

Description: the Tarvisio monitoring station is located in a residential area next to the A23 highway.

FRIULI VENEZIA GIULIA SITE

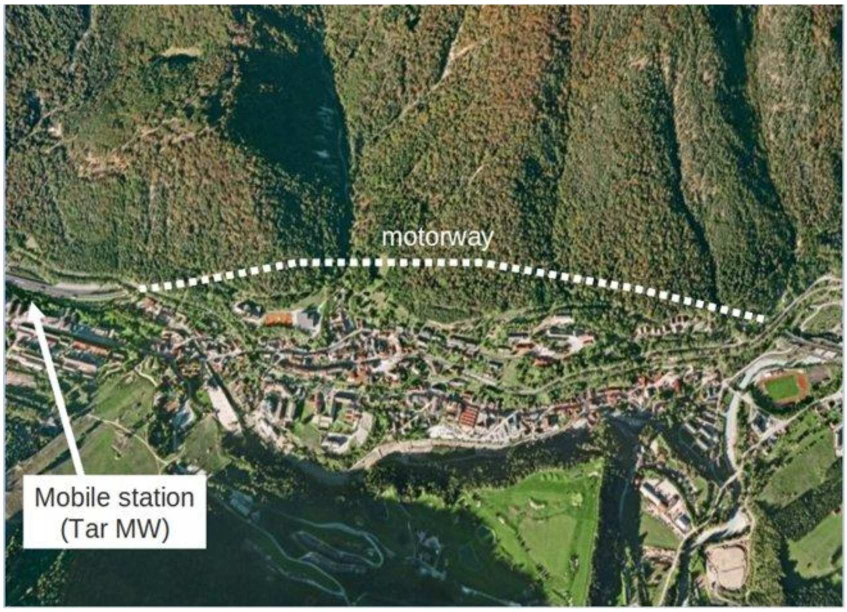

Figure 5: *Friuli Venezia Giulia site*

3 Air Quality Results

3.1 Spring

The first period of time taken into account was spring. The average diurnal cycle of nitrogen dioxide observed in this season shows the classical peaks during the early morning and during late afternoon and evening(figure 2, upper panel). In general the morning peak is much more sharp than the afternoon one, apart from the Tarvisio corridor. This is interpreted as an effect of night-time stratification of atmosphere that favours pollutants accumulation.

SPRING RESULTS

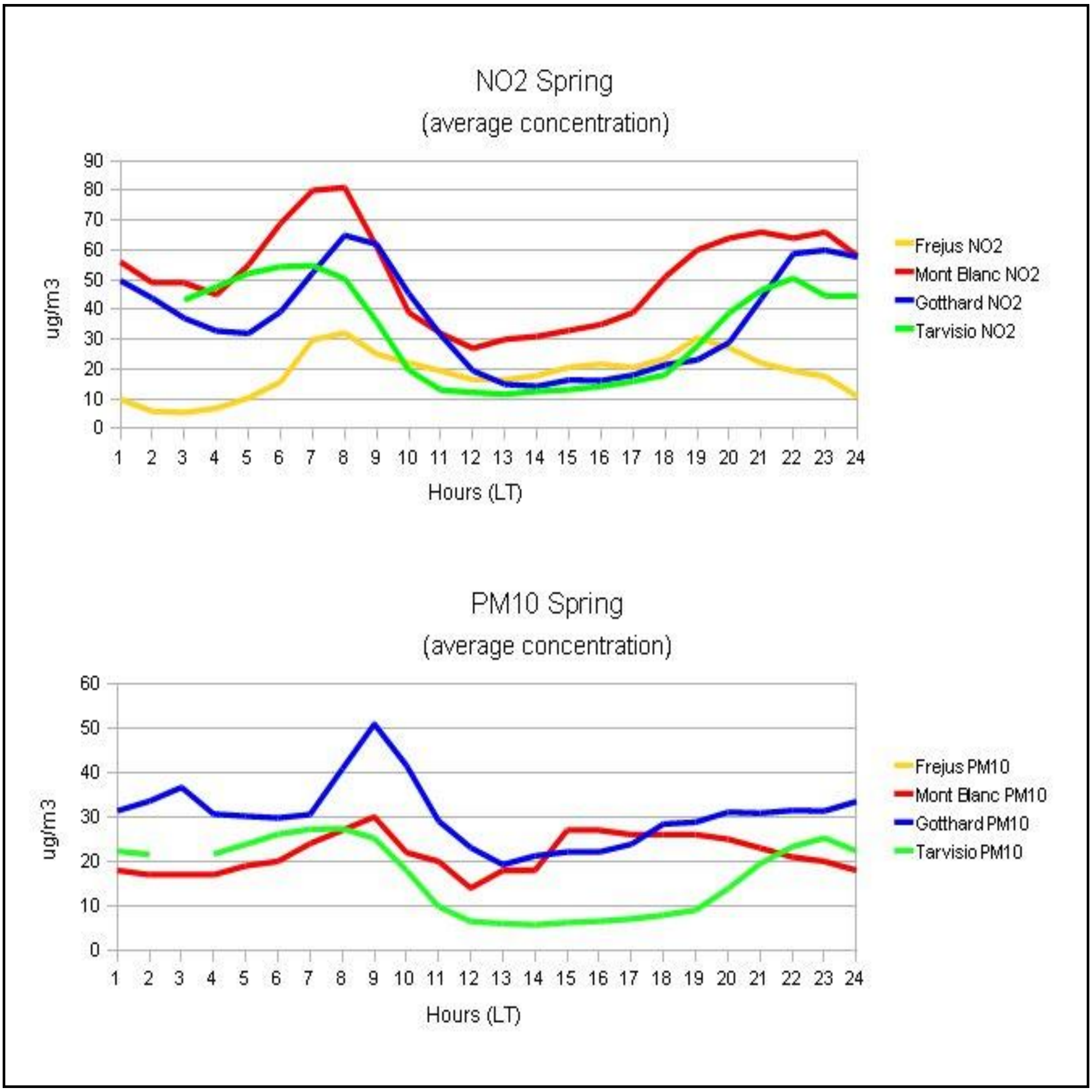

Figure 6: *The average diurnal cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Spring over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

The diurnal cycle of particulate matter shows a slightly different behaviour, in general with a less pronounced morning peak, apart from Gotthard, and a sort of late afternoon and evening plateau. This behaviour might be explained by the fact that particulate matter is emitted not only by road transports but even by other sources, among which there is even the domestic heating. Even for particulate matter, however, meteorological determinants play a relevant role. In particular, specially for areas characterized by a low density of inhabitants, the night-time values of particulate matter are a result of both increased stability and enhanced formation of secondary aerosols (nitrates and sulphates originate with nucleation, favoured by low temperatures).

SPRING RESULTS

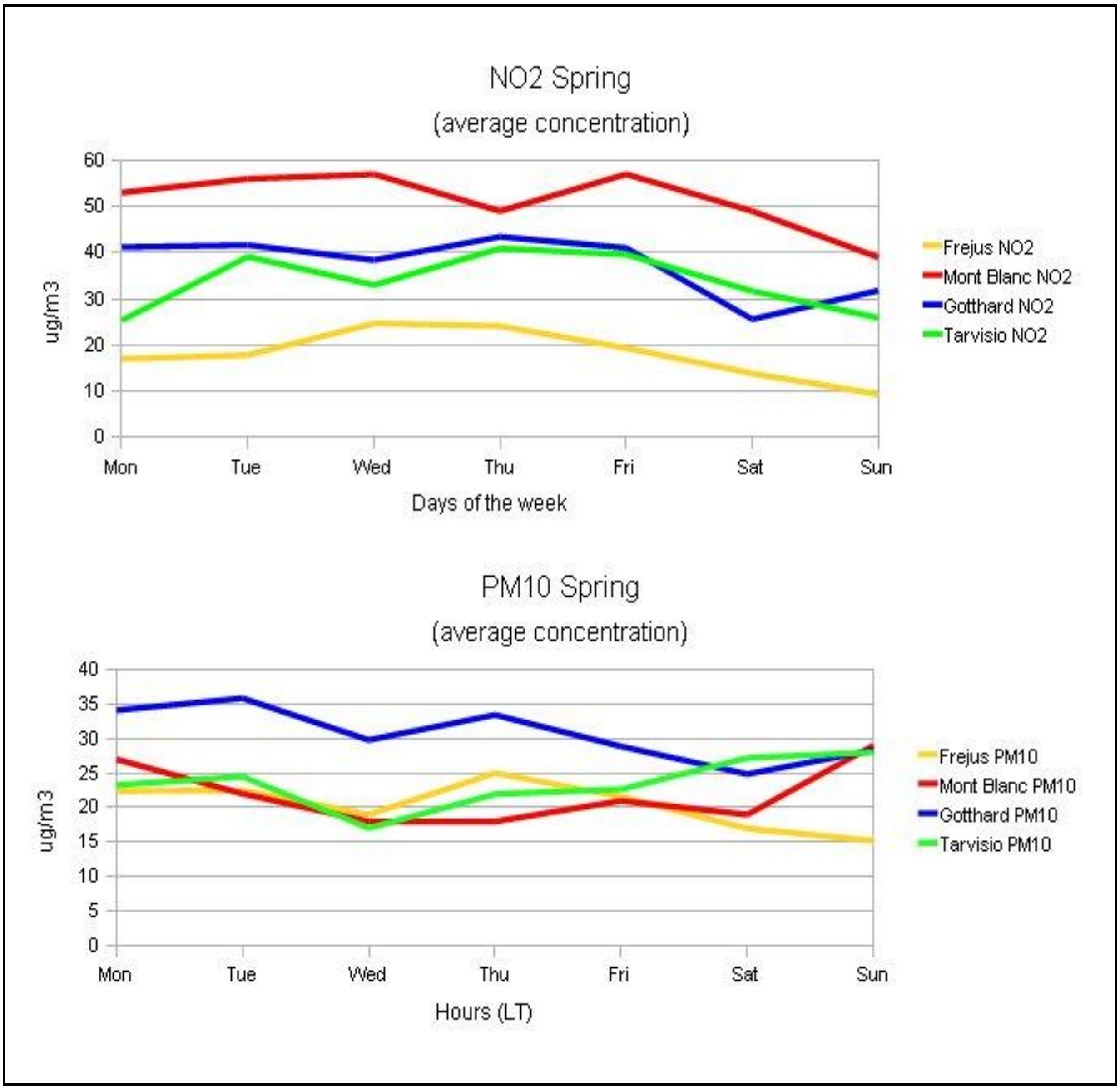

Figure 7: *The average week cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Spring over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

Concerning the weekly cycle, in all the corridors it is clearly recognizable a decrease in NO2 concentrations (figure 3, upper panel) during the week end. This decrease seems sharper on Mont Blanc than in the other corridors.

Other peculiarities worth to be noticed are the Sunday increase in NO2 concentration on the Gotthard corridor and the low NO2 concentration in Monday on the Tarvisio corridor.

The weekly cycle of PM during spring is slightly different (figure 3, bottom panel), in fact there is not a clear decrease during the week end and, in come cases, Sunday concentrations appear higher than in the other days of the week, e.g., for the Mont Blanc and Tarvisio corridor. This behaviour might be explained remembering that PM has even different sources than road transports.

3.2 Summer

The diurnal cycle of NO2 (figure 4 upper panel) continues to show the two classical peaks observed in spring, even if with lower absolute values than those observed in spring. The observed peaks are almost all centered around 7-8 and 20-22 local time.

SUMMER RESULTS

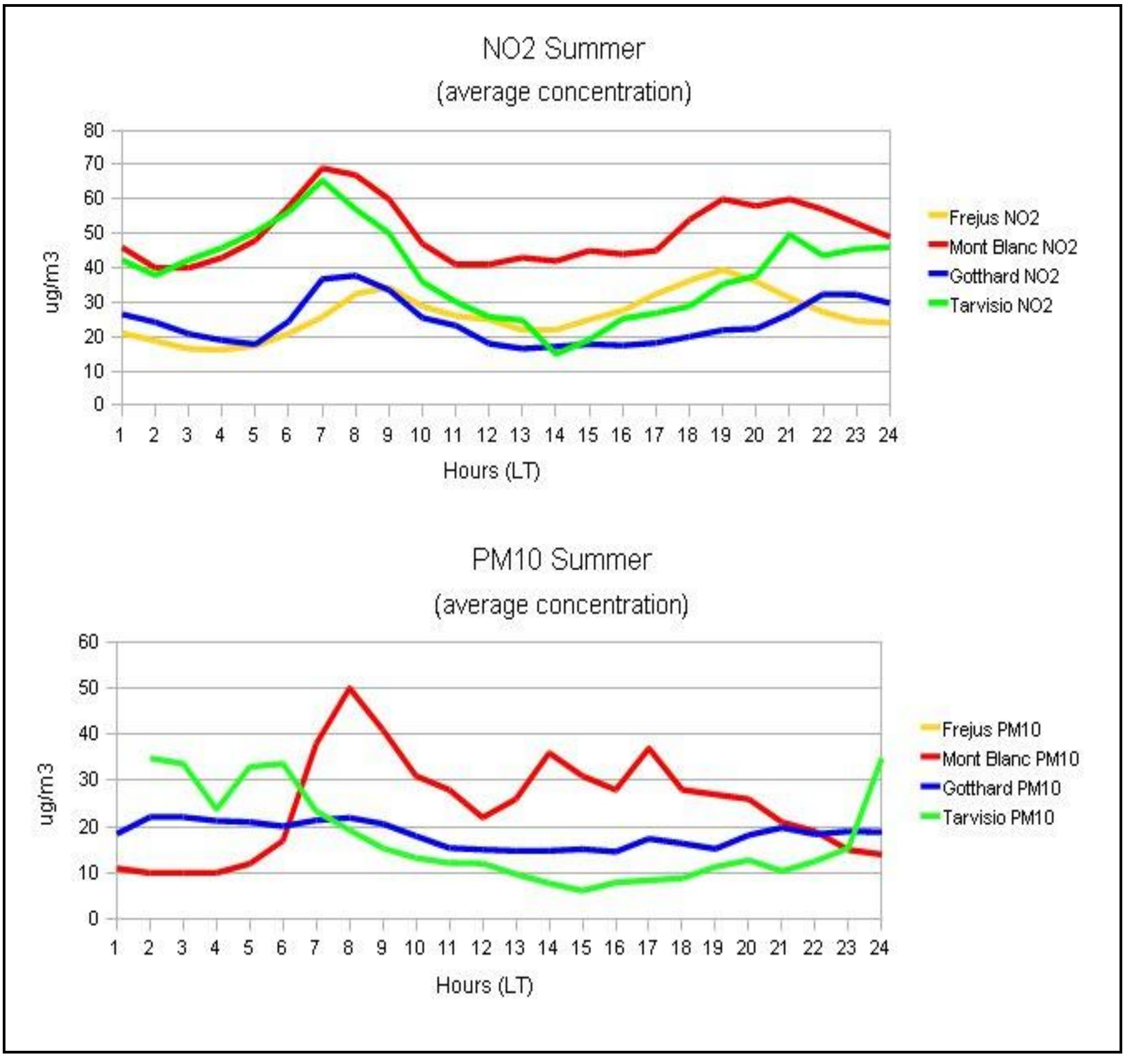

Figure 8: *The average diurnal cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Summer over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! Project. The summer monitoring campaign could not be carried out in the Frejus corridor.*

Concerning particulate matter, the average diurnal cycle seams quite flatten for Gotthard, which shows lower values than Mont Blanc, while the vice versa was true in spring. Moreover, Mont Blanc seems to be the only corridor with higher values during day-time that during night-time.

The analysis of week cycles on NO2 during summer (figure 5, upper panel) shows the same trends observed in spring, and almost with the same absolute values, while the week cycle of PM (figure 5, bottom panel) seems much more noisy even if at the same absolute values. In any case, all the corridors, differently from spring, shows a decrease during Sunday.

SUMMER RESULTS

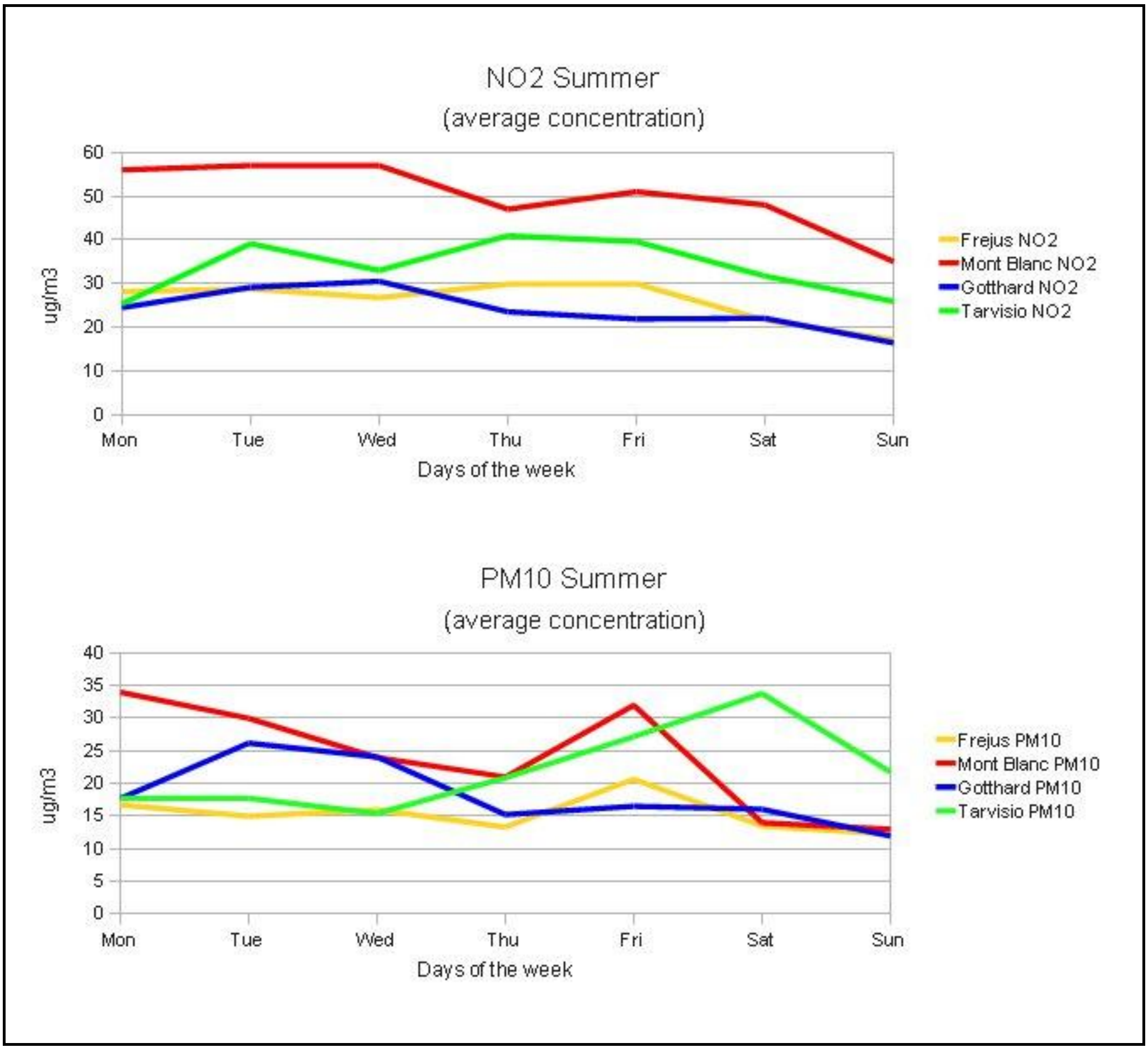

Figure 9: *The average week cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Summer over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! Project. The summer monitoring campaign could not be carried out in the Frejus corridor.*

3.3 Autumn

During autumn, the diurnal cycle of NO2 (figure 6, upper panel) reveals the classical morning and evening peaks, but in this case the peaks do not appear to be contemporary, in particular those occurring during evening. If confirmed, these differences might be a fingerprint of the different types of road transports that are interesting the four corridors.

AUTUMN RESULTS

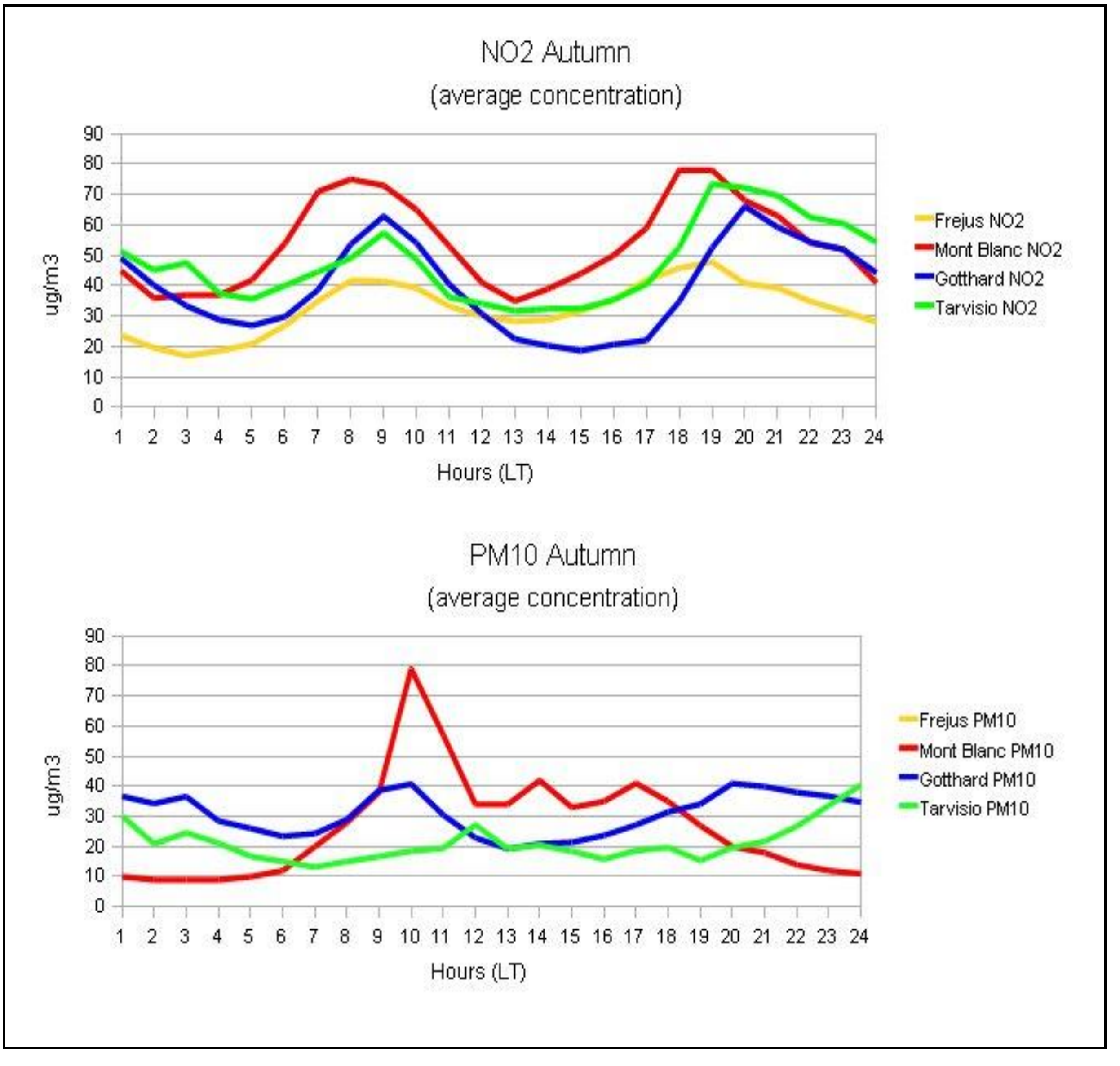

Figure 10: *The average diurnal cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Autumn over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

The diurnal cycle of PM10 (figure 6 bottom panel) shows a different behaviour for the three monitored corridors, in fact both Tarvisio and Gotthard have high PM concentrations during night-time while Mont Blanc reaches its highest concentrations during day-light, in particular during the early morning. The early morning peak is observable even in the Gotthard, but less pronounced and it is completely missed in the Tarvisio Corridor.

