ANNEX

1. REFINING ACTIVITIES ON THE HEAVEN CHAIN IN ROME

Refining activities have been constantly and continuously carried out on the system during the whole evaluation phase. Those activities led to a constant update and improvement of the system performances (in terms of accuracy of roadside description), and are related to the information gained within on-line testing of the system.
The most important refining activities carried out on the system are related to:

- Emission model (TEE);
- Dispersion model: sensitivity tests on ADMS.

Modification to the emission module TEE have been carried out in order to have a stronger correlation between traffic flows dynamics and emission; to achieve this the Kinematic Correction Factor has been activated.

A sensitivity test has been carried out on the dispersion model ADMS in order to evaluate how input meteo condition impact the final concentrations distribution. The ADMS sensitivity test has been carried out by the University of Rome “La Sapienza”.

1.1 Emission Model (TEE) Calibration

TEE is a computer model for the calculation of consumptions and emissions from vehicular traffic at ‘microscopic’ (street) and ‘macroscopic’ (city or region) level.

The road stretch is the geometric elementary domain of TEE. The stretch can (but not necessarily must) coincide with a road joining two nodes of the network. Typical data defining the stretch are:

- the stretch length
- the number of vehicular flows (not necessarily coincident with the physical lanes) running along the stretch
- the steepness of the road for the various vehicular flows
- the altitude above the sea level.

The traffic flows running along the stretch are characterised by:

- three flow ‘modes’ (‘transit’, ‘parking’ and ‘insertion’, defined for taking better into account the different driving patterns in a real road): both ‘distributed’ (i.e. along street side) and ‘concentrated’ parkings (parking lot) are considered

- a number of vehicular categories, both 'standard' (i.e. defined by CORINAIR/COPERT) and 'user provided', with different consumption/emission characteristics
- several Kinematic options (currently eight) available for the description of the driving patterns of the different vehicle categories, anyway belonging to one of the following four main Kinematic models:
    - average speed
    - simplified four – phases cycle (cruise + acceleration + slow down + idling)
    - speed cycle (i.e. speed vs time curve)
    - average speed with a correction coefficient (KCF) related to congestion.

Consumptions and emissions are calculated for each category in each vehicular flow and in each traffic mode, on the grounds of the selected Kinematic options. Values of consumption and emission obtained for 'standard conditions' (e.g. COPERT III curves and drive MODEM and DVB data) are then corrected by taking into account the specific vehicle age distribution, maintenance level, road steepness, engine temperature, altitude.

The basic set of input data of TEE model are of two different types: the first one is an input regarding the geometric and typologic description of the whole network to analyse: the second one is an input needed by the inner module for the calculation.

The inner Fortran module needs three types of data:

- data related to the whole network (stretches data)
- vehicular composition data (local data)
- traffic flows data (traffic volumes)
- vehicles Kinematic data (e.g. average speed).

The output of TEE is of two different types according to the aggregation requested. The first type of results is an output for each stretch (of the network considered) and for each hour (of the temporal window considered) based on the total value of energy consumption and pollutant emissions. The second one (this output is possible only for one road stretch and one hour, in the 'off line' mode) is based on a comprehensive set of tables (having in general the vehicle categories and the vehicular flows as dimension) showing the consumption and emission value at microscopic level (for every stretch, foe every flow in the stretch, for each traffic 'mode' and for each vehicular category present in the flow) in three different ways:

- 'specific' values (grams per vehicle and KM)
- 'length integrated' values (grams per vehicle along the stretch)
- 'length and flow integrated' values (Kgs per hour)

Both 'normal' (i.e. in standard conditions) and 'real' (in calculation conditions) values are available for this extremely detailed way of output.

The software architecture of TEE inner module is quite modular and fitted for continuous development and updating of the model. The basic 'back – bone' of the code is made of the following subroutines:

- INPUT, for the input of most of the data;
- TRAFIC, for the analysis and further elaboration of traffic provided data;
- ENCO, for the calculation of fuel and energy consumptions;
- EMI, for the estimate of pollutant emissions;
- OUTPUT, for the flexible presentation of micro results in the off line mode.