AUTUMN RESULTS

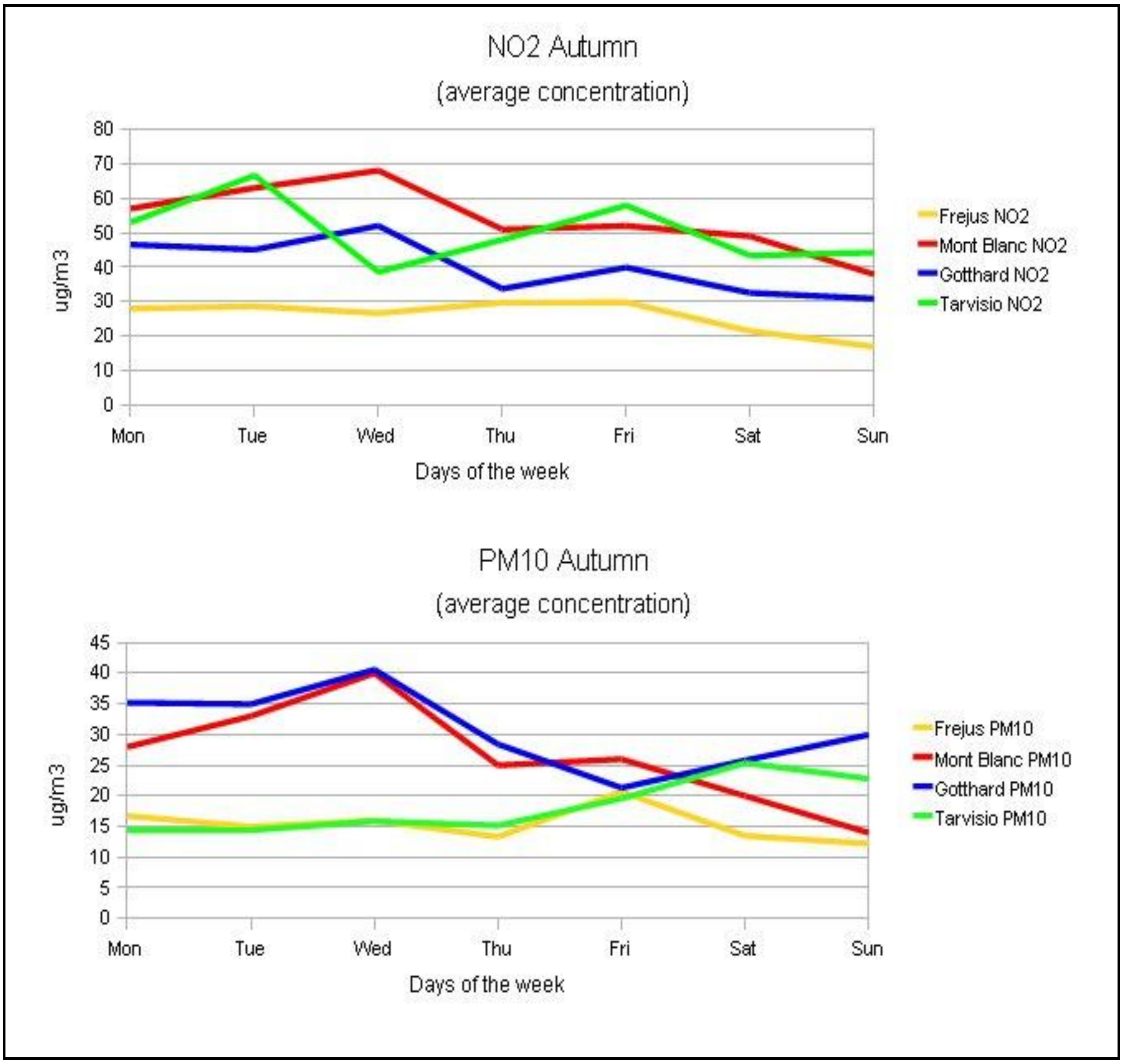

Figure 11: *The average week cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Autumn over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

The week cycle of NO2 and PM10 (figure 7, respectively upper and bottom panel) confirm what observed during the previous seasons with a decrease during week-end for NO2, sharper for Mont Blanc, and with a symmetric behaviour on the Mont Blanc and Gotthard compared with the Tarvisio corridor, where PM concentration increases during week-end.

3.4 Winter

During winter time, the diurnal cycle of NO2 (figure 8, upper panel) shows the classical morning and evening peaks for all the corridors, but with higher amplitudes than those observed during the previous seasons, more-over, the peaks do not seem contemporary, in particular the morning ones, with an early maximum in the Mont Blanc corridor compared with the Tarvisio and Frejus corridor, which occur earlier than that in the Gotthard corri-dor. Unfortunately, further measurements, carried out in different years would be necessary to understand it these are systematic effects or due just to chance.

WINTER RESULTS

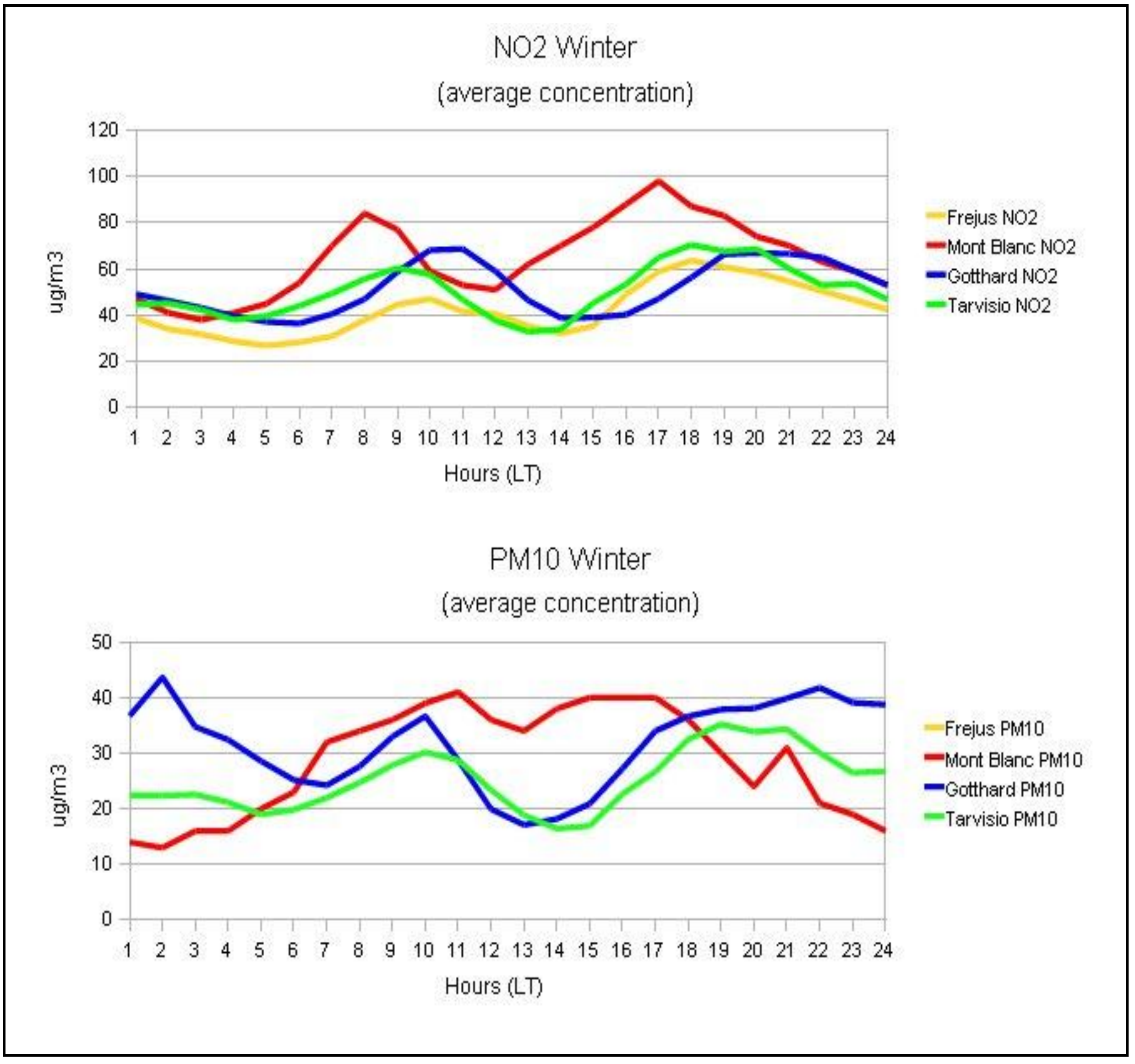

Figure 12: *The average diurnal cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Winter over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

The diurnal trend of PM10 (figure 8, bottom panel) confirms what found in the autumn seasons.

WINTER RESULTS

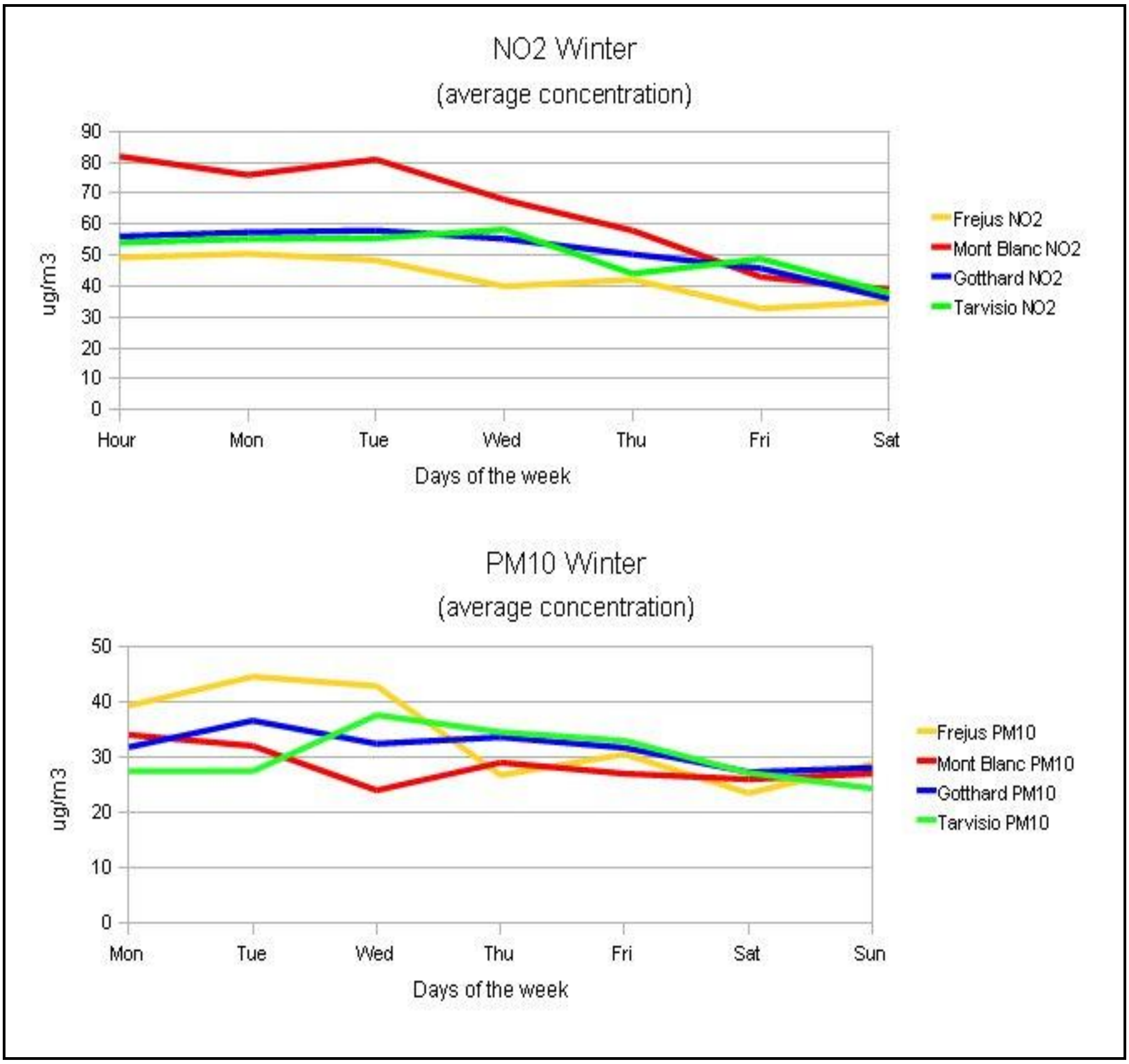

Figure 13: *The average week cycle on NO2 (upper panel) and PM10 (bottom panel) as it is observed in Winter over the four corridors analyzed by the EU ETC – Alpine Space iMONITRAF! project.*

The weekly cycle of NO2 and PM10, shown respectively in the upper and bottom panel of figure 9, show a clear decrease for NO2 during week end and a less clear and noisy situation for PM10. Differently from the previous season, there is no increase in PM10 during week end for the Tarvisio corridor and the concentration of this pollutant in the Mont Blanc and Gotthard seems quite flat. On the contrary there is a net and clear decrease for the concentrations of PM10 on the Frejus corridor.

4 The VDA Measurement in the iMONITRAF! Project

The main measurements conducted by ARPA VDA during the iMONITRAF Projects regarded PM10, PM2.5 and benzopyrene; in additions to these measurements, the mobile laboratory has been used on the highway A5 to measure the PM10 and NO2 concentrations.

4.1 Gravimetric analysis

Inside the Entrèves monitoring station two low volume samplers (Skypost – Tecora) were installed in order to be able to measure the particulate concentrations, being it PM10 or PM2.5, with gravimetric analysis. In addition to this type of instrument, an oscillating micro-scales (Teom - Rupprecht & Patashnick), capable of measure the hourly PM10 concentrations was used.

The concentrations obtained in the two years of analysis are reported in the following graph:

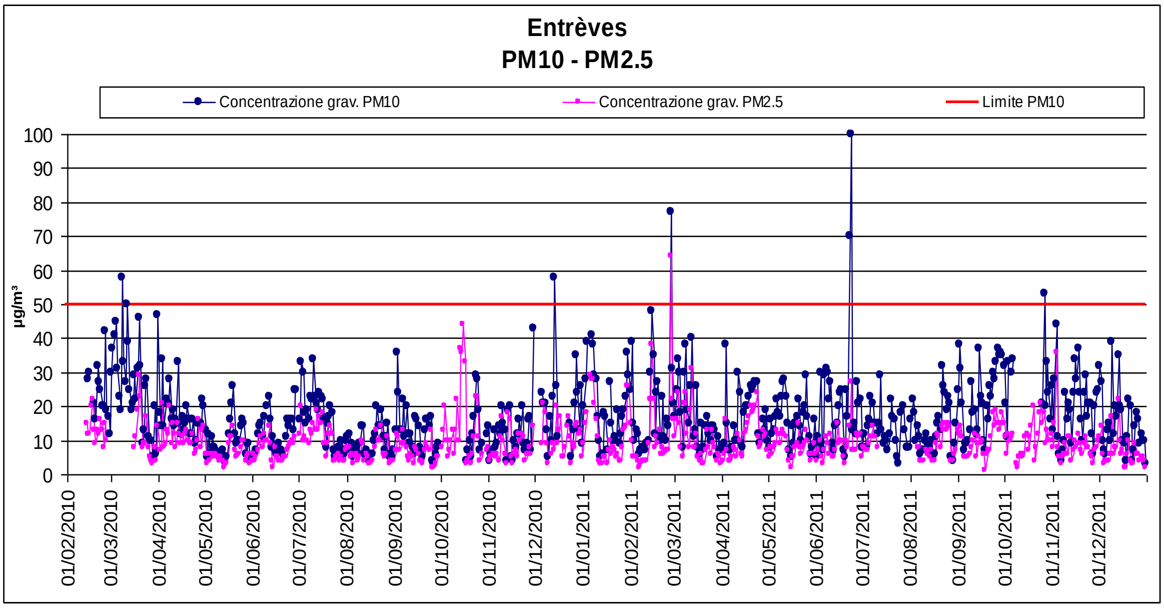

Figure 14: *Gravimetric concentrations of PM10 and PM2.5 at Entrèves.*

The two data series are very similar and there aren't any criticalities neither in the yearly number of exceedings nor in the mean yearly concentration.

In the first two years the station gathered data for more than 90% of the time.

4.2 Statistical analysis of the PM10 and PM 2.5 concentrations

The goal of the statistical analysis is to look for a correlation between the PM10 and the PM2.5 concentrations.

The PM10 values obtained from the gravimetric measures have been subdivided in five concentration classes, as follows:

class (µg/m³)	mean PM10	dev st PM10	mean PM2.5	dev st PM2.5	PM2.5/PM10 ratio
0 < PM10 < 10	7	1.9	5	1.4	0.71
10 < PM10 < 20	15	2.8	9	2.7	0.60
20 < PM10 < 30	25	2.9	13	4.2	0.52
30 < PM10 <40	35	2.6	17	5.4	0.49
40 < PM10 <70	49	9	21	10.6	0.43

For each class the mean PM10 and the correspondent PM2.5 averages were calculated. In order to verify the significativity of the intervals the standard deviation is used. The PM2.5/PM10 ratio was calculated using the calculated averages for each class.

The last class contains an interval of concentrations bigger than the others in order to have a statistical sample more representative and confirm the tendency of the other classes.

In the following graph it is possible to observe that, with the increase of the PM10 concentration the PM2.5/PM10 ratio decreases.

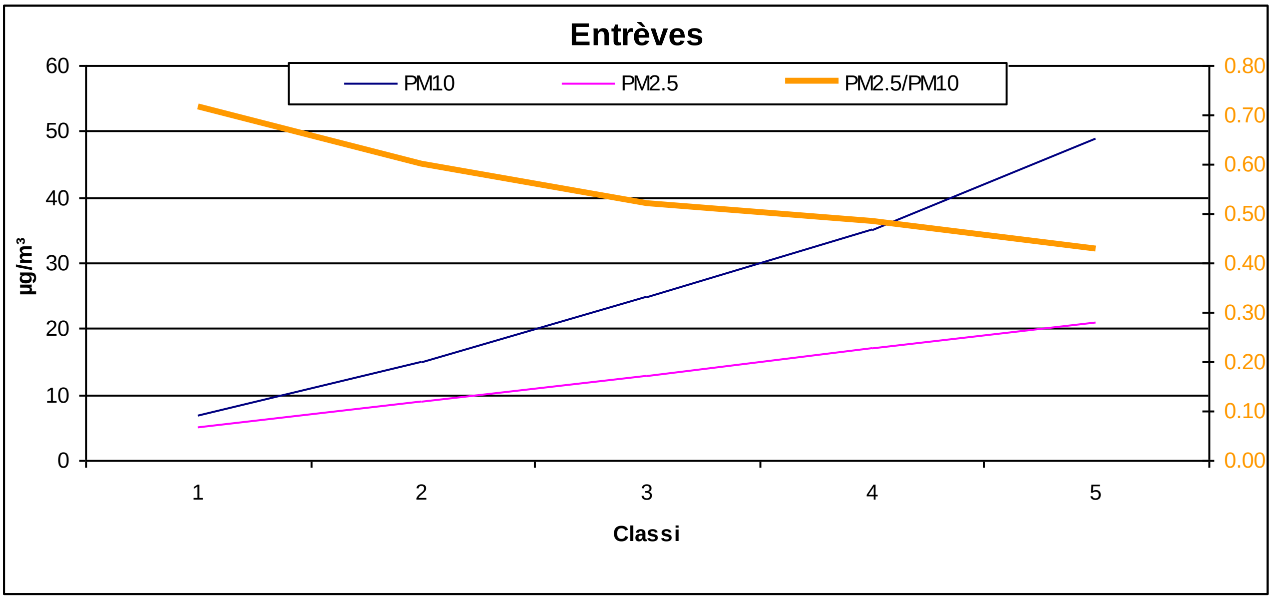

Figure 15: *PM2.5/PM10 ratio*

The very same statistical analysis has been conducted in an urban site affected by traffic only, in Aosta, yielding the following results:

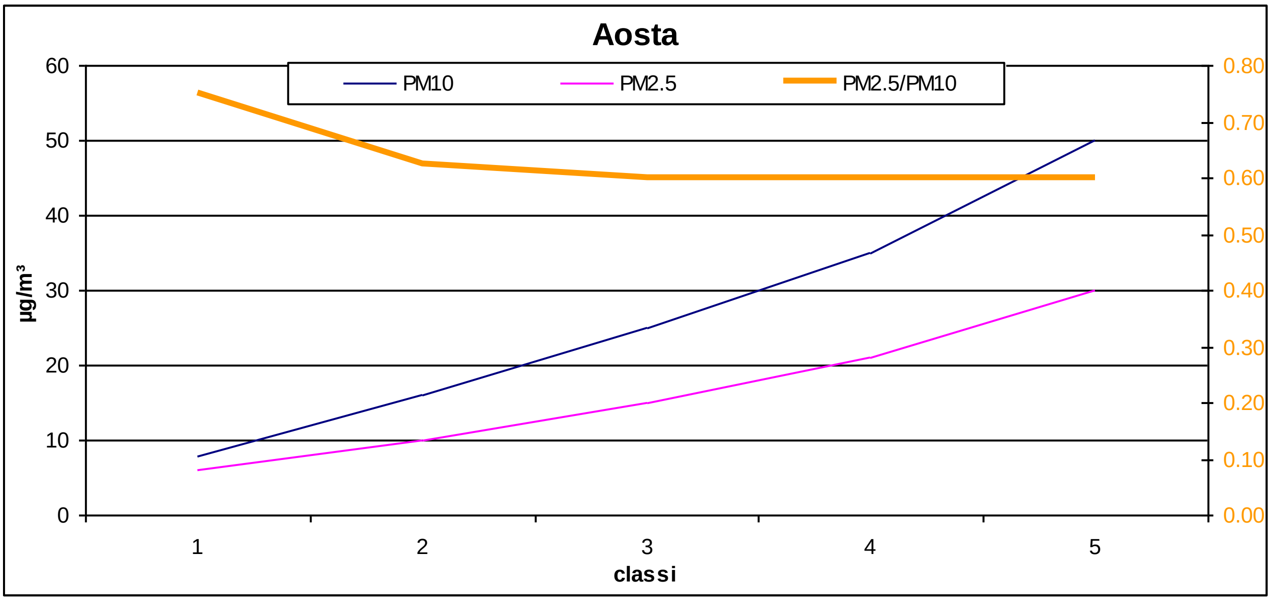

Figure 16: *Aosta PM10, PM2.5 and PM2.5/PM10 ratio*

For very low PM10 concentration values (less than 20 µg/m³) the PM2.5 values of the two sites is confrontable. Otherwise, for higher PM10 values (more than 20 µg/m³) the concentration ratio in the urban site remains constant while in the Entrèves site the ratio decreases.

We can therefore suppose that in the Entrèves site the increase in the particulate concentrations is to be attributed more to the re-suspension of the heavy particles than the one of the lighter ones that are emitted by the vehicles.

4.3 Benzopyrene

On the PM10 filters a few tests were conducted, in order to measure the Benzopyrene concentration, that is one of the few IPA with an actual law limit.

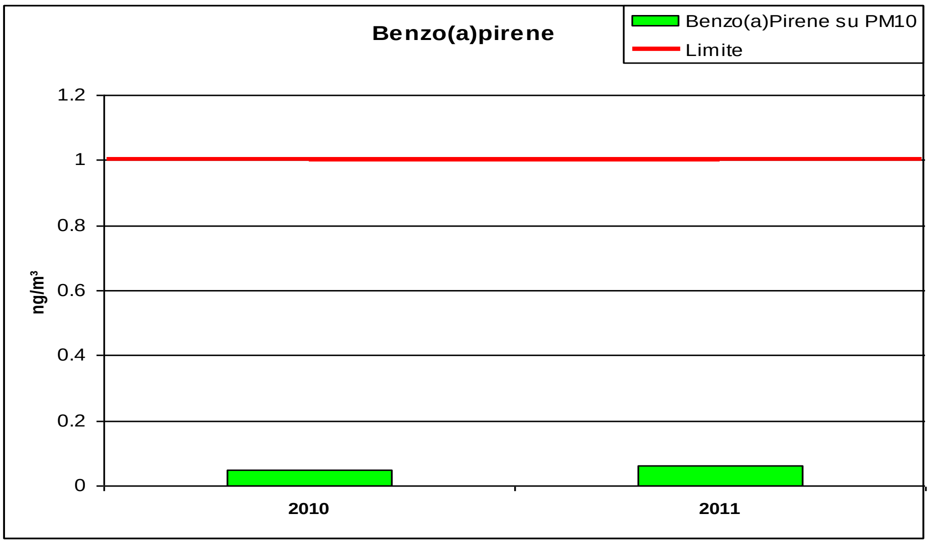

Figure 17: *Benzopyrene vs limit*

The analysis show that the concentration of this substance is about ten times less than the limit indicated by the law, that is 1 ng/m^3.

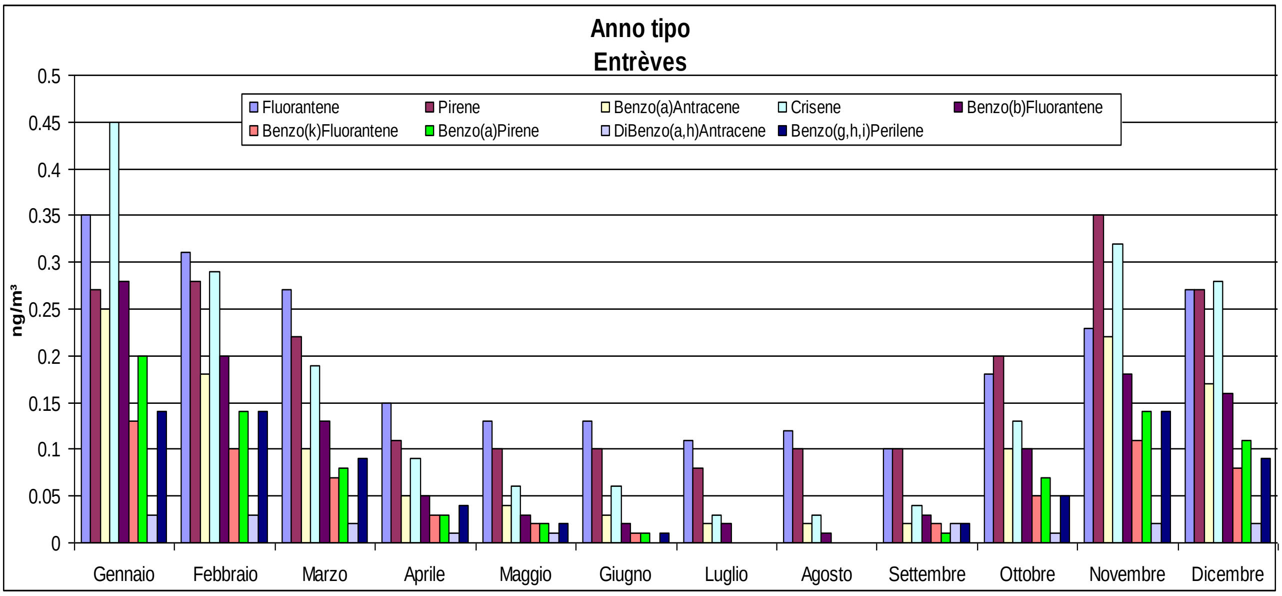

Figure 18: *concentration substances in the months*

There are not correlations with the traffic, but it is easy to see how the observed concentration is linked to the season.

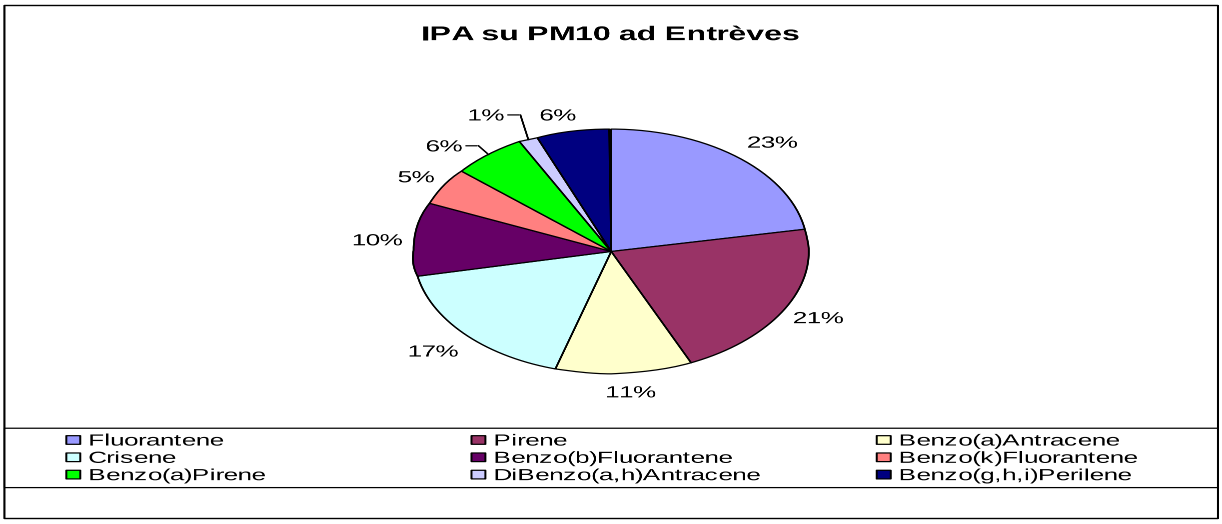

Figure 19: *IPA/PM10 at Entrèves*

4.4 Mobile Laboratory A5

A second measuring point has been chosen to complete the analysis on the air quality on the Mont Blanc corridor. The place has been found on the A5 highway, at 10 meters from the road side, in the proximities of the Châtillon town.

The mobile laboratory was used in five periods:

- I period: 02/06/2010 -28/06/2010, Summer.
- II period: 01/09/2010 - 30/09/2010, Autumn.
- III period: 10/12/2010 – 25/01/2011, Winter.
- IV period: 29/03/2011 – 03/05/2011, Spring.
- V period: 15/06/2011 – 31/08/2011, Summer.

A third measuring point is located in the Bossons station, on the French side. The data are the result of a collaboration between Switzerland (Genève, Vaud et Valais), France (Ain, Savoie et Haute-Savoie) and Italy (Valle d'Aosta), and are available for free download at www.transalpair.eu.

To compare the Italian Mont Blanc Tunnel Side (Entrèves), the center of the valley (Châtillon) and the "Route Blanche" (Bossons-Chamonix), firstly, the means of the valid data were considered. Note that the temporal aggregation used in the following two graphs is not the one used in the law; we chose to use this aggregation in order to quickly evaluate the NO2 and PM10 concentrations.

Nitrogen dioxide

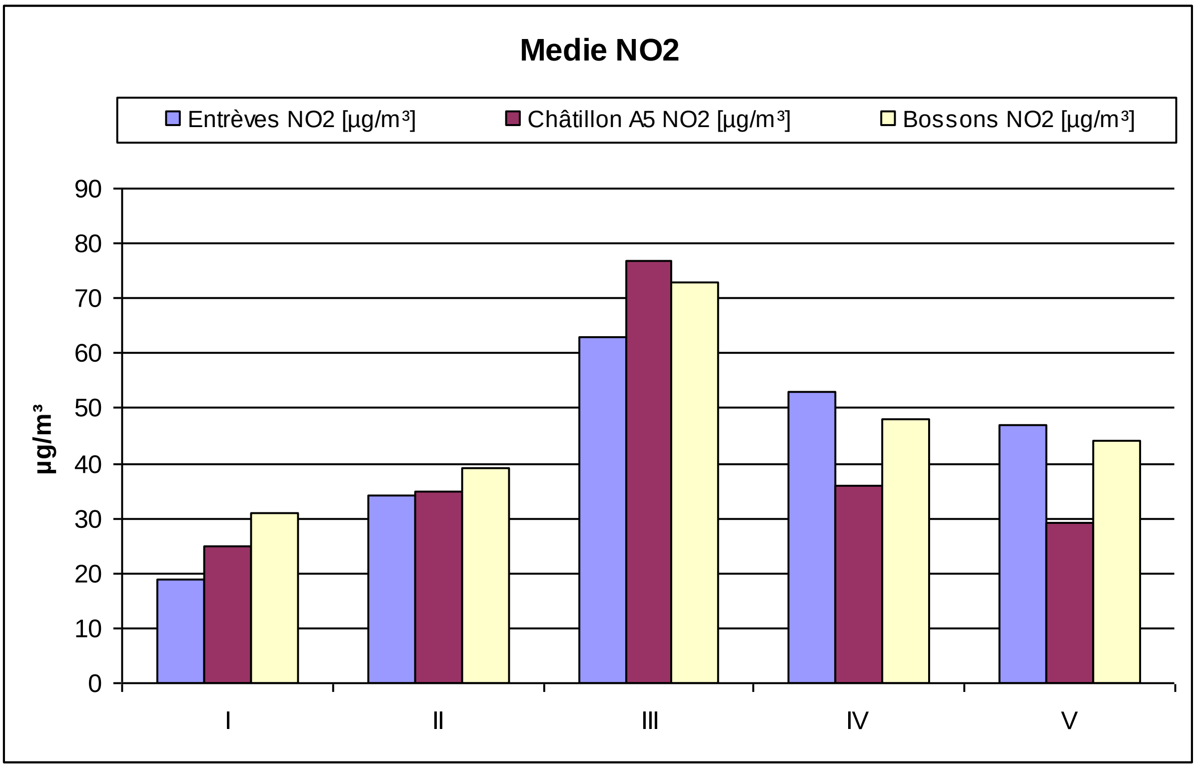

Figure 20: *NO_2 means at the various measurement stations*

The NO_2 concentrations in the two years of observations had, as expected, the higher values in the winter season while the values recorded in other seasons were lower.

PM10 Particulate

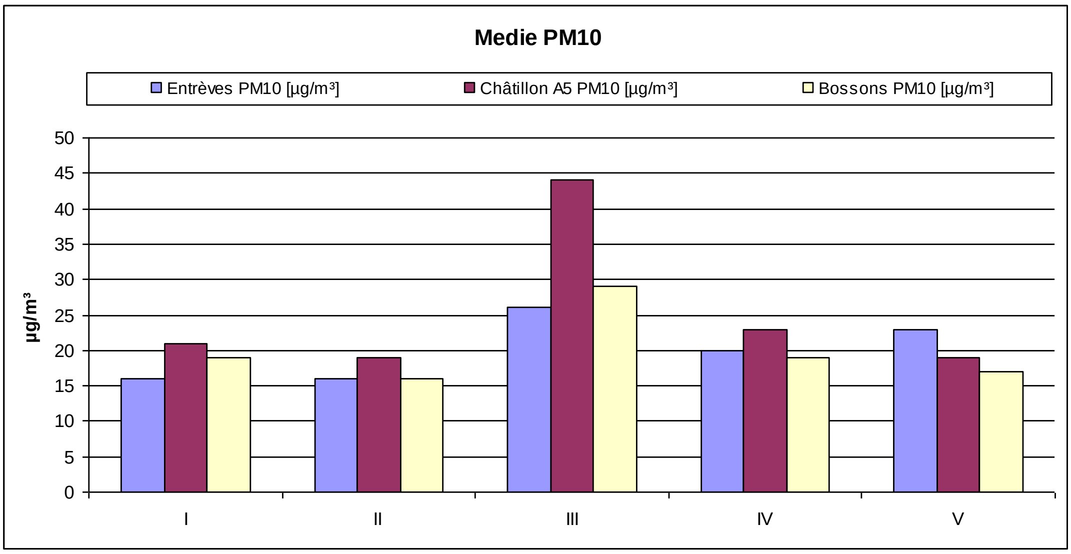

Figure 21: *PM10 means at various measuring stations*

The PM10 particulate concentrations measured in Châtillon is higher than the one measured in Entrèves four times out of five. In particular the difference between these two measuring points is higher in the winter season: we can assume that this is due to meteorological reasons because in Châtillon (550 m from sea level) conditions of atmospheric stability due to thermal inversion were observed.

Considering the data gathered by the mobile laboratory we can calculate the “typical day” and provide some additional considerations.

Nitrogen dioxide

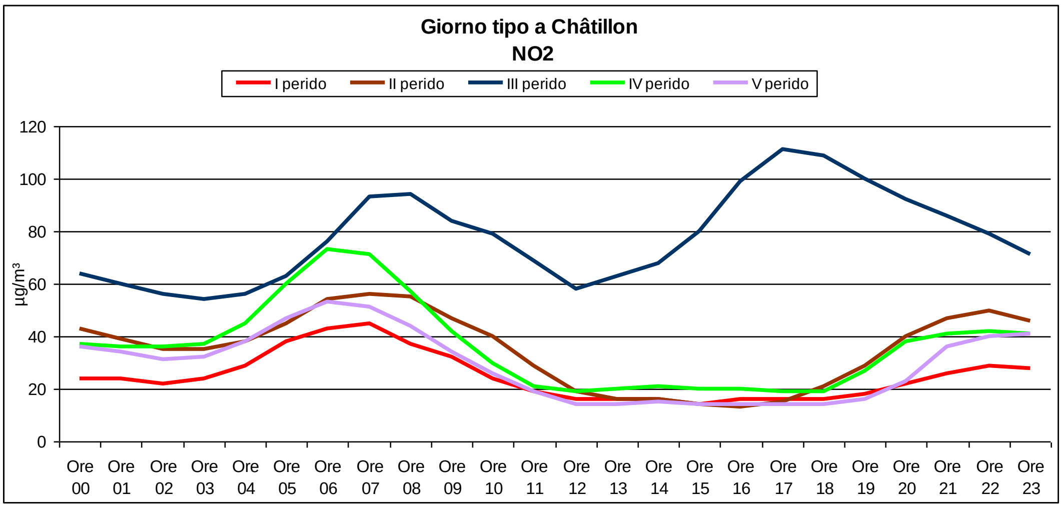

Figure 22: *Typical day at Châtillon*

In the winter days we observe two maximum concentration values: the first during the morning and the second during the afternoon. In the other seasons, instead, the minimum values are always observed during the afternoon.

This phenomenon is explained by the higher mixing of the lower atmospheric layers operated by the local breezes.

PM10 Particulate

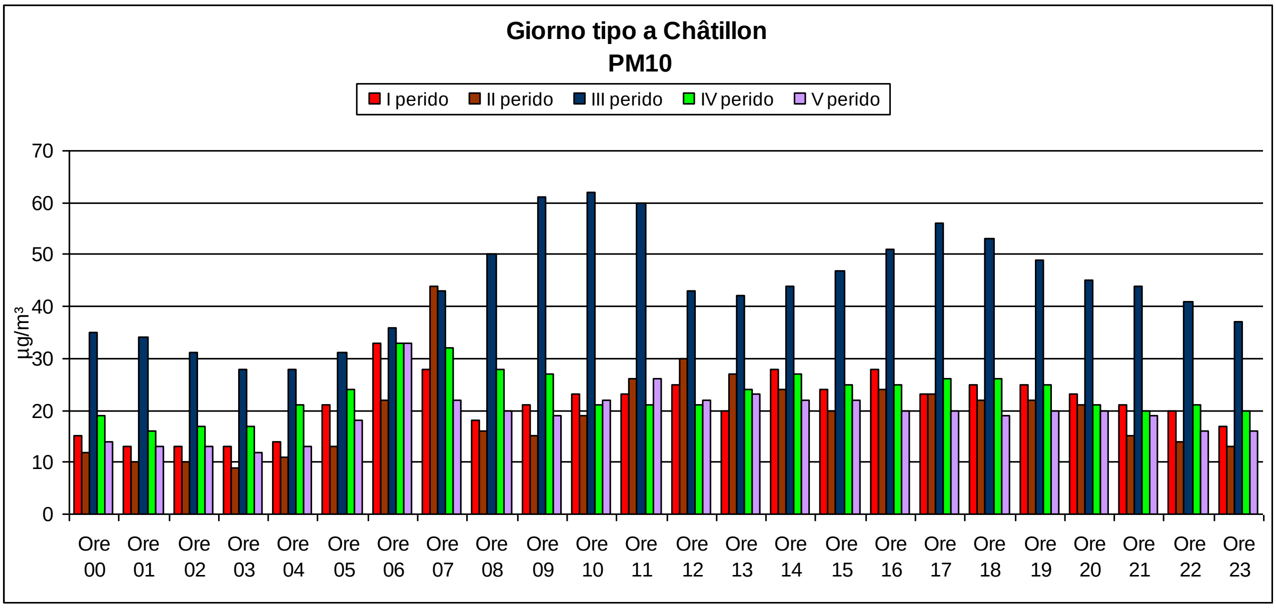

Figure 23: *Typical day at Châtillon*

The PM10 trend during the day is very similar to the NO_2 one: in the winter days we observe two distinct maximal values, while in the other seasons the hourly concentration is relatively constant having a maximum value in the morning and a minimum one during the night.

5 The Piemonte Measurements in the iMONITRAF! Project

5.1 Introduction

The study of size distribution and chemical composition of aero-disperse particulate matter (PM) is rather interesting because it gives useful information about the impact on the human health of the different fractions, permitting to formulate hypothesis on their origin. The European Project iMONITRAF! was an opportunity to deepen the topic in a context less urbanized than the metropolitan area that surrounds Torino. The analyzed area is influenced by the emissions of the vehicles that travel on the A32 Torino-Bardonecchia Highway.

In this study the preliminary results of the monitoring campaign are shown; the particulate matter measurement were carried out by means of a multistage aerosol sampler able to collect six size-segregated aerosol fractions.

5.2 Goals

In the European Project iMONITRAF!, in addition to the measurement of the pollutants provide for by the European Laws on air quality, an extensive analysis of particulate distribution and chemical characterization of the various sampled fractions were conducted, in order to evaluate the impact of the emissions of the highway traffic on the alpine environment. The monitoring site was located in Susa (San Giuliano), next to the Torino-Bardonecchia highway,

The measurement were carried out during three periods (1-29/9/2010; 8/4/2011-13/5/2011, 11/10/2011-8/11/2011) in order to represent different seasons and meteorological conditions. The sampler was located at about 3.5 meters from the A32 highway side.

The results were compared with the ones obtained in the monitoring campaign conducted next to the monitoring station of Torino-Lingotto, a background station in the city of Turin, from October 2011 to January 2011, in order to highlight the differences in the size distributions and chemical composition of particulate during the winter period , which is the most critical one for this pollutant.

Furthermore, in order to evaluate the genotoxic action of the chemical components of the particulate, mutagenesis tests were conducted on eleven samples; the results are reported in the dedicated section

5.3 Materials and methods

The particulate matter was sampled through a high volume sampler (Analitica Strumenti) with a flow rate of 1130 L per minute, according to European standard EN 12341:2001 . The device has a PM10 sampler head and a series of impactors able to fractionate different size intervals (< 0.49 µm, 0.49-0.95 µm, 0.95-1.5 µm, 1.5-3 µm, 3-7.2 µm, 7.2-10 µm). The particulate was collected on quartz filters. As regards laboratory analysis :

- the gravimetric analysis were conducted according to the EN 12341:2001 method;
- the determination of the polycyclic aromatic hydrocarbons was conducted following D.M. 25/11/94 ALL VI ;
- the analysis on metals followed the UNI EN 149002:2005 method ;
- the determination of anions and cations is based on the following steps:
- Extraction of the ions present in the particulate collected by the filter by leaching it, or part of it, with a 30 mL volume of de-ionized water ultrasonically treated
- Determination of the anions present in the solution using ionic chromatography; in particular the method APAT CNR IRSA 4020 manual 29/2003 was used

- Determination of the cations present in the solutions using ionic chromatography, in particular the method APAT CNR IRSA 3030 manual 29/2003 was used

The sampling time was 48 hours, in order to have a sufficient amount of analyses The number of samples in Susa and Torino was 23 and 25 respectively

The analytical determination of the six fractions was conducted on twelve samples for Susa and five for Torino, selected in order to represent different meteorological conditions.