The most important features of TEE model are the following:

- Spatial flexibility (from the single stretch to the whole network)
- Temporal flexibility (from one hour to one year)
- Flexible fleet definition
- Possible differentiation of the fleet according to the stretch type (highway, local street, down town)
- Kinematic option flexibility
- Multiple emission database usage (COPERT, MODEM, DVB data)
- Consideration of the most important parameters affecting the emissions (steepness, maintenance, real age, altitude above the sea level, engine temperature
- Consideration of the parking areas
- Possibility of Interfacing with traffic and dispersion models
- Possibility of flow and speed data reconstruction

1.1.1 Kinematics Correction Factor

The analysis on the emissions produced assigning the O/D matrixes (corrected by traffic counts) highlighted the importance of having more precise and "dynamic" simulation of traffic flows because, it is known that, higher is the traffic congestion (number of stop and go) and higher is the emission produced by traffic flows.

For this reason it has been decided, after first results evaluation, to activate TEE's Kinematics Correction Factor (kcf) whose functional logic is briefly reported below.

One of the conceptual alternatives to the classic average speed emissions approach aims at obtaining a reasonably adequate kinematics description on the basis of an easily available input: an essential speed cycle is 'reconstructed' by the model itself as a function of the average

speed along the link, a congestion indicator such as the 'lane flow density' (flow to speed ratio in the link lanes), and the fraction of green time at the intersection at the end of the link. The information required in this case is rather easily obtainable and the reconstructed cycle can be sophisticated enough for taking into account the essential characteristics of the different driving phases: time spent in acceleration and related acceleration rate, cruise speed, idling time. The congestion level represented by traffic density (vehicles/km) is initially used for calculating the fractions of time spent during cruising, acceleration, deceleration and idling (see Fig A.1).

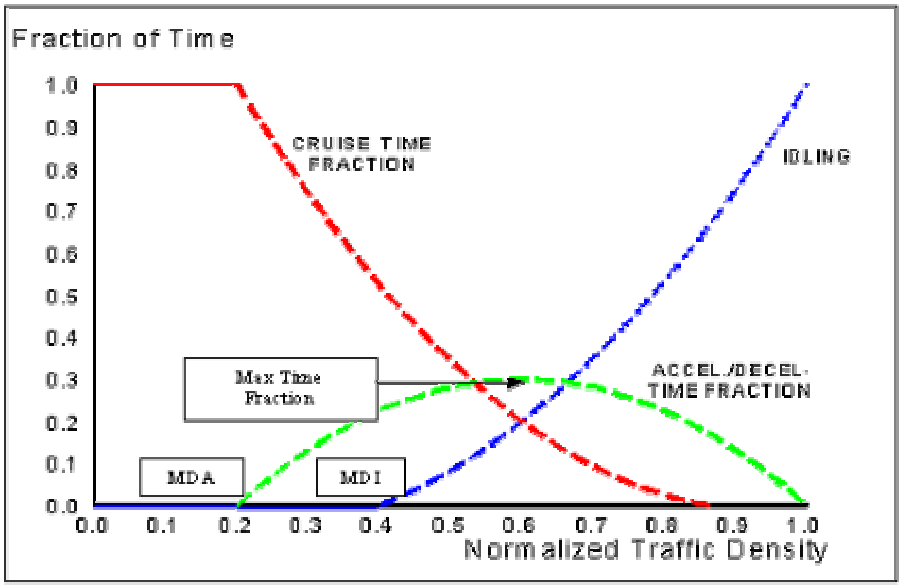


Fig A.1. Qualitative curves of Time Fractions spent in kinematics phases during free flow (Source: EC DG XII ESTEEM Project Final Report – 1999