5.4 Results

5.4.1 Mass Concentrations

In the Susa site, the more relevant mass fraction is the one below 0.49 µm, that accounts for 37% of the PM10; the particulate smaller than 0.95 µm accounts for 58% of the total PM10. Overall, PM10 data show the typical seasonal periodicity with maximum in winter and minimum in summer, as shown in Table 1 and Figure 1. The highest concentrations were recorded on 18th and 19th October and 3rd and 4th November 2011, periods that had great atmospheric stability; in those periods we observed peaks on the pollutants concentrations in the whole Torino province.

As regards size distribution, in the winter period the fine component increases, while the fraction greater than 1.5 µm decreases in comparison with the spring period, during which the biggest fractions are more relevant due to the re-suspension caused by the greater atmospherical instability and higher wind speed. Another possible cause of the phenomenon could be the greater presence of aerosol of natural origin (pollen, spores). Comparing the data with the ones observed in Torino at the urban background fixed station of Torino-Lingotto, in the same periods of the year (October-November 2010 in Torino and October-November 2011 in Susa) the fraction larger than 1 µm is 41% of PM10 in Torino and 38% in Susa; Table 2 shows that the percentages of single fractions are similar as well .

Size Interval	SUSA mean weekly concentration 2010	SUSA concentration MEAN APRIL-MAY 2011	SUSA concentration MEAN OCT-NOV 2011	SUSA concentration MEAN
7,2 – 10	0.9	3.2	1.3	1.8
3,0 - 7,2	2.1	4.6	3.4	3.4
1,5 - 3,0	1.2	2.8	2.7	2.2
0,95 - 1,5	1.7	4.0	5.4	3.7
0,49 - 0,95	2.9	5.9	9.3	6.0
0,0 - 0,49	5.4	10.8	9.9	8.7
total	14.2	31.3	32.0	25.8

Table 1: *PM Mass Concentrations (µg/m3) observed in Susa (S.Giuliano)*

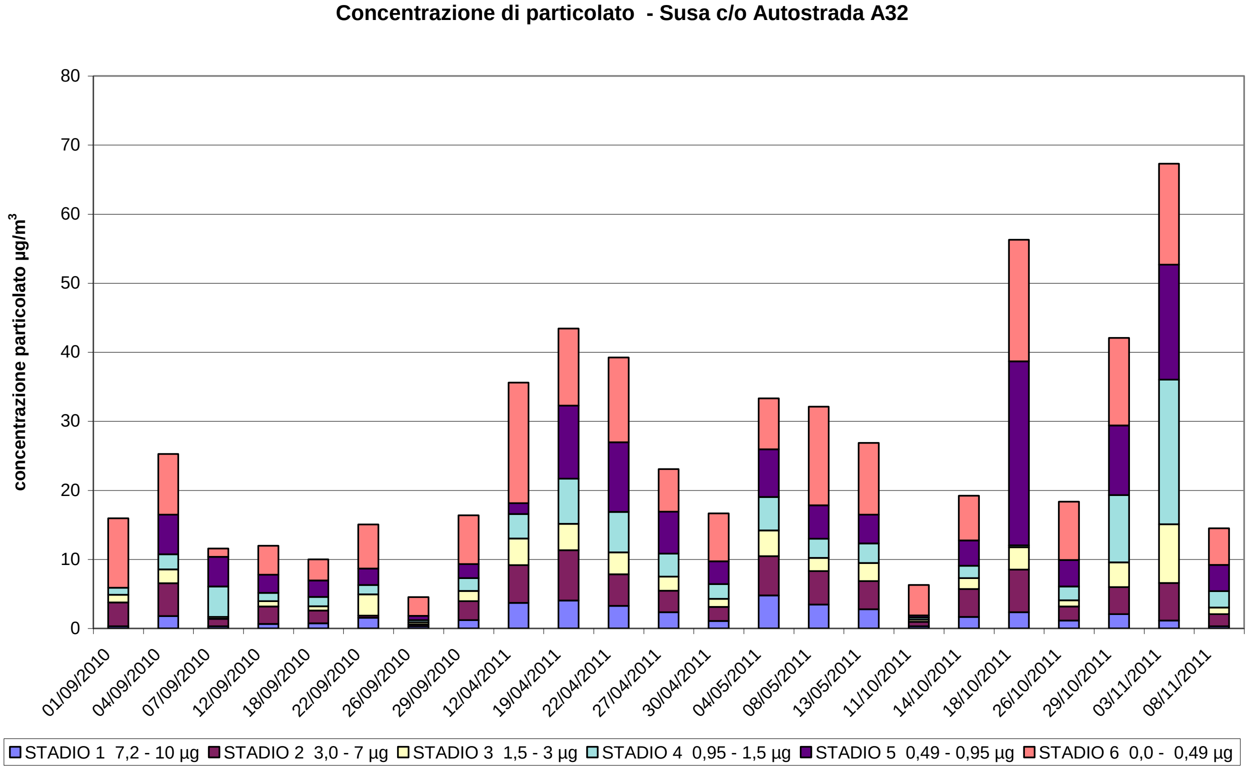

Figure 24: *Concentrations of the different particulate fractions in Susa analysis.*

Size Interval	SUSA mean percentage 1/9/2010-29/9/2010	SUSA mean percentage 8/4/2011-13/5/2011	SUSA mean percentage 11/10/2011-8/11/2011	SUSA mean percentage COMPLESSIVA	TO-LINGOTTO mean percentage OTT-NOV 2010	TO-LINGOTTO mean percentage OTT 2010 - GEN 2011
7,2 - 10	6	10	5	7	3	3
3,0 - 7,2	14	15	12	14	12	9
1,5 - 3,0	8	9	7	8	8	7
0,95 - 1,5	13	13	14	13	18	16
0,49 - 0,95	21	19	24	21	25	28
0,0 - 0,49	37	35	39	37	34	38

Table 1: *Size distribution of the particulate mass at Susa and Torino-Lingotto*

The meteorological variables greatly affect the size distribution of the particulate, that is far from the mean value in the days with rain or wind.

As an example consider the sample obtained on 7th-8thSeptembre 2010: on the first day it rained constantly for the whole day and on the second one it rained for a few hours, for a total of 11.8 mm of precipitation; the rain determined the decrease of the finest fraction (< 0,49 µm) and of the largest one (>1,5 µm), as shown in Figure 2, where those days are compared with the mean distribution of the other September days.

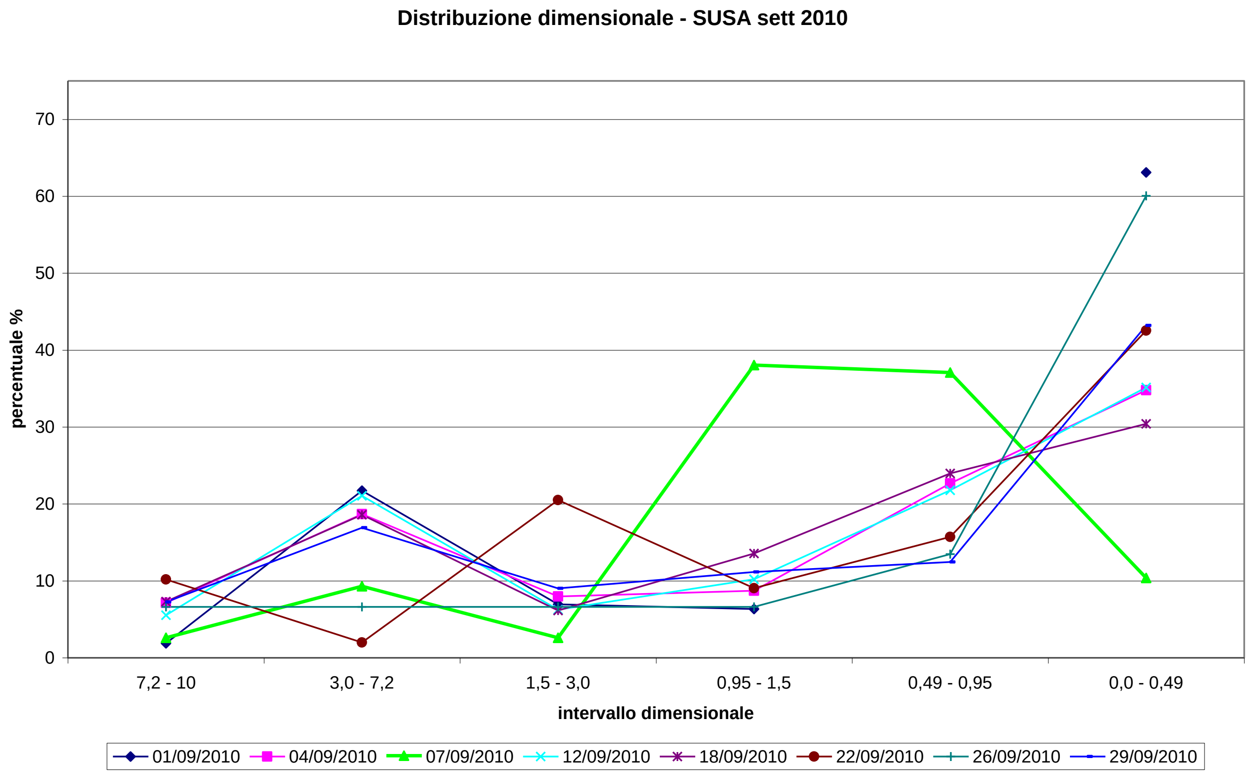

Figure 25: *Size distribution of the mass concentrations in Susa, September 2010*

A phoen episode took place on 11th October 2011 (see figure 3) and caused the almost complete decrease of all the size fractions, so that almost only the fraction smaller than 0.49 µm is detectable and shows the lowest value in that period (4 µg/m^3).

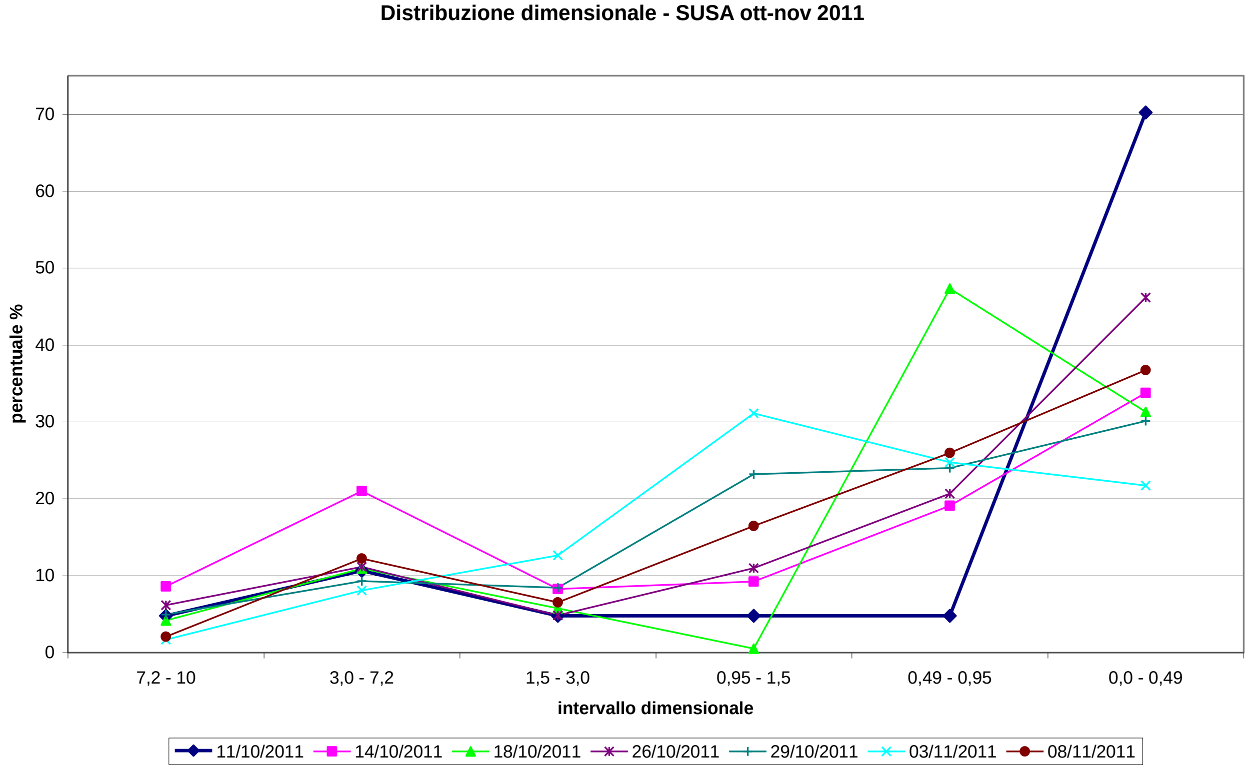

Figure 26: *Size distribution of the mass concentrations in Susa, October-November 2011*

5.4.2 Soluble inorganic components

The analyzed ions were ammonium, chlorides, nitrates, sulfates, sodium, potassium, calcium and magnesium.

The components with the highest concentrations were nitrates, sulfates, ammonium, sodium, calcium, magnesium and chlorides that account for 24% (during spring) and 42% (during summer) of the total PM10 mass. These data were confirmed by the analysis conducted on the monthly samples obtained by means of a gravimetric sampler that meets the EN 12341 standard , equipped with a 2.3 m^3/h flow rate PM10 sampling head.

In Susa and Torino sites the percentage of nitrates, sulfates and ammonium is larger in the fraction below 0.95 µm, in agreement with bibliography data concerning secondary inorganic fraction of the particulate.

During cold periods of the year the nitrates percentage is generally higher than the sulfates one. In Susa and Torino during winter the nitrates percentage is six times, whereas during summer the percentages are very similar or the sulfates one is larger (as in April when they account for 9% vs 7% of the nitrates). In September nitrates are 1.7 times larger than sulfates.

Other monitoring campaigns conducted in Piemonte yielded similar results (Arpa Piemonte, RSA 2008, Lo stato delle componenti ambientali, Aria; Provincia di Torino, Arpa Piemonte, Uno sguardo all'aria 10 anni dopo, 2007).

Figures 4, 5, 6 and 7 show the percentages of soluble inorganic components in the sites of Susa and Torino-Lingotto. In the figures 8 and 9 the concentrations measured in Susa, calculated as whole dataset mean, are shown

In the following section the distribution in the six fractions is described in detail for every component

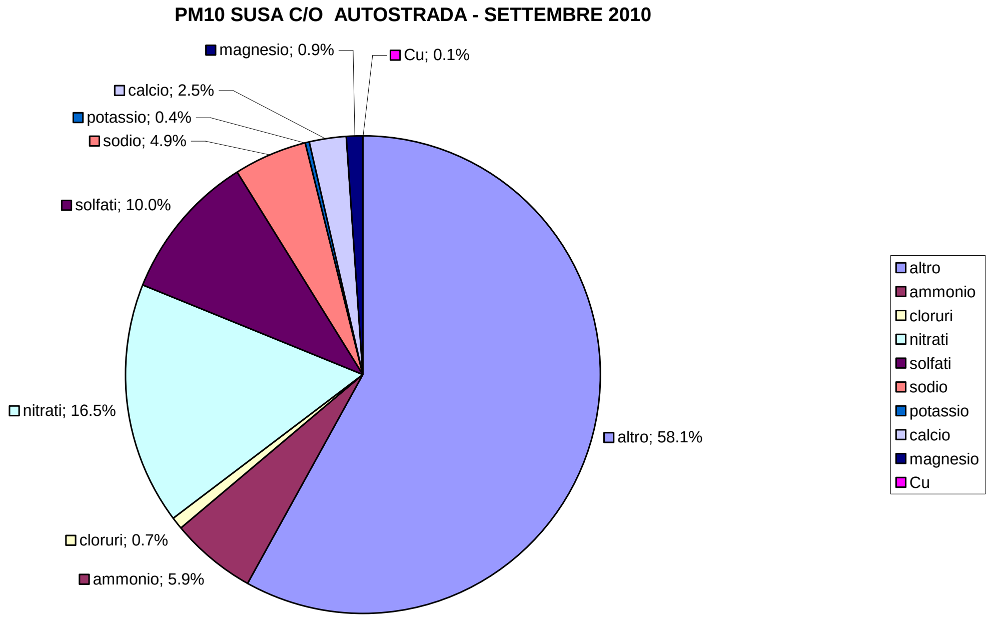

Figure 27: *Percentage distribution of PM10 soluble inorganic components in Susa (S. Giuliano) – September 2010*

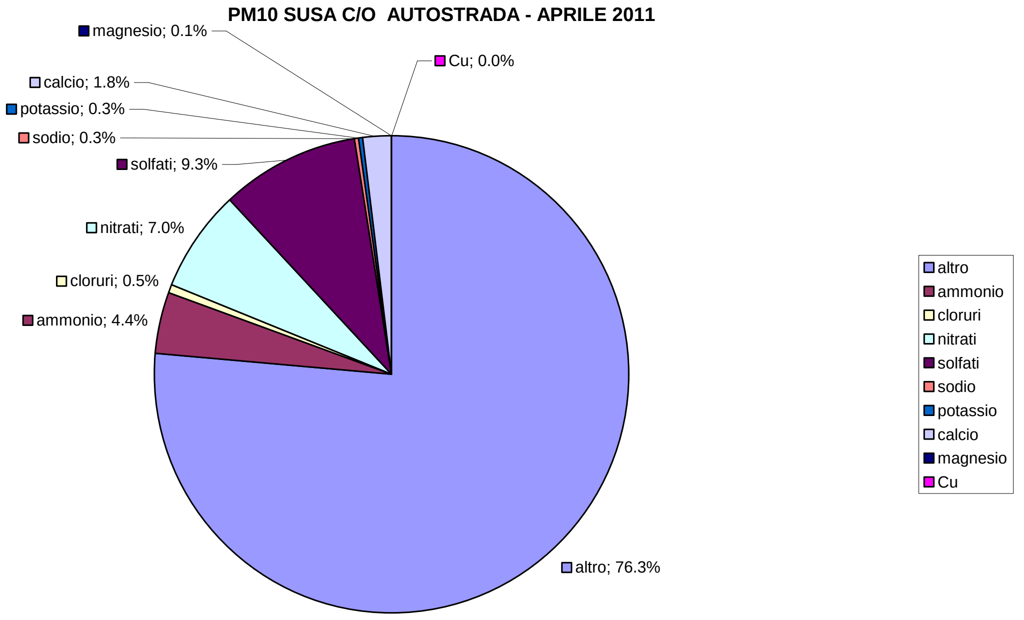

Figure 28: *Percentage distribution of PM10 soluble inorganic components (S.Giuliano) April-May 2011*

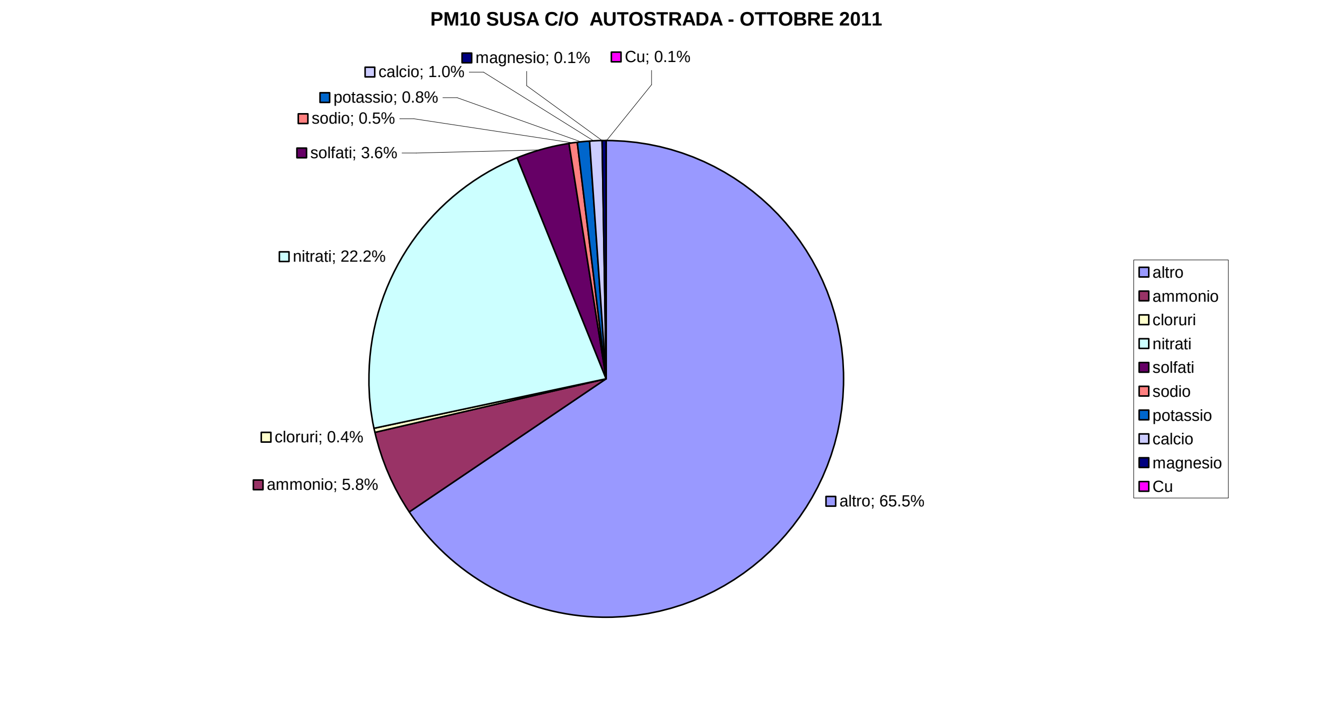

Figure 29: *Percentage distribution of PM10 soluble inorganic components in Susa (S.Giuliano), October-November 2011*

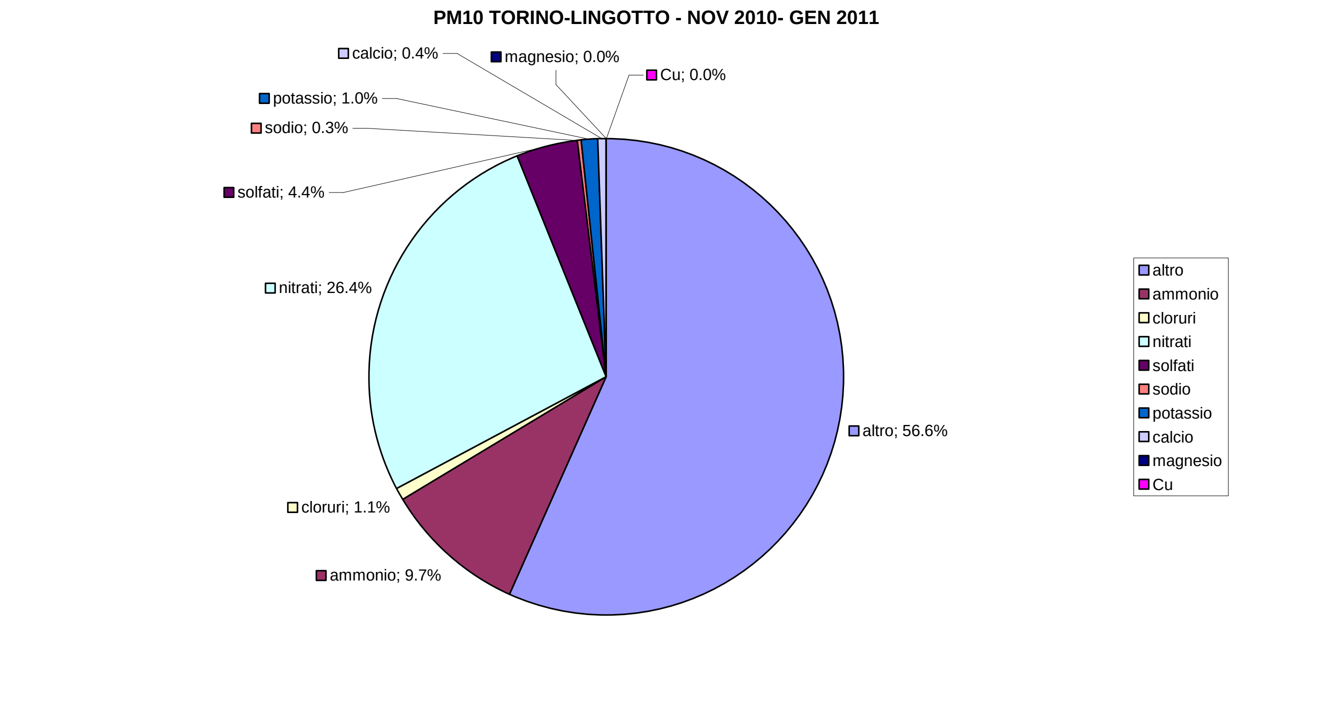

Figure 30: *Percentage distribution of PM10 soluble inorganic components in Torino-Lingotto, November 2010-January 2011*

Ammonium

The 90% of ammonium is present in the finest fractions (< 1.5 µm), with the highest presence in the fraction 0.49-0.95 µm (about 35 %). In the larger fractions this component is almost absent in Summer, even if it is present in very little concentrations (1-2%) in Autumn and Spring. The main source is the ammonia used in agriculture and its linked activities (ISPRA Annuario dei dati ambientali – Anno 2008, Regione Piemonte, Inventario Regionale delle Emissioni in Atmosfera – Anno 2005), in particular with regards to animal manure and nitrogenous fertilizer.