The 'Kinematics Correction Factor' (KCF) Model makes extensive use of the 'reconstructed cycle' algorithm. The KCF approach assumes that the effect of speed variability can be expressed by means of a 'kinematics correction factor', i.e. a multiplying coefficient representing the variability of emissions with the speed profile shape depending on the congestion level for the same average speed. According to this approach, the emission 'E' is obtained as the product of the 'average' emission 'e', calculated from the average speed 'v', and the 'kinematics correction factor' KCF:

$$E = e(v) * KCF \qquad (1)$$

The KCF can be derived from a set of emission calculations in which both the 'reconstructed cycle' model and the average speed model are used. By considering a discrete number of average speeds, of 'green time percent', of congestion levels represented by traffic density, and of different link lengths, it is possible to define a four-dimensional matrix of possible traffic situations where emissions are calculated with both the approaches. This way the influence of the speed cycle can be quantified and the characterisation of the KCF as a function of speed, density, green time fraction and link length can be performed.

Validation calculations have been run in order to assess the absolute and relative accuracy of the KCF approach :

- steady speed fuel consumption was calculated with the KCF obtaining lower errors than those deriving from average speed emissions (differences in the range 5-30 % instead of 20-50%);
- speed cycles with similar average speed and very different content of acceleration show emission differences up to 300-400 % for both consumption and emissions of CO and HC: these changes can be predicted by the KCF, sensible to traffic density used for calculating the time spent in acceleration (Fig A.2).

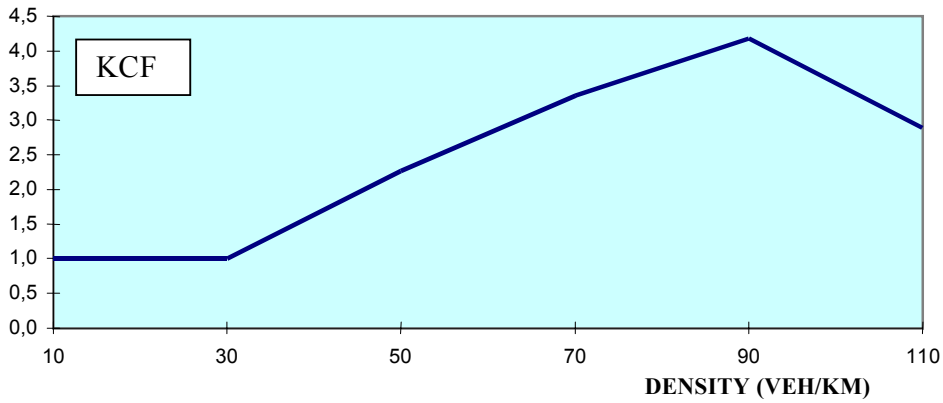


Fig A.2 Density sensitivity of the KCF for Fuel Consumption (Source: EC DG XII ESTEEM Project Final Report – 1999)

The most relevant validation activities were performed on the basis of CO pollution levels measured in Rome within the ESTEEM Project (1998).

Result obtained within the evaluation activities of the HEAVEN project are coherent with the previous validation studies.

1.2 Dispersion Model (ADMS) Sensivity Tests

The sensitivity analysis has been carried out starting from a base case (reported in Tab. A.1) and changing one parameter value at a time. Meteorological input can be provided through different datasets. Speed and direction of the wind are always necessary, plus one of the following parameters: reciprocal of Monin-Obukhov length, surface sensible heat flux and cloud cover (together with time of day and time of year). Monin-Obukhov length and sensible heat flux are not routinely recorded at stations, therefore cloud cover has been utilised for all the simulations.

Tab. A.1 Parameters of the base case

Wind Speed	Wind Direction	Cloud Cover	Julian Day	Local Time	Boundary Layer Height	Height of Recorded Wind
(m/s)	(degrees)	(oktas)	number	(hours)	(m)	(m)
1	0	4	161	10	800	2

The road source considered for the sensitivity test is a “test link” that, without lost of any generality, has been considered of 1 km long, 35 m wide and oriented in south-north direction; lined on both sides by buildings of height 15 m, thus the ADMS street canyon module has been activated. Output concentrations have been calculated at a receptor point positioned at half-way, 15 m east of the road centerline and at a height of 3 m. This receptor corresponds to a hypothetical roadside monitoring station. The source emission rate was fixed to 1 g/km/s. The site location is defined by a latitude of 41°, a surface roughness of 1 m and a minimum Monin-Obukhov length of 30 m. The last two data are suggested by the model help for cities and large towns.