Chlorides

During the summer chlorides are in the finest fraction, whereas during spring and autumn they are mainly in the largest fractions (>3 µm), most probably owing to the salt used against ice formation on the roads.

Nitrates

They can be found in every fraction, but concentrated in the three finest ones (< 1.5 µm).

In autumn the concentrations are higher (and so are the percentages) than in spring and summer; this is confirmed by the measurements carried out at Torino-Lingotto.

Nitrates are typically in the form of:

- Ammonium nitrate (NH_4NO_3) originated from the neutralization of HNO_3 owing to NH_3 ; it can be found mainly in the finest fractions.

- Sodium nitrate $NaNO_3$, originated from the reaction between NaCl and the HNO_3

(Colbeck) and mainly present in the largest fractions.

The ammonium nitrate, which is the dominant component, is a semi-volatile compound, since the condensation of the ammonium nitrate in the particulate phase (Perrone et al, 2010). increases at low temperatures . Moreover, in the cold months the emission of nitrogen oxides increases owing to house heating and HNO_3 photolysis effects are weaker (Regione Toscana- Progetto Regionale PATOS).

The results confirm that North Italy is one of the European territories with higher concentration of nitrates in the particulate during cold months (Perrone et al, 2012).

Sulfates

As the nitrates, they are concentrated in the finest fractions (< 1.5 µm),.because they are secondary components in the particulate which originate from the oxidation of SO_2.

During summer the percentage in the finest fraction (<0.49 µm) is lower than the one observed during Spring and Autumn (7% vs. 41-47% of Summer and Autumn respectively).

Contrary to nitrates, sulfates are lower in autumn-winter than in spring-summer, because the oxidation of SO_2 to sulfate is favoured (Perrone et al, 2010 during hot months). This confirms what can be found in the literature (Perrone et al, 2010, e Perrone et al, 2012, Arpa Emilia Romagna, Progetto PolveRe – 2ª fase,2005) for other northern italian zones.

Sodium

It is evenly distributed in the various fractions during Summer, whereas it is concentrated in the fractions greater than 3 µm in the cold months , probably due to the use of sodium chloride on the roads.

Potassium

Present in all the fractions, it can be mainly found in the finest fractions, i.e. smaller than 0.95 µm. The highest values occur in autumn when more than 70% is found in the fraction smaller than 0.49 µm. The concentration increases in the cold seasons. The potassium represents a marker the wood combustion and its importance was evaluated in a study conducted in Susa and Torino (Piazzalunga et al, 2010).

Calcium

During summer it is concentrated mainly in the fraction between 1.5 and 7.2 µm, and it is probably originated by erosion and re-suspension of soils; during spring it can be found in the finest fraction as well, while during cold seasons prevails in the largest fractions.

Magnesium

The concentrations are very low, often below the detection limit and the higher values are found during summer.

It is absent in the finest fraction (<0.49 µm) and it is evenly distributed in all the other fractions. As calcium it comes from erosion and re-suspension of soils.

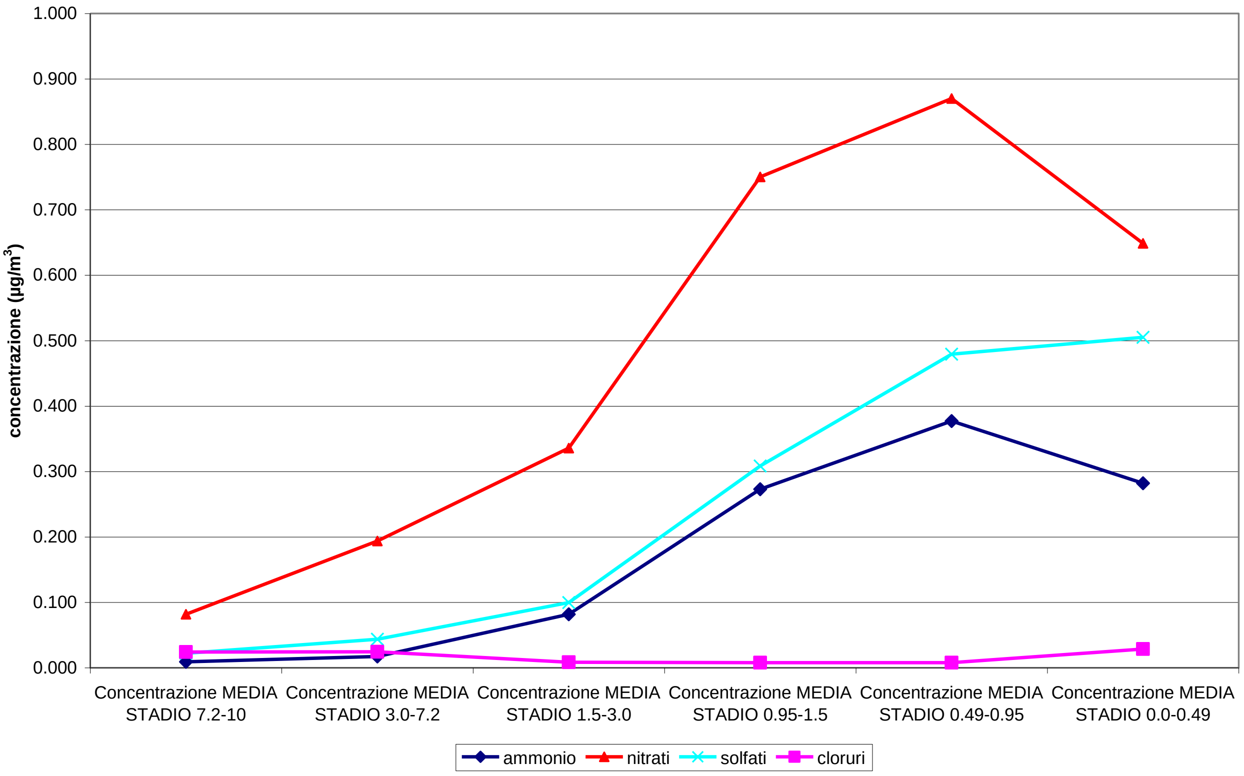

Figure 31: *Concentrations of ammonium, nitrates, solfate and chlorides in PM10 in Susa, whole dataset mean*

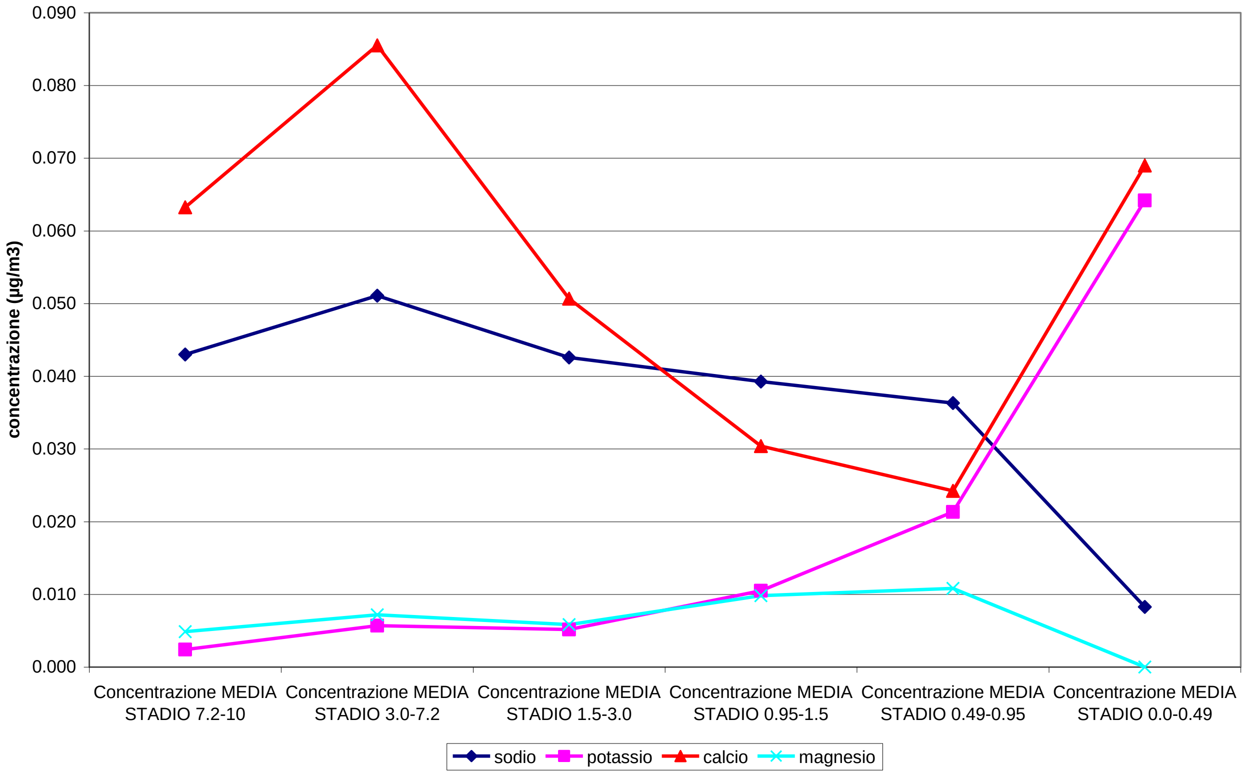

Figure 32: *Concentrations of sodium, potassium, calcium and Magnesium in PM10 in Susa, whole dataset mean*

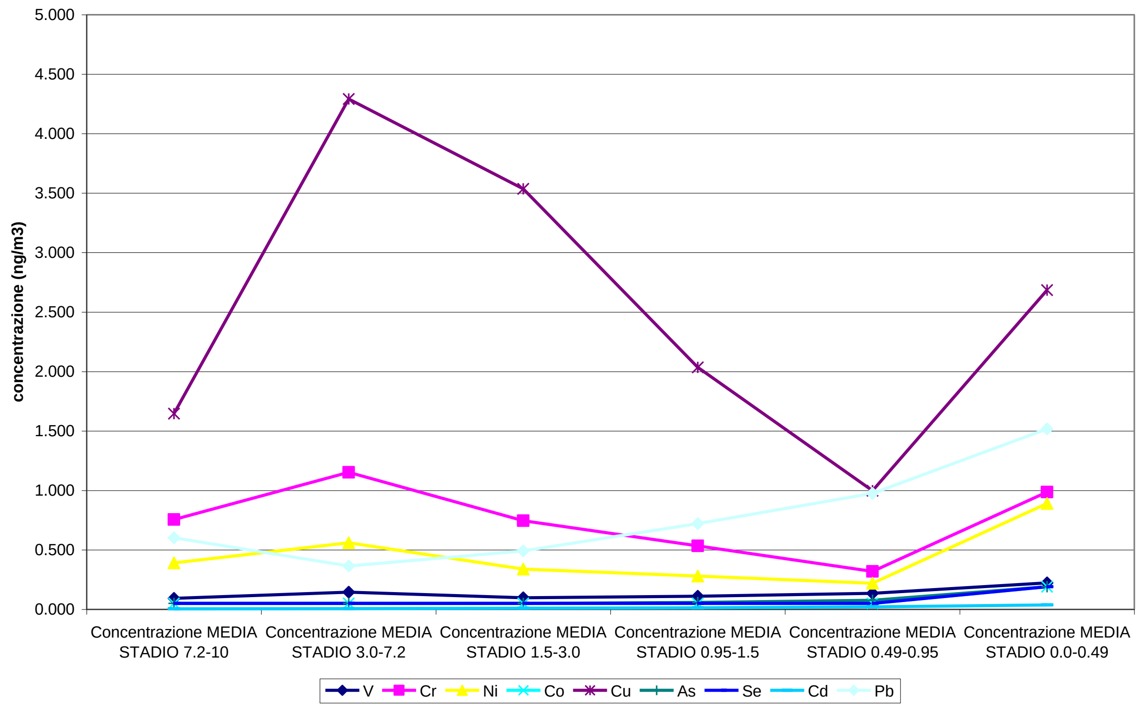

Figure 33: *Concentrations of V, Cr, Ni, Co, Cu, As, Se, Cd, Pb in PM10 at Susa, whole dataset mean*

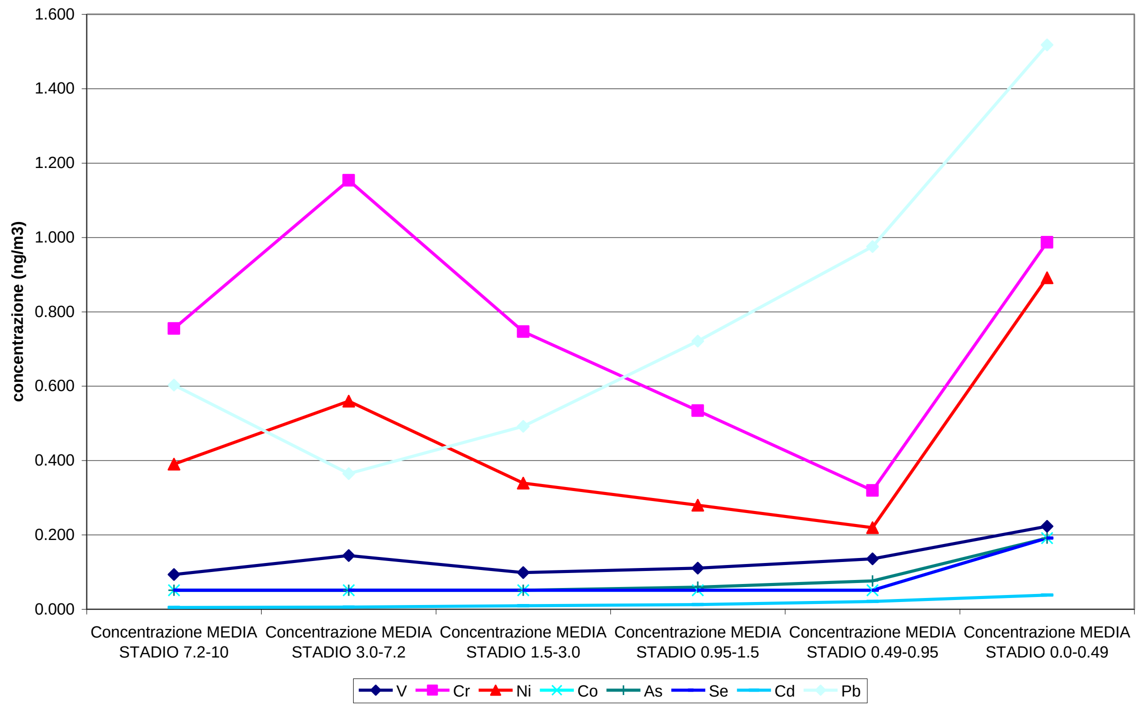

Figure 34: *Concentrations of V, Cr, Ni, Co, As, Se, Cd, Pb in PM10 at Susa, whole dataset mean*

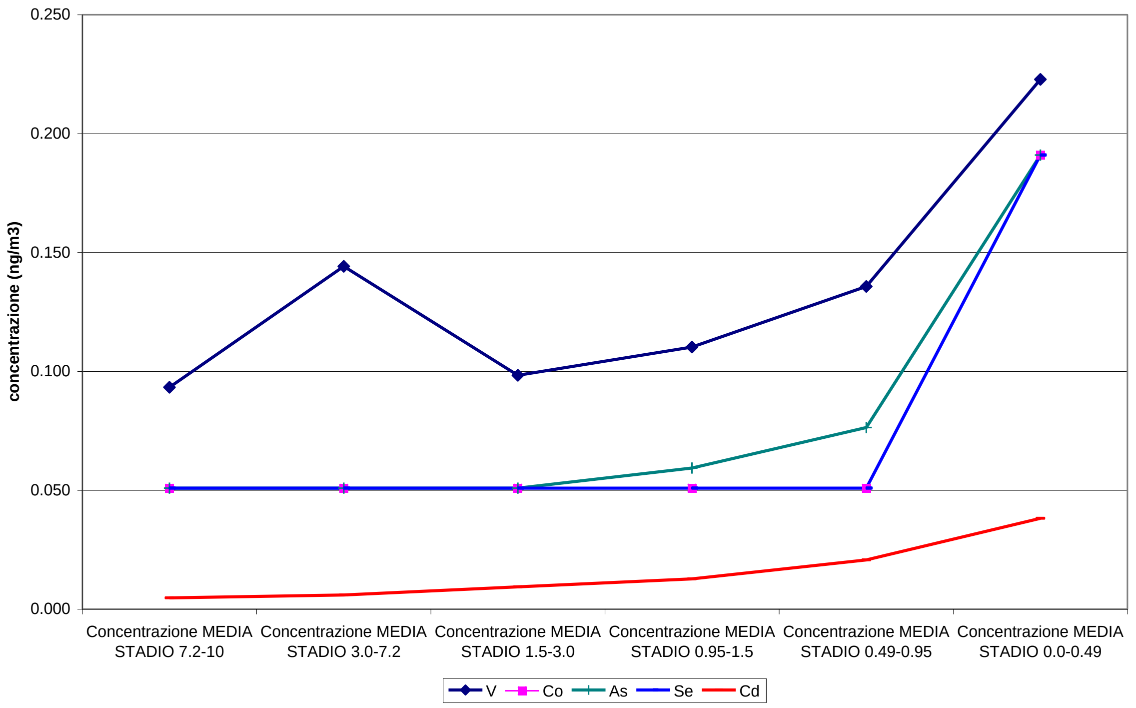

Figure 35: *Concentrations of V, Co, As, Se, Cd in PM10 at Susa, whole dataset mean*

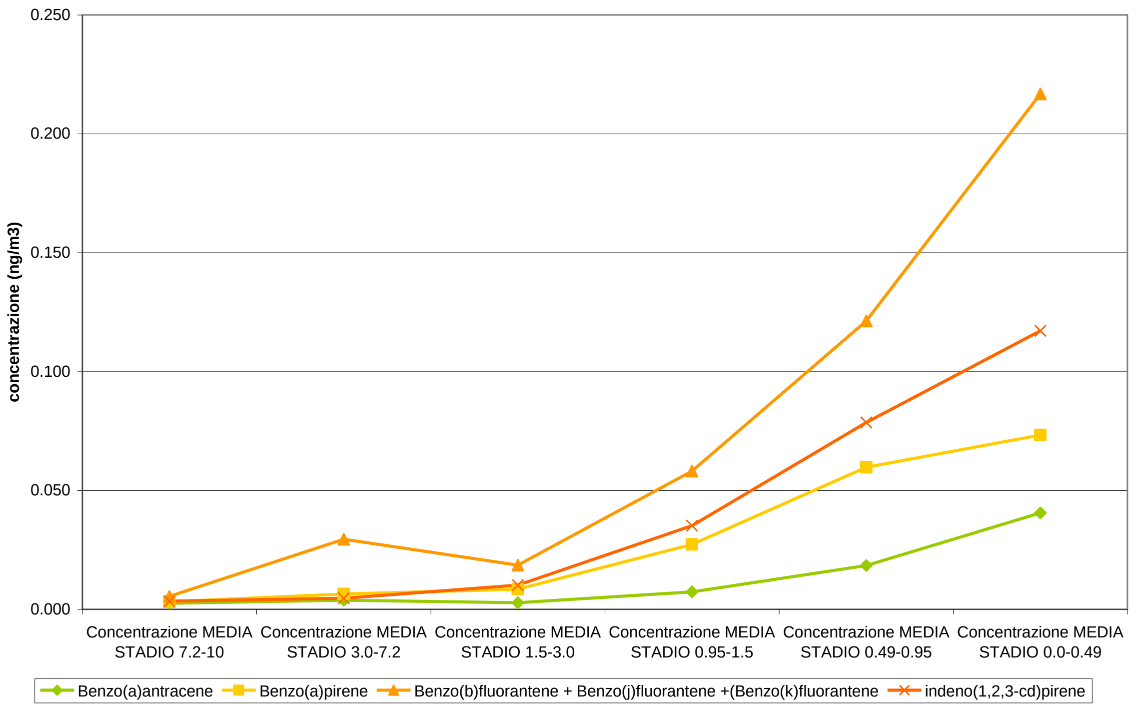

Figure 36: *Concentrations of polycyclic aromatic hydrocarbons in PM10 at Susa, whole dataset mean*

5.4.3 Non alkaline or alkalin-earth metals

The aerosol composition is originated by natural and anthropic sources, therefore size distributions of various metals depends on the ratio of the different sources.

The anthropogenic sources are constituted mainly by high temperature processes, biomass and fossil fuel combustion, industrial activities, etc. The high temperature process release volatile metals and create particles by condensation or reactions from gas to particle (Colbeck).

The natural emissions of metals in trace result from various processes (erosion, surface winds and volcanic eruptions) and from natural combustions .

The metals measured in the monitoring campaigns are vanadium, chromium, nickel, cobalt, copper, arsenic, selenium, cadmium and lead. The metal with the highest concentration is copper, followed by the chromium-lead-nickel group. The lowest concentrations were found for vanadium, arsenic, selenium, cobalt and cadmium. All the measured concentrations of metals at the Susa measurement point are shown in figure 10, 11 and 12.

Arsenic

It is present in summer and spring only in the finest fractions; during winter the fractions smaller than 0.95 µm accounts for 80%, but arsenic is found in the largest fractions as well.

One of the arsenic source is the combustion of fossil fuels, that increases the concentrations of the finest fraction; the largest fraction could come from the wear of tyres and re-suspension.

Cadmium

It is found in all the size fractions, but with greater percentage in the finest ones, smaller than 1.5 µm (about 80 % in autumn, 90 % during spring-summer), because it mainly comes from the combustion of fossil fuels and the emissions of vehicles.

Cobalt

The concentrations are always very low, during summer below the detection limit ; during spring-autumn it is found mainly in the fractions greater than 3 µm.

Cromium

It is evenly found in all the size fractions. During summer-spring it is mostly found in the fraction smaller than 0.49 µm and in the one between 3 and 7.2 µm, this last one originated from re-suspension of the surface dust (Colbeck). It can be originated from tyre wear and from industrial combustion as well. In autumn it is present in fractions greater than 1.5 µm (approximately 70%).

Copper

It is found in all the fractions, but mainly in the fractions greater than 3 µm during autumn. It is the most relevant metal, with the highest concentrations (53% in Summer, 59% Spring, 68 % Autumn). Its origin can be abrasion of vehicles mechanical parts and its use in agriculture as treatment for plants.

Nickel

The higher concentrations are in the fraction smaller than 0.95 µm.

The main source is the combustion of fossil fuels and the emissions of vehicles.

During autumn it is found in the fraction greater than 3 µm.

Lead

As the Nickel, it is present mostly in the finest fraction (80% is in the fraction smaller than 0.95 µm and more than 40% is found in the fraction smaller than 0.49 µm). During spring 75% is found in the fraction smaller than 0.95 µm and during autumn it is found in the fraction largest than 7.2 µm too.

Selenium

The measured concentrations are very low; during Summer 65% is in the fraction between 0.49 and1.5 µm, during spring and sutumn is totally in these fractions. It mainly comes from the combustion of fossil fuels.

Vanadium

The highest concentrations are found during spring and it is distributed quite evenly in all the fractions. The main source is the combustion of fossil fuels, but it also comes from soils.

5.4.4 Polycyclic aromatic hydrocarbons

The polycyclic aromatic hydrocarbons, as the majority of metals, are mainly present in the fraction smaller than 1.0 µm. At the Susa and Torino sites more than 70% is found in that fraction, as shown in Figure 13.

Those substances have a seasonal pattern that resembles the one of total PM10, with maximums in the cold seasons. Their origin is, in fact, bound mainly to combustions and in the cold months, exactly as for PM10, the condition of atmospherical stability increase their concentration. During summer, moreover, the concentrations decrease because the PAHs present a strong photochemical reactivity, favoured by temperature and sun light, that lead to the formation of nitro PAHs and oxiPAHs (Schauer cited in Perrone, 2010). The percentage of PAHs in PM10 is higher in the cold months than in hot ones. The winter period is therefore the most critical one for exposition to pollutants, both in terms of concentrations and composition.

5.5 Conclusions

Even if PM10 and PM2.5 concentrations are higher in the urban area respect to the Susa site, the percentage distributions of masses in the various fractions appears to be, under a preliminary point of view, comparable. It confirms for both sites the general literature data according to which more than half of PM10 is composed by particulate smaller than 1 µm. Those fraction are confirmed to be of fundamental importance for the analyzed sites; they pose a serious threat to human health, because they can carry toxic compounds in pulmonary alveolus. With regard to the different fractions of the secondary inorganic components, the Susa site is similar to Torino, with high nitrates, sulphates and ammonium concentrations which can be up to 33% of the total particulate mass. Lead, nickel, vanadium, arsenic, cobalt, selenium and cadmium are toxic metals whose concentration is higher in the finest fraction of the particulate.

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Regione Toscana – Progetto regionale PATOS -Particolato Atmosferico In Toscana

Il materiale particolato fine PM10 -2011

6 Mutagenesis test on atmospheric particulate

6.1 Preface

The participation to the Project represented the chance to point out some environmental criticalities using the analytical data obtained from mutagenesis tests. In particular, the Ames test was performed using Salmonella tiphimurium TA 98 and TA 100 with and without the metabolic activator S9. This test permits to evaluate the presence, in the atmospheric particulate object of the analysis, of chemical compounds with genotoxic potential both directly and using the mechanics of the metabolic activation that are reproduced in laboratory with the use of the microsomal fraction S9. The purpose is that of highlight the genotoxic action of a chemical compound, that can manifest carcinogen power , therefore the significance of the Ames test is predictive and very important, because it signals a possible risk for the environment and for human health, coming from the exposition to substances that act on the DNA.

When possible the samplings were executed in such a way to represent the different seasonal periodicities in order to be able to forecast a trend useful to highlight the periods with maximum criticalities. We focused in particular to the data coming from the analysis of the particulate with diameter smaller or equal than 2.5 µm, considered the most dangerous for its ability to go past the first breathing channels reaching the lungs with huge impacts on the health of the dwelling population.

For this study 3 sampling campaigns were organized. The samplings were conducted at the Sitaf site (A32 highway – S. Giuliano); each sampling lasted 48 hours and took place in the following dates:

Campaign 1	Campaign 2	Campaign 3
Sampling date 04-05/09/2010	Sampling date 22-23/04/2011	Sampling date 14-15/10/2011
Sampling date 12-13/09/2010	Sampling date 04-05/05/2011	Sampling date 03-04/11/2011
Sampling date 22-23/09/2010	Sampling date 08-09/05/2011	Sampling date 08-09/11/2011
Sampling date 29-30/09/2010	Sampling date 13-14/05/2011	

The type of sampling being used (multistage) permitted to gather fractions of atmospherical particulate on six different filters, each used to handle a different particle size; at each filter correspond a "stage" of the sampler:

Stage 1: particulate with size between 7,2 ÷ 10 µm.

Stage 2: particulate with size between 3,0 ÷ 7,2 µm.

Stage 3: particulate with size between 1,5 ÷ 3,0 µm.

Stage 4: particulate with size between 0,95 ÷ 1,5 µm.

Stage 5: particulate with size between 0,49 ÷ 0,95 µm.

Stage 6: particulate with size between 0,0 ÷ 0,49 µm.

6.2 RESULTS EVALUATION

In order to evaluate the data we decided to use the criterions believed to be more significants, trying to highlight not only the "positivity" of the data (this meaning that a value exceeding the limit is considered a mutagen effect), but for example evaluating the contemporary presence of a number of revertants, equal to at least the double of the revertants of the negative controls in one or more of the tested doses, rather than any increasing trend of the line doses/response and good correlation index.

In order to make the reading and interpretation of the presented data easier, a few graphs were inserted.

Relatively to each stage, for each sampling date, a gravimetric analysis was conducted and its results are shown in graph 1.

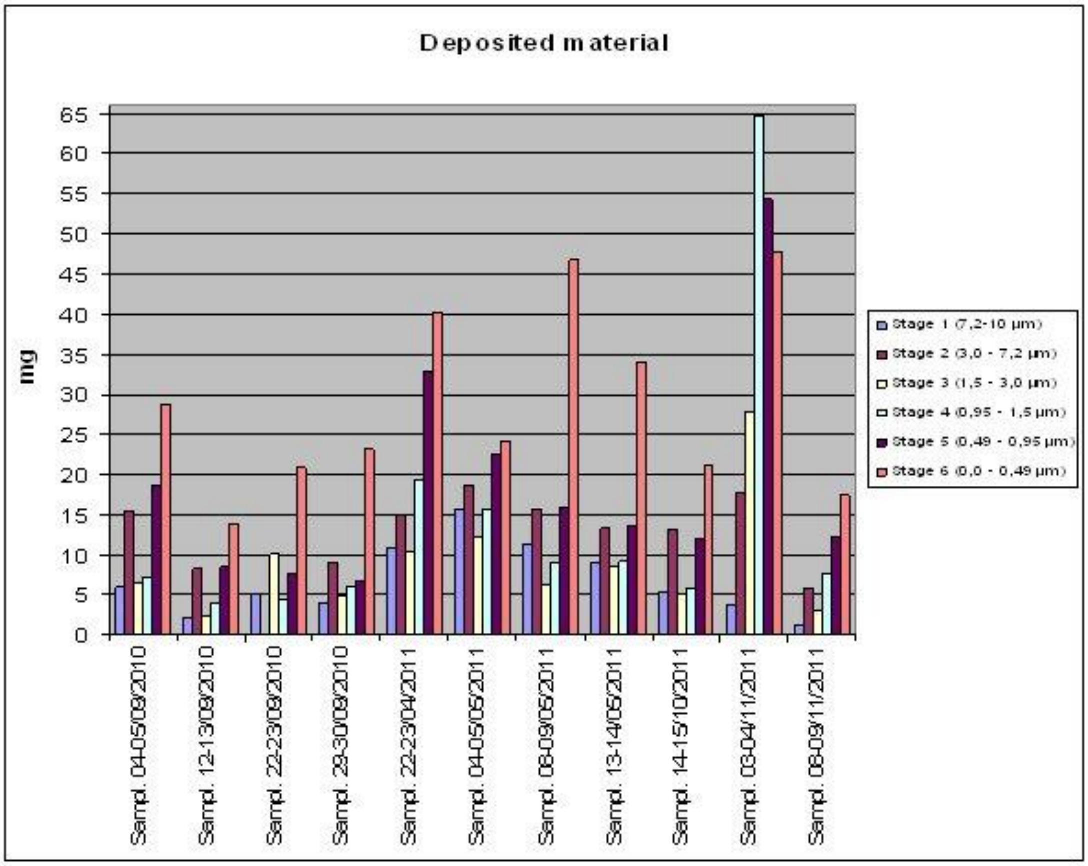

Figure 37: *Graph Considerations: In the majority of cases the stage 6 results to be the one that gathered more material than every other stage. Even if the number of sampling was rather limited, it is possible to note how in the periods preceding the winter period (campaign 1 and 3), we assist to an increase in the quantity of the deposited material, trend confirmed by the literature.*

On each sampling stage an Ames test, using the different bacterial strains of Salmonella tiphimurium listed in the preface, was conducted.

The results are expressed as Mutagenic Ratio per mg of fine particulate matter (MR/mg) and were considered positive if the sampling shown a value of MR/mg **≥**1, as expected in the reference procedures.

The threshold value corresponds to the red line in the graphs from 2 to 7.

The uncertainty of the measure correlated to the data is shown with the conventional symbology, its extension represents the range of possible oscillation of the obtained data.

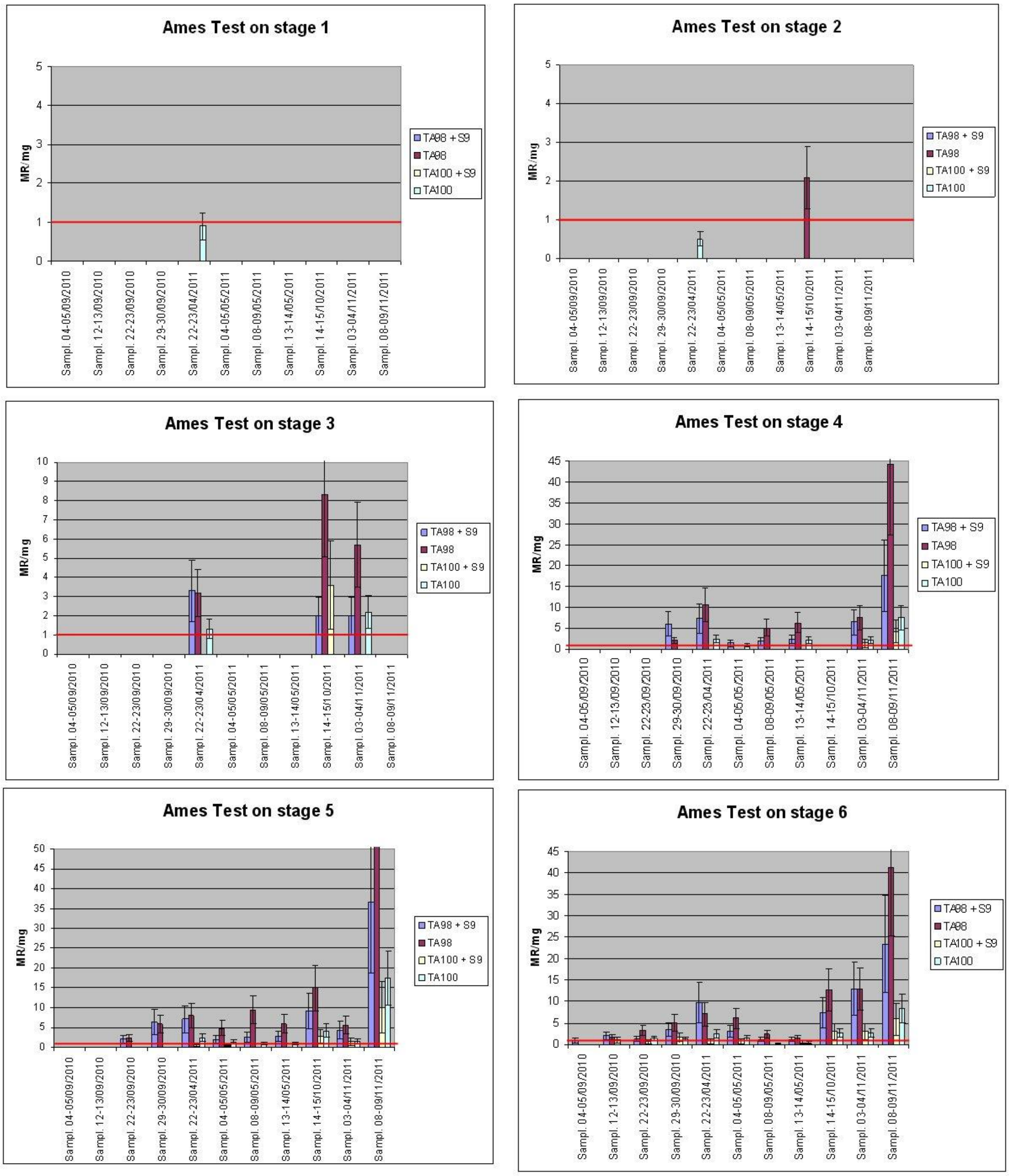

Figure 38: *Graphs Considerations: From the data analysis (both considering the greater number of positivities demonstrated with the tests that used the different bacterial strains, and the greater "values" of positivity) it results that the most significant MR/mg values are found from stage 3 and increase to stage 6. This means that eventual substances that produce mutagen effects on the tested organisms are contained in the particulate with sizes in the range 3,0 ÷ 0,0 µm. In this case, even in presence of a limited availability of data, it is possible to verify the increasing trend in the MR/mg values, relative to the samplings conducted in the periods near to the winter season (campaigns 1 and 3). This comparison confirms what it is possible to deduce from the literature data on the subject. Finally, it is interesting to conduct another analysis summing, for all the different campaigns, the number of positive tests obtained on the different stages.*

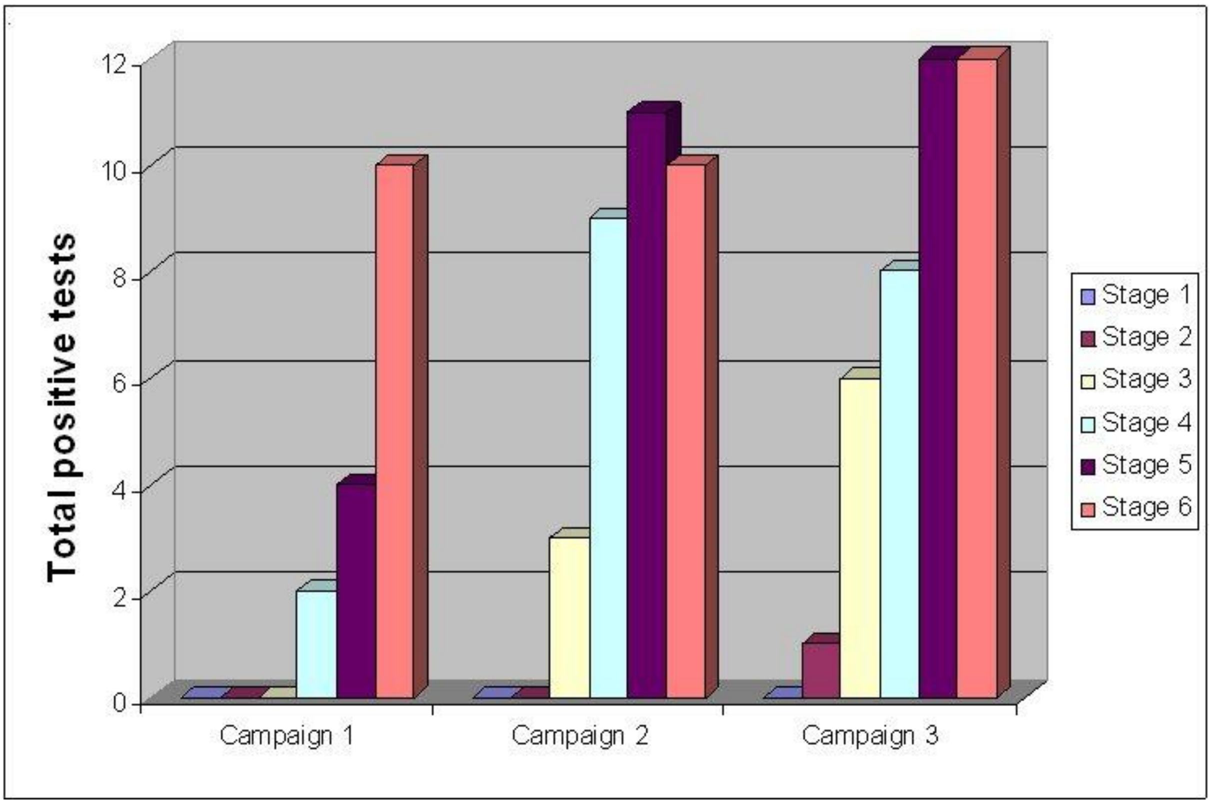

Figure 39: *Graph Considerations: If, rather than analyze the values of mutagenicity obtained with different bacterial strains, we consider the number of positive tests found (values of MR≥1), it is clear that the stages 1 and 2 do not show significant positivities while, gradually, from stage three to six the number of positive tests increases greatly. A certain influence on the positive test number is to be attributed to the quantity of sample used, but it appears clearly demonstrated a greater response, in terms of positivity, from the tests conducted on the stages that gather the fine particulate matter with sizes smaller than 3,0 µm. Furthermore it is useful to note that during the campaign 3 it was possible to conduct only 3 samplings instead of 4, as usual done; we can therefore assume that the number of positive tests have been underestimated.*

6.3 Conclusions

It is reasonable to affirm that the most interesting data that comes from this study is, substantially, an "increasing trend", represented by the tabulation of data obtained with the Ames tests using the cited bacterial strains on the various fractions of particulate. It is evident that, both considering the aspect correlated to the results of the gravimetrical analysis and considering the data that demonstrate a certain positivity, the fraction that "respond" in an unequivocal way are those with smaller sizes, with a greater presence in the winter season, that is to be attributed at the climatic conditions of the season and to the greater contribution of the fine dusts in the atmosphere that come from the emissions of the heating systems that adds to those of the road traffic and to those of the industries in the considered area.

It is important to note that the results of this analysis could be validated even further by data gathered in a winter campaign and, even more, that it would be very interesting to continue the analysis in the future in order to obtain a large amount of data, that would permit the elaboration of a, even if limited, statistical study about this very interesting research subject.

7 The Friuli Venezia Giulia Measurements in the iMONITRAF! Project

The Tarvisio corridor, thanks to its relatively low altitude (roughly 700 m a.m.s.l.) and being in direct connection with the harbors of Northern Adriatic is of great importance for the North-South European mobility.

The monitoring campaign carried out in Friuli Venezia Giulia and the related pilot study were devoted to highlight the impacts of transports on the observed levels of pollution. The adopted strategy had been twofold and complementary: i) determine the fingerprints of the different sources in the particulate matter collected in the Tarvisio Corridor; ii) determine the impacts of the different classes of transports on the observed level of pollution.

The first action was pursued by way of chemical analysis carried out on the particulate matter (PM10) collected 50 m far from the border of the highway during the winter period (January and February 2011). The analyses were oriented to estimate the ionic component as well as the carbon component. Among the ionic component, the main species looked for were nitrates, sulphates and ammonium even if the analysis revealed as well quite a large set of minor ionic constituents. Among the carbon component, the main looked for species were organic and elemental carbon, plus a minor constituent, levoglucosan, used as a fingerprint to discriminate between fossil and biomass origin of organic carbon. In this way it had been possible to perform the so called “mass closure” of particulate matter, i.e., apportion the amount of PM10 in its different components. In fact, the difference between the observed mass and the bulk ionic and carbon components revealed by the above mentioned analysis, had to be associated to silicates and carbonates, that is to the “crustal component” of particulate matter, ascribable to natural sources. The results of this work show that, during the monitoring period, a relevant amount of particulate matter was due to biomass combustion, which is reasonable, keeping into account the fact that particulate matter was collected during winter, a period of the year in which domestic heating is at its maximum and in a place, an alpine valley, where the use of biomasses is an intrinsic aspect of social behaviour. Apart from the component ascribable to biomasses, the analyses show that a significant amount of particulate matter springs out from fossil fuels with a percentage which is comparable to that observed in a suburban environment of a town with roughly 100 000 inhabitants (Udine) even if the largest village on the area (Tarvisio) has less than 5 000 inhabitants. Particularly relevant is the component ascribable to the ionic component (nitrates and sulphates) of particulate matter, which, in general, can be ascribed to road transports because, under the emissions point of view, the most important source of nitrogen oxides in the area is represented by transports.

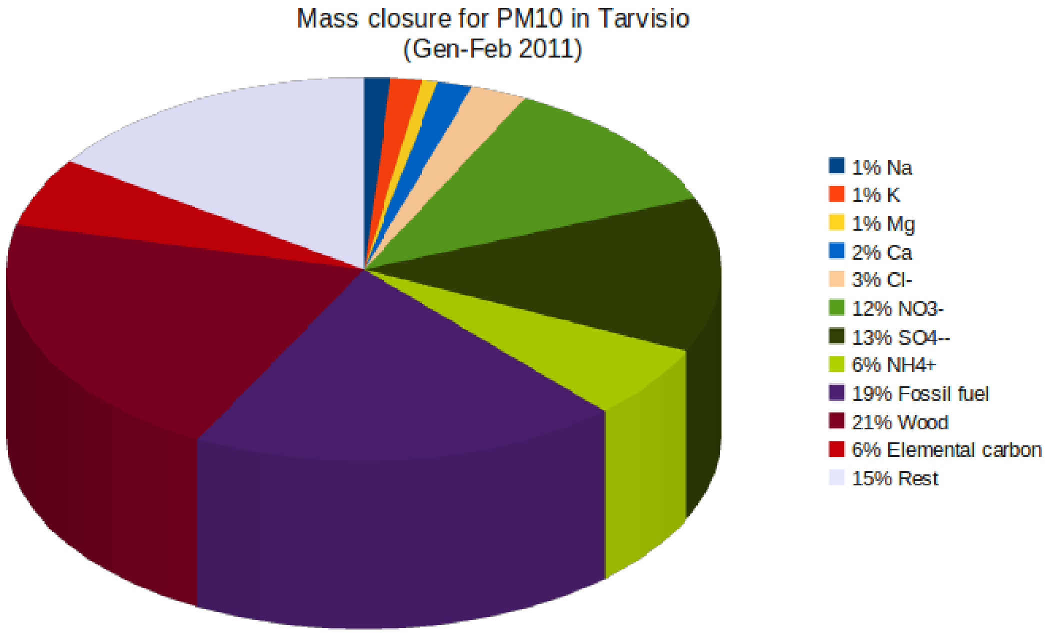

Figure 40: *Mass closure of the particulate matter (PM10) over the Tarvisio corridor in the monitoring site.*

The second goal was pursued through the use of a Gaussian numerical model capable to disperse the primary pollutants according to the observed flows (in terms of personal cars and of heavy duty vehicles) and with an average vehicle fleet in terms of emission concepts (Euro classes). This analysis was performed only on the nitrogen oxides (NOx) and not on the particulate matter. The reason of this choice was double. The first aspect was based on the fact that, through the above described particulate matter speciation it was clear that a significant amount of particulate matter had its origin in the biomass burning, then it would be difficult if not impossible to calibrate the performances of the numerical model on the observed data, retrieved through the in situ monitoring campaign. The second is that, as shown by the particulate matter speciation, the secondary component of particulate matter plays a major role to achieve the observed amounts of this pollutant, then it would be not correct try to reproduce the spatial behaviour of particulate matter ascribable to road transports by way of a purely dispersive numerical model. This would not be a problem for nitrogen oxides, because they are originated essentially by road transports and, even if singularly taken nitrogen monoxide and dioxide are photochemically active, their sum is conserved (once deposition and ammonium nitrate formation are neglected), which is true (as a first approximation) on a small spatial scale (of the order of a few hundred meters).

To reproduce the observed NOx concentrations the first action to be accomplished was that to retrieve the traffic flows on the area of the in situ monitoring campaign. The flows, obtained with an hourly time resolution by the Society that manages the motorway were obtained, did not distinguish vehicles according to their emission concept (Euro Classes) but only between personal cars and heavy duty vehicles. The first problem to overcome, then, had that to obtain an average emission factor for each of these two macro classes of vehicles. This was done computing the average emission factor for each macro class weighted according to the average Friuli Venezia Giulia fleet. Results are shown in the figures below.

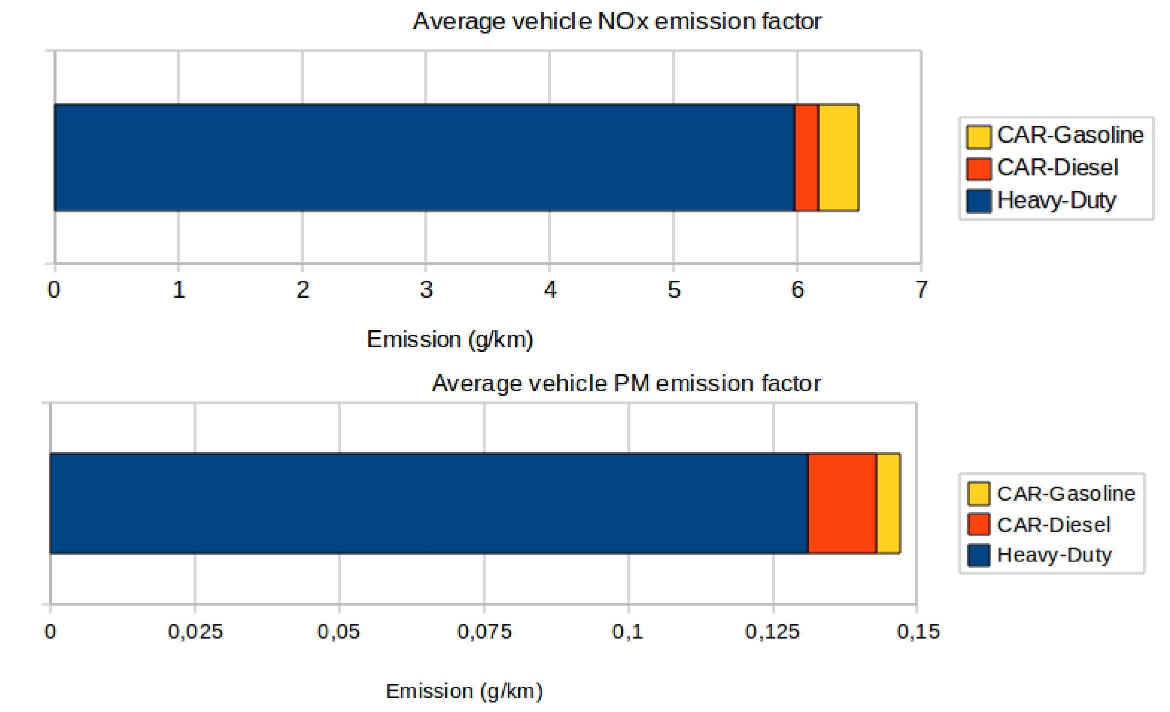

Figure 41: *Average emission factor for cars and heavy duty vehicles computed using a weighted mean based on the average vehicle fleet of Friuli Venezia Giulia.*

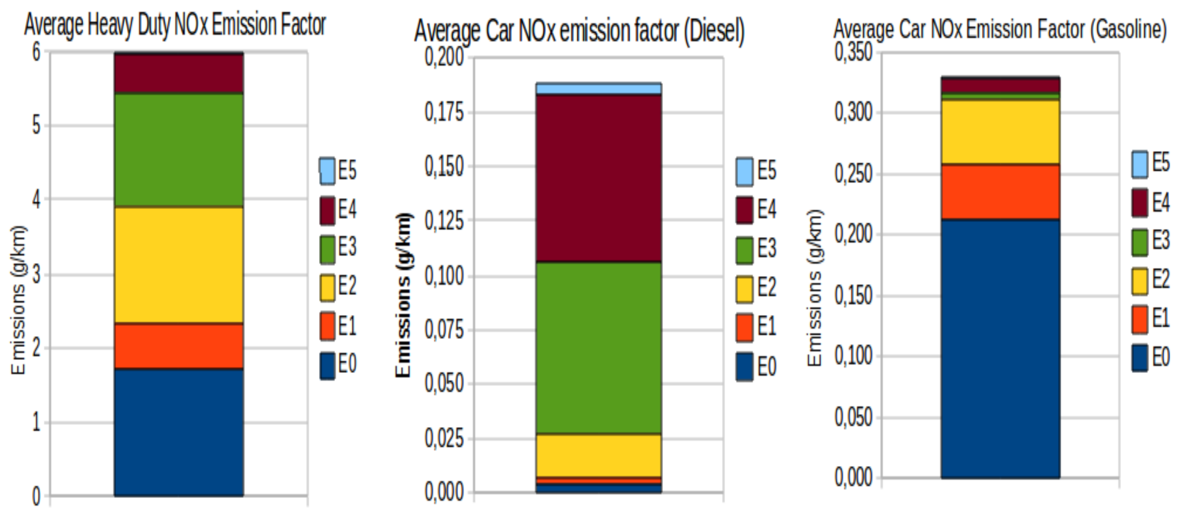

Figure 42: *Split of the NOx average emission factor in the contributions coming form heavy duty vehicles, Diesel cars and gasoline cars*

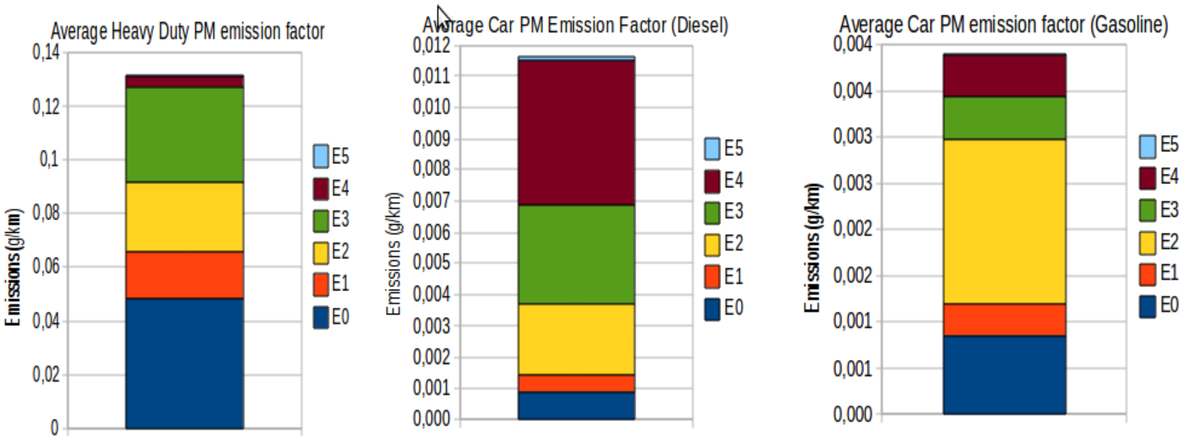

Figure 43: *Split of the PM average emission factor in the contributions coming form heavy duty vehicles, Diesel cars and gasoline cars.*

From the above figures, it is interesting to notice that, even from the mere emissions point of view, contributions coming from heavy duty vehicles overwhelm the emissions coming from personal cars both for nitrogen oxides and particulate matter. Looking in deeper detail, it is interesting to notice how low emission concepts contribute heavily on emissions. As an example, more than half of the average NOx and PM weighted emissions come from pre Euro III heavy duty vehicles.

Once average emission factors were obtained, emissions dispersion was simulated through a Gaussian model. This was done using the meteorological conditions observed (horizontal wind) and retrieved (mixing height and stability classes) through a meteorological post processor (CALMET). The goal of the dispersion simulation was that to calibrate the parameters choice with a maximum likelihood between in situ NOx observations and simulations. This calibration procedure was done on the days in which flows and measurements were available (Spring 2011). After the calibration of the Gaussian dispersion model, a final simulation was carried out with archetypal meteorological conditions (1 m/s wind speed along the road). As mentioned above, this simulation was carried out only for nitrogen oxides because they were mainly emitted by road transports and would had been difficult carry out a calibration of the Gaussian model for particulate matter, which had other sources in the area comparable to that of transports.

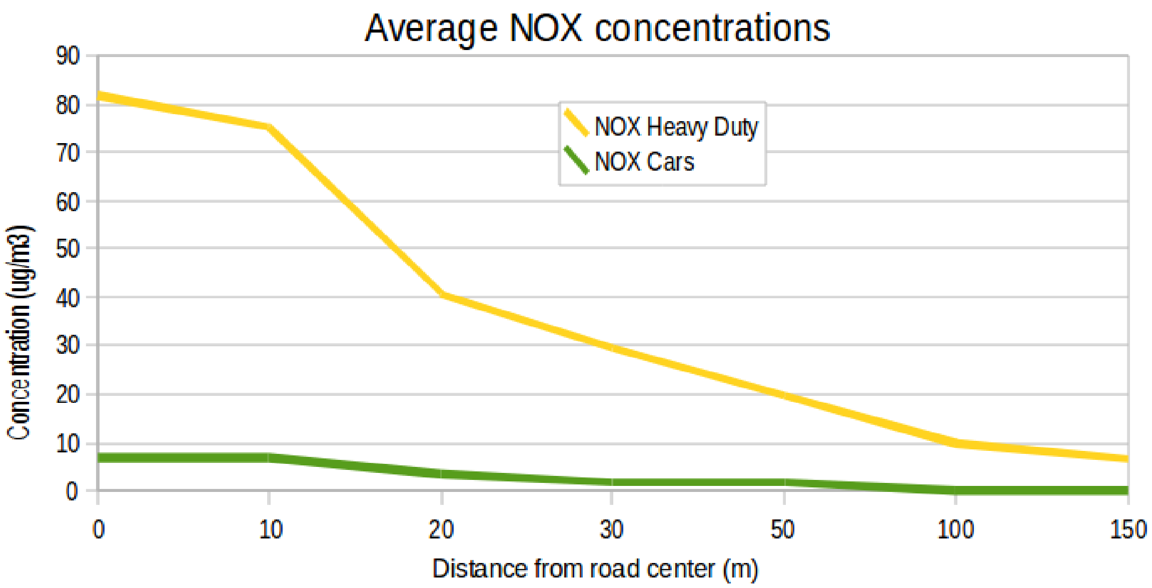

Figure 44: *Archetypal dependence of NOx concentrations by road-center distance, split for heavy duty vehicles and personal cars.*

From the above picture, it emerges clearly that, even if transport emissions are relevant, nevertheless they are circumscribed into a relatively narrow strip centered on the road center. In particular, for the Tarvisio corridor, in the monitoring place, 100 m far from road center concentrations of NOx ascribable to road transports reach the background value.

Before to conclude, a final aspect explored in the pilot study carried out in the frame of the iMONITRAF! project on the Tarvisio Corridor was that of the diurnal impacts of transports on air quality. Using the calibrated version of the Gaussian dispersion model, for the week where transport fluxes were available, the average hourly concentration of NOx at 50 m form the road-center was calculated using the observed meteorological conditions. The diurnal cycle of this concentrations, computed for all the days, was merged to obtain a weekly average diurnal cycle of pollution. The average procedure was carried out to smooth possible effects due to peculiar meteorological conditions. The results of the simulation, shown in the following figure, highlight the fact that night-time fluxes give the major contribution to the average level of pollution. This result is not due to the fact that fluxes are larger during night-time than during day-time, but can be ascribed to peculiar conditions that characterize, in particular, narrow valleys. During night-time, in fact, because of the radiative cooling, alpine valleys are filled by the so called “cold-air-pillow”, which enhances stability, then pollutants concentration. Under the micro-meteorological point of view, in fact, wind speed in the Tarvisio area reaches its minimum (often even null value) during night-time. On the contrary, pollutants dilution is enhanced during day-time for the heating effect of mountain valleys.

Because of this interesting diurnal cycle, a final simulation was carried out, removing the traffic fluxes during night-time (from 22 LT to 06 LT) and redistributing it during day-time in an homogeneous way (i.e., the same extra percentage assigned to all the hours keeping constant the bulk value of fluxes). Results, shown in the figure below, are quite surprising, because it is immediately evident how a nocturnal reduction of transports might reduce the average pollutants concentrations in the neighborhood of a road.

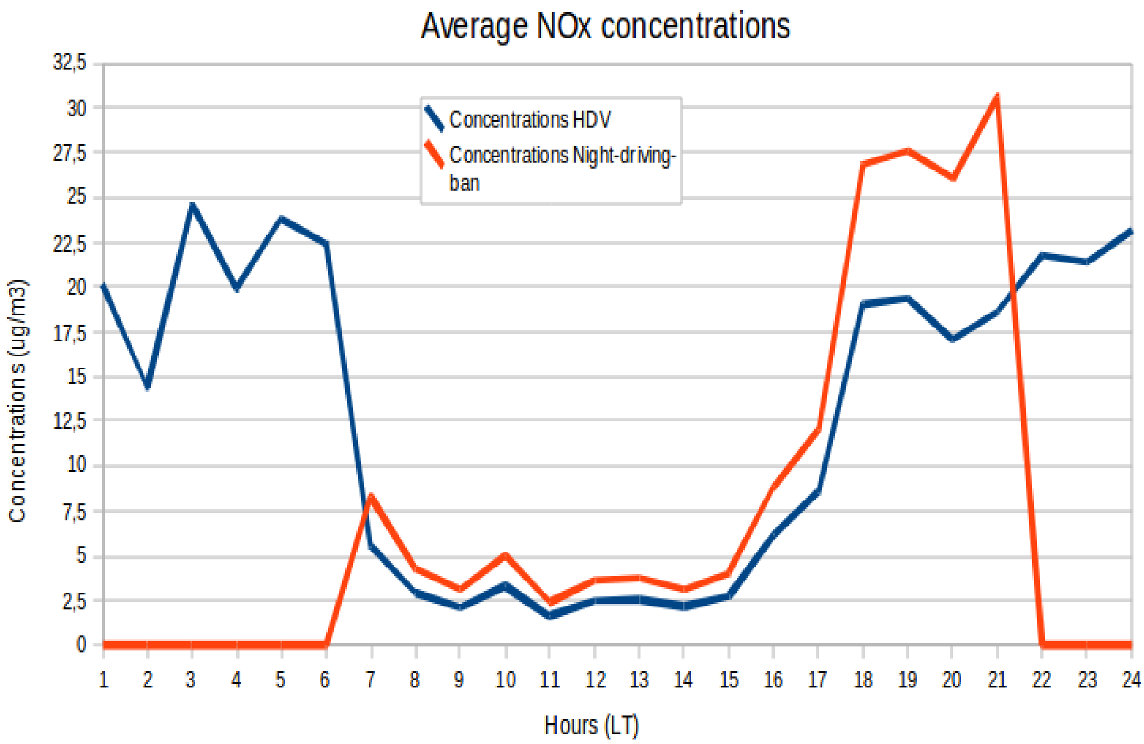

Figure 45: *Simulation of the effects of a heavy duty vehicles shift from night-time (from 22 LT to 06 LT) to day-time (from 07 LT to 21 LT). Blue line represents the average NOx hourly concentrations at 50 m from the road-center with the observed fluxes, red line represents the average NOx hourly concentrations at 50 m form the road-center assuming that the night-time flux of heavy duty vehicles had been redistributed during day-time.*

8 Noise Monitoring

The iMONITRAF! Project analyzes the effects of traffic in the Alpine regions. Observations are conducted on different corridors: Fréjus, Mont-Blanc, Gotthard, Brenner and Tarvisio.

In this chapter we will examine the quantity of noise pollution produced by these infrastructures.

For the iMONITRAF indicator 6, which is the goal of the measurements, each partner has to indicate the yearly mean noise levels of the day and of the night periods.

Since the corridor are located in different regions, and nations, it has been necessary to establish a common measurement protocol in order to make the results coming from different noise sources, and nations, confrontables. In the whole project a great amount of noise data has been collected in order to analyze the corridors.

8.1 Guidelines

General guidelines have been developed in order to have the same type of measurements for each project partner.

The developed guidelines state that noise measurements have to be conducted at a distance of no less than 4 meters and no more that 20 meters from the noise source (being it a road or a rail track), in accordance to national and European laws the microphone must be placed at an height of 4 meters from the ground and far from reflecting surfaces.

Measurements should last at least one week, in order to have a measure of the levels of every day of the week.

To obtain enough data to calculate a valid mean through the year, the guidelines ask each partner to conduct one measurement per season, when this is possible, or at least to have three measured weeks for each year. The final mean levels are therefore calculated from the measurements done within the year.

Along with the noise measurement, when possible, traffic data and meteorological ones are gathered as well.

When meteorological data is taken, all the noise levels measured with a wind speed greater or equal than 5 meters per second must be considered invalid. Levels measured while it's raining are excluded too.

The total set of the measured parameters is:

- Traffic count: number of light vehicles
- Traffic count: number of heavy duty vehicles
- Traffic: mean speed of light vehicles
- Traffic: mean speed of heavy duty vehicles
- Temperature
- Pressure
- Relative humidity
- Wind speed and direction
- Rain: hourly precipitation

Regarding the noise data, in each measurement the levels for day, evening and night have to be taken into account.

In accordance to European guidelines and laws, the day is defined from 7 am to 7 pm; the evening is defined from 7 pm to 11 pm and the night is defined from 11 pm to 7 am of the next day.

The level of the whole day, L_{DEN} is then calculated from the three periods levels with the formula:

$$L_{dn} = 10\log\left(\frac{12}{24}\left(10^{\frac{LAeq,d}{10}}\right) + \frac{4}{24}\left(10^{\frac{LAeq,n+5}{10}}\right) + \frac{8}{24}\left(10^{\frac{LAeq,n+10}{10}}\right)\right)$$

It is asked to Project Partners to record the noise spectrum when the instrument used is able to do so. Furthermore, in each measurement the statistical levels should be gathered too, in order to have some indications of the background noise of each site.

The measured levels are finally normalized to 10 meters distance and 4 meters height in order to obtain a final level for each corridor that resembles the real emission of the analyzed road. In the iMONITRAF! Indicator 6 those normalized level are used, because using those it is easy to compare the emission of different corridors.

For the future 2020 WP6 scenarios, a methodology has been developed to calculate the normalized sound levels from the traffic data.

Towards the end of the iMONITRAF! Project some new, improved, the guidelines were updated. These final guidelines are much more complete than the previous ones and suggest the best practices to be used to conduct the noise measurement in an international context. The project partners agreed to use the final developed guidelines for all future projects.

8.2 Measurement points

In this section we present all the measurement points used in the project.

For each point it is asked, to the project partner that monitor that corridor, to indicate the coordinates of the site and some information about the peculiarity of the noise source.

It is important to note that for the whole duration of the project the project partners used the same site or, when a site became non usable for whatsoever reason, choose another one with the same characteristics of the first one.

In the tables displayed in this chapter we will report the most used measurement sites used in the noise acquisition campaign.

8.2.1 Valle d'Aosta: Courmayeur

Corridor	Tunnel del monte bianco
Noise Source Name	Strada Statale 26
Measurement station type	mobile
Georeferenced coordinates: latitude	45,81751
Georeferenced coordinates: longitude	6,959162
Number of lanes per direction	1
Road Surface	asphalt
Road slope	X
Road Profile (trench, raised, normal)	normal
Distance from microphone to road border	4
Height of microphone from ground	5
Height of microphone from road	5
Obstacles in noise propagation line	none
Type of ground cover between noise source and microphone	asphalt

Figure 46: *Courmayeur measurement site.*

8.2.2 Valle d’Aosta: Chatillon

Corridor	Tunnel del monte bianco
Noise Source Name	Autostrada A5
Measurement station type	mobile
Georeferenced coordinates: latitude	45,748992
Georeferenced coordinates: longitude	7,6251359
Number of lanes per direction	2
Road Surface	asphalt
Road slope	X
Road Profile (trench, raised, normal)	normal
Distance from microphone to road border	18
Height of microphone from ground	5
Height of microphone from road	4
Obstacles in noise propagation line	guardrail
Type of ground cover between noise source and microphone	asphalt

Figure 47: *Chatillon measurement site.*

8.2.3 Fréjus: Borgone

Corridor	Frejus
Noise Source Name	Autostrada Torino - Bar-donecchia
Measurement station type	mobile
Georeferenced coordinates: latitude	45° 7' 25,573' N
Georeferenced coordinates: longitude	7° 13' 16,971'' E
Number of lanes per direction	2
Road Surface	aphalt
Road slope	0
Road Profile (trench, raised, normal)	raised
Distance from microphone to road border	6
Height of microphone from ground	4.5
Height of microphone from road	4
Obstacles in noise propagation line	none
Type of ground cover between noise source and microphone	gass

Figure 48: *Borgone measurement site.*

8.2.4 Fréjus: Bardonecchia

Corridor	Frejus
Noise Source Name	Autostrada Torino - Bar-donecchia
Measurement station type	mobile
Georeferenced coordinates: latitude	45° 4' 2,697' N
Georeferenced coordinates: longitude	6° 43' 23,255" E
Number of lanes per direction	2
Road Surface	aphalt
Road slope	0
Road Profile (trench, raised, normal)	raised
Distance from microphone to road border	10
Height of microphone from ground	4
Height of microphone from road	4
Obstacles in noise propagation line	none
Type of ground cover between noise source and microphone	asphalt

Figure 49: *Bardonecchia measurement site.*

8.2.5 Gotthard: Reiden

Corridor	Gotthard
Noise Source Name	Autostrada A2
Measurement station type	fixed
Georeferenced coordinates: latitude	47,2391739406483
Georeferenced coordinates: longitude	7,9611042704635
Number of lanes per direction	2
Road Surface	splitmastix 0-11 mm
Road slope	~0,55%
Road Profile (trench, raised, normal)	raised
Distance from microphone to road border	4.7
Height of microphone from ground	3.5
Height of microphone from road	3.5
Obstacles in noise propagation line	guardrail
Type of ground cover between noise source and microphone	asphalt and grass

Figure 50: *Reiden measurement site.*

8.2.6 Gotthard: Camignolo

Corridor	Gotthard
Noise Source Name	Autostrada A2
Measurement station type	fixed
Georeferenced coordinates: latitude	46,0972446087489
Georeferenced coordinates: longitude	8,92813676719636
Number of lanes per direction	2
Road Surface	MR11 (Macrorugoso)
Road slope	1,7%
Road Profile (trench, raised, normal)	raised
Distance from microphone to road border	4.9
Height of microphone from ground	3.5
Height of microphone from road	3.2
Obstacles in noise propagation line	guardrail
Type of ground cover between noise source and microphone	asphalt and grass

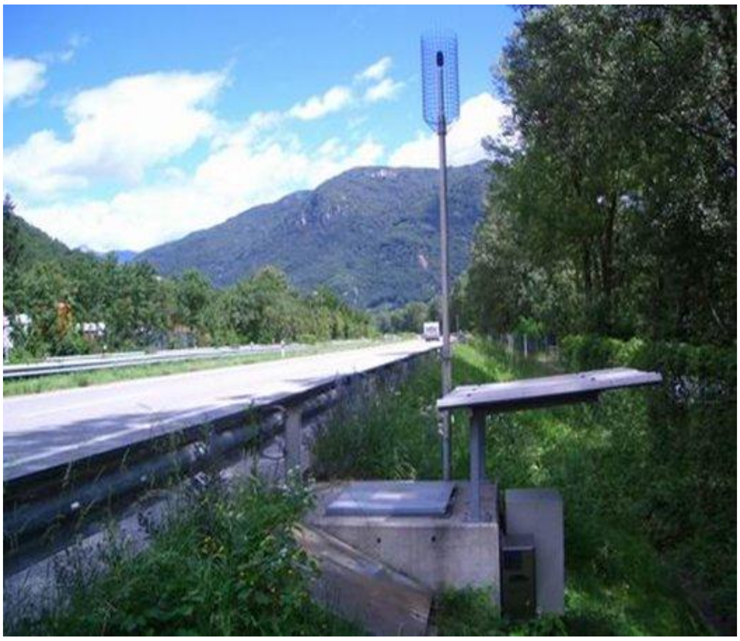

Figure 51: *Camignolo measurement site.*

8.2.7 Tavisio: Camporosso

Corridor	Tarvisio
Noise Source Name	Autostrada A23
Measurement station type	mobile
Georeferenced coordinates: latitude	46,509607
Georeferenced coordinates: longitude	13,551977
Number of lanes per direction	2
Road Surface	draining asphalt
Road slope	~1.8%
Road Profile (trench, raised, normal)	normal
Distance from microphone to road border	19
Height of microphone from ground	4
Height of microphone from road	4
Obstacles in noise propagation line	guardrail
Type of ground cover between noise source and microphone	grass

Figure 51: *Camporosso measurement site.*

8.3 Meteorology

It is very important to note that, since the measurements are ran at a small distance from the infrastructures, the meteorological effects are weak. In fact, it is well known that the meteorological conditions affect the propagation of noise and not the emission directly.

We therefore expect to have the measured noise levels very little dependents of the meteorological variables.

Meteorological data are used only to determinate which noise values are not valid. All the noise levels recorded in presence of a wind with speed greater or equal than 5 meters per seconds or of precipitation are considered invalid.

8.4 Traffic

It is well known that noise levels are directly connected to the traffic count. For this reason, it is extremely important to consider, for each corridor, the light vehicles and the heavy duty vehicles traffic that travel in the observed road.

In the iMONITRAF! Project there are five different corridors, each with different traffic characteristics. The project wants to account the effects of the international traffic, so it is very important to consider how much local traffic it is present on each road in order to understand how the noise levels are affected by the different types of vehicles.

The traffic travelling at each measurement point is displayed in the iMONITRAF! Indicator 1. Here we show the basic data to ease the comprehension of the noise data that will be presented and discussed in this document.

The traffic values for light and heavy duty vehicles, for the various corridors, are (values in number of vehicles per day):

		TGM: LV	TGM: HDV
Gotthard	Reiden	31681	4266
	Camignolo	41173	8387
Fréjus	Bardonecchia	2449	2058
	Borgone	10216	3334
Mont Blanc	Courmayeur	3336	1609
	Chatillon	14127	3231
Tarvisio	Tarvisio	8235	4319
Brenner	Brenner	17719	8105

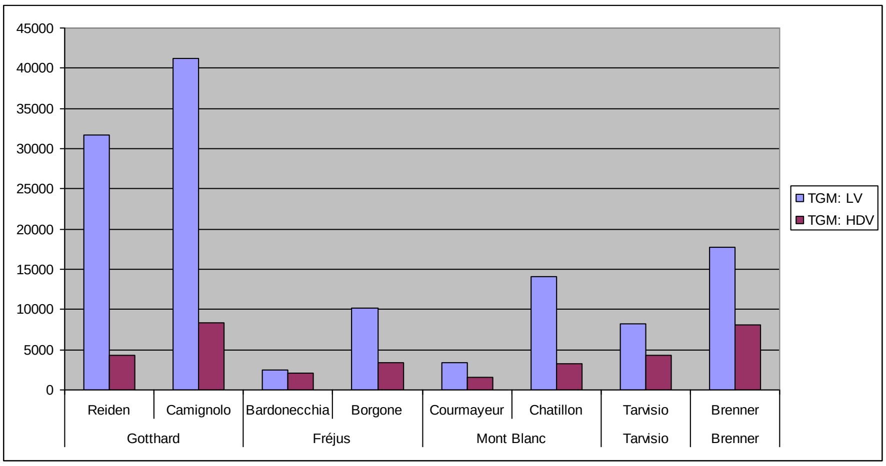

***Figure 52:** Traffic Fluxes of the corridors*

8.5 Noise Campaigns: Results

In this section the results of the noise campaigns are shown. The tables are part of the iMONITRAF! Indicator 6 data. As asked by the indicator, the noise level of the day and night are reported.

		2005	2006	2007	2008	2009	2010	2011
CSC	Reiden	*78,5*	78,7	79,2	79,2	79,6	79,6	79,6
Ticino	Camignolo	*78,5*	78,7	78,9	79,1	79,6	79,5	79,8
VdA	Courmayeur	*x*	x	73,8	74,1	74,8	72,6	70,7
	Chatillon	75,4	x	x	x	x	77,5	74,6
Piemonte	Bardonecchia	*x*	x	x	x	x	72,8	71,4
	Borgone	*x*	x	x	x	x	74,9	73,3
FVG	Tarvisio	*76,9*	x	x	x	x	71,2	71,3

Table: *L_{den} in the iMONITRAF! Years of activity and reference years.*

L_{night} in the iMONITRAF! Years of activity and reference years

		2005	2006	2007	2008	2009	2010	2011
CSC	Reiden	*70,5*	70,9	71,4	71,5	71,9	72,0	71,9
Ticino	Camignolo	*70,3*	70,6	70,8	71,0	71,5	71,4	71,7
VdA	Courmayeur	*x*	x	66,5	x	x	65,3	63,4
	Chatillon	67,1	x	x	x	x	69,3	66,6
Piemonte	Bardonecchia	*x*	x	x	x	x	66,0	64,1
	Borgone	*x*	x	x	x	x	67,5	65,2
FVG	Tarvisio	*69,7*	x	x	x	x	64,9	64,3

Table: *L_{night} in the iMONITRAF! Years of activity and reference years.*

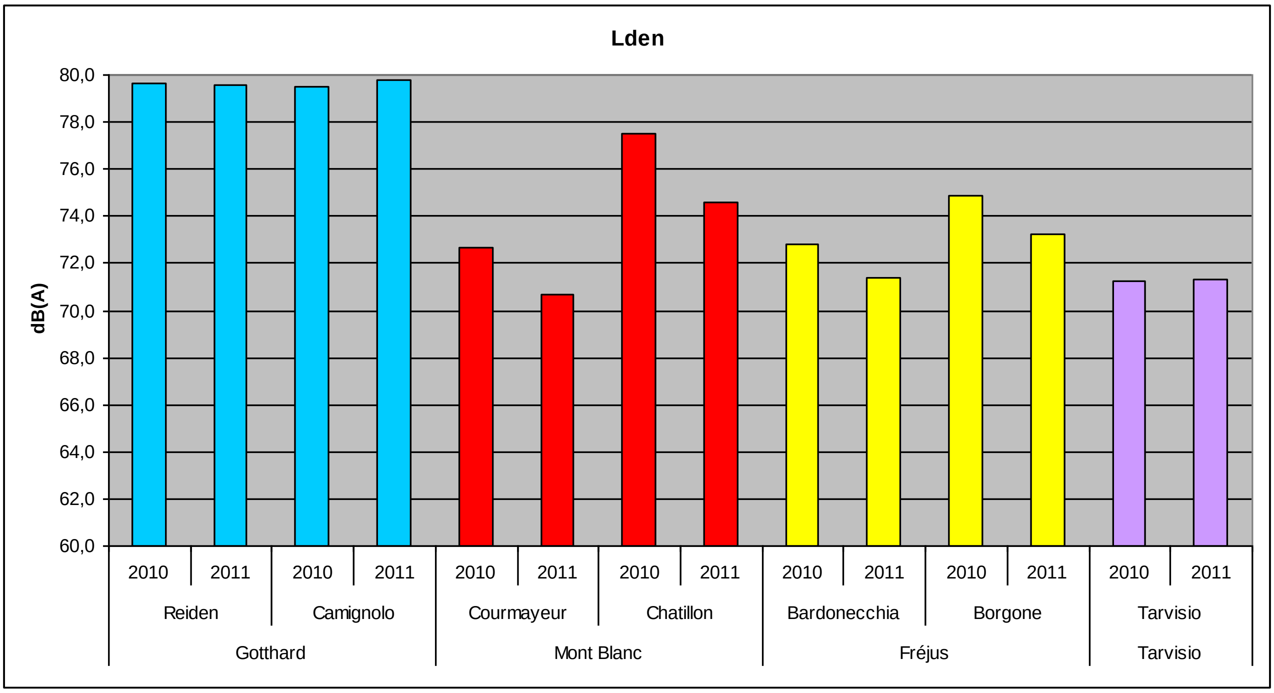

Figure 53: *L_{den} in the iMONITRAF! Years of activity*

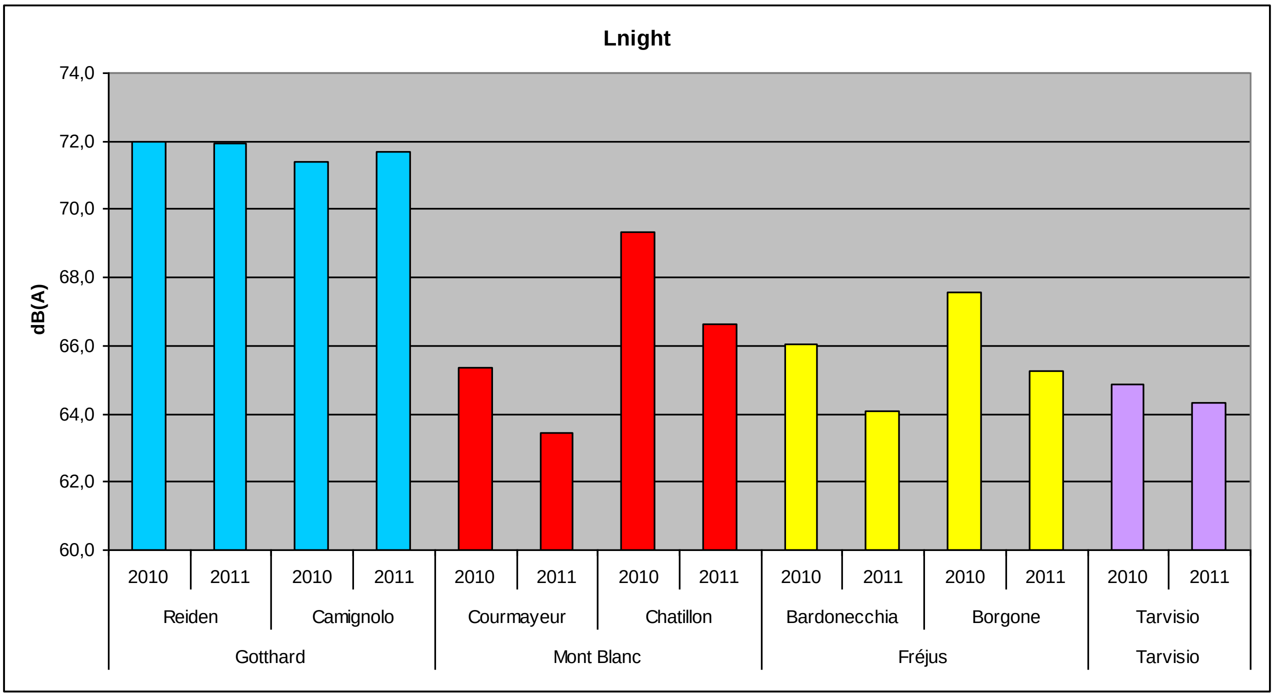

Figure 54: *L_{night} in the iMONITRAF! Years of activity*

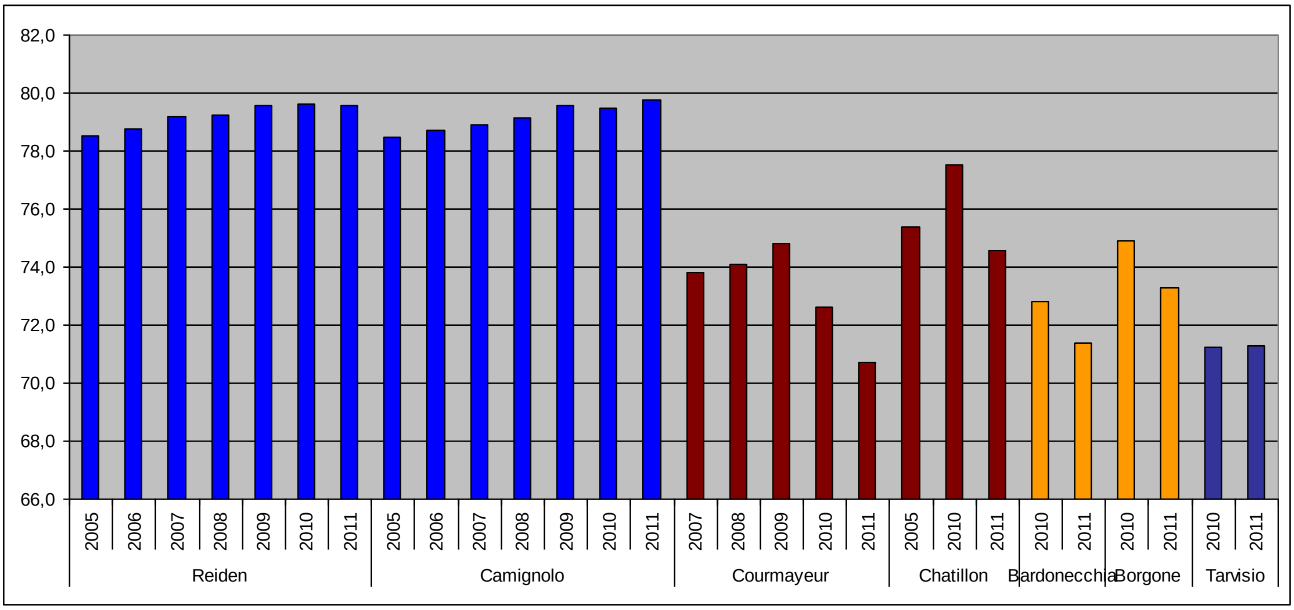

***Figure 55:** L_{den} in the iMONITRAF! Project and reference values*

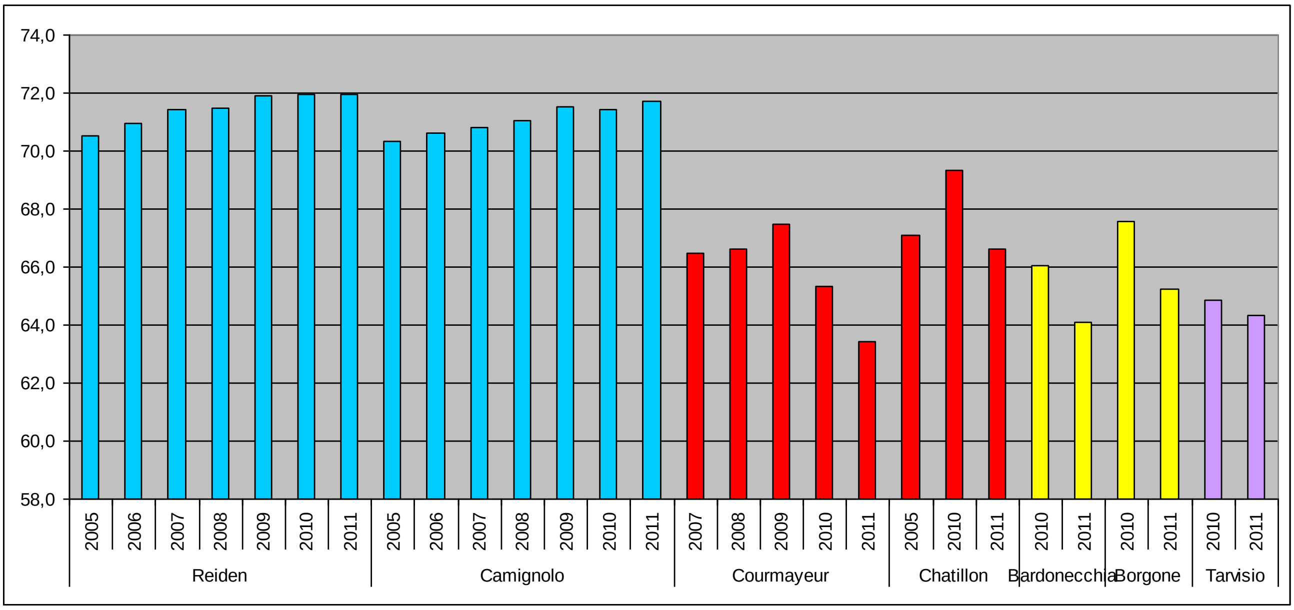

***Figure 56:** L_{night} in the iMONITRAF! Project and reference values*

8.6 Conclusions

The values measured in Reiden and Camignolo are higher than the ones of the other corridors due to the large number of light vehicles that travel on those roads. In these two measurement points there is a quite large local traffic.

All the measures have been conducted in accordance to guidelines written and approved by all the project partners to ensure measures are confrontable between different corridors. Every measured level is standardized at a fixed distance (10 meters from infrastructure) and height (4 meters).

Note that the reference noise levels, obtained before the beginning of iMONITRAF! project, were measured before the creation of the guidelines and were, therefore, obtained using different procedures.

The Project Partners agreed to conduct at least one measurement per season, in order to have the same minimum amount of data for each corridor.

It should be noted at Courmayeur there is a two lanes road and that the inclination of that road is very high, while all the others are four lanes highways with about flat terrain.

For these reason the shown values are good indicators of the real emission levels of the infrastructures.

In the last year it is possible to observe a reduction of the noise levels of about 2 dB in the Piemonte and Valle d'Aosta corridors. The levels measured in Switzerland and Tarvisio did not change significantly from the previous years.