1.2.1 Sensitivity Results Analysis

The model response to the variations of each input parameter has been tested. The results related to wind parameters are reported in Fig A.3.

All the parameters that are not in abscissa assume the base case values. The sensitivity can be associated to the slope of the diagrams. The model shows a high sensitivity at low wind speed. In this conditions the meteorological pre-processor introduces a threshold. All the wind velocities below 0.75 m/s are enhanced to this value and the corresponding wind directions are fixed to the first value for which the threshold was activated. The wind angle forcing may

introduce unrealistic levels of concentration. The model is very sensible to wind direction variations (Figure 1), a difference of 45° around to 270° introduces an error of 200% on the concentration. Note that angle differences of this entity between urban meteorological stations are not rare.

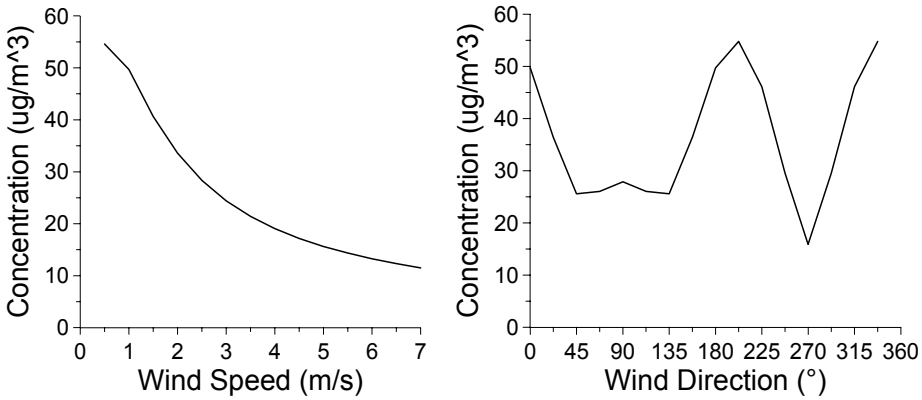


Fig A.3. Pollutant concentration calculated by ADMS-Urban versus wind speed and wind direction, for a road source located in a street canyon.

1.2.2 Sensitivity to sources of meteorological data

Wind data taken at stations within Rome area have been compared with data of rural stations located in the neighbourhood of the city. Data taken from these stations are alternatively provided to ADMS-Urban. The corresponding effects on model output have been evaluated.

a. Comparison among data from different weather stations

In the city of Rome there are several weather stations. Most of them are roadside stations and are not representative of the whole dispersion area. In this study two urban stations located on the top of high buildings have been considered: S. Pietro in Vincoli (41°53'N-12°29'E) and Colli Aniene (41°54'N-12°34'E). The first one is situated in the centre of Rome, the anemometer is placed on a 6-metre mast. Colli Aniene station is located in a suburban area of Rome, the anemometer is installed on a 3-metre mast.

In addition to urban stations two rural stations have been analysed: Fiumicino (41°48'N-12°14'E) and Ciampino (41°47'N-12°35'E). They are rural synoptic stations of the Aeronautical Meteorological Service, placed in the homonymous airports of Rome. The anemometers are located on standard 10-metre masts.

Meteorological data were obtained for individual days in June 2002. The results of the comparisons of wind speeds and directions on 14 June are shown in Fig A.4. Starting from 10.00 LST the effects of the sea breeze are evident: the wind turn to west and the magnitude

grows to its maximum value. During the night the land breeze appears: wind turn to east and its magnitude grows again. In the Rome area, because of the vicinity between mountains and coastline, the effects of sea-land and valley-mountain circulation interact. Nocturnal breeze is not evident at every station. At Fiumicino the direction of the nocturnal wind is classified as variable, hence no data are available.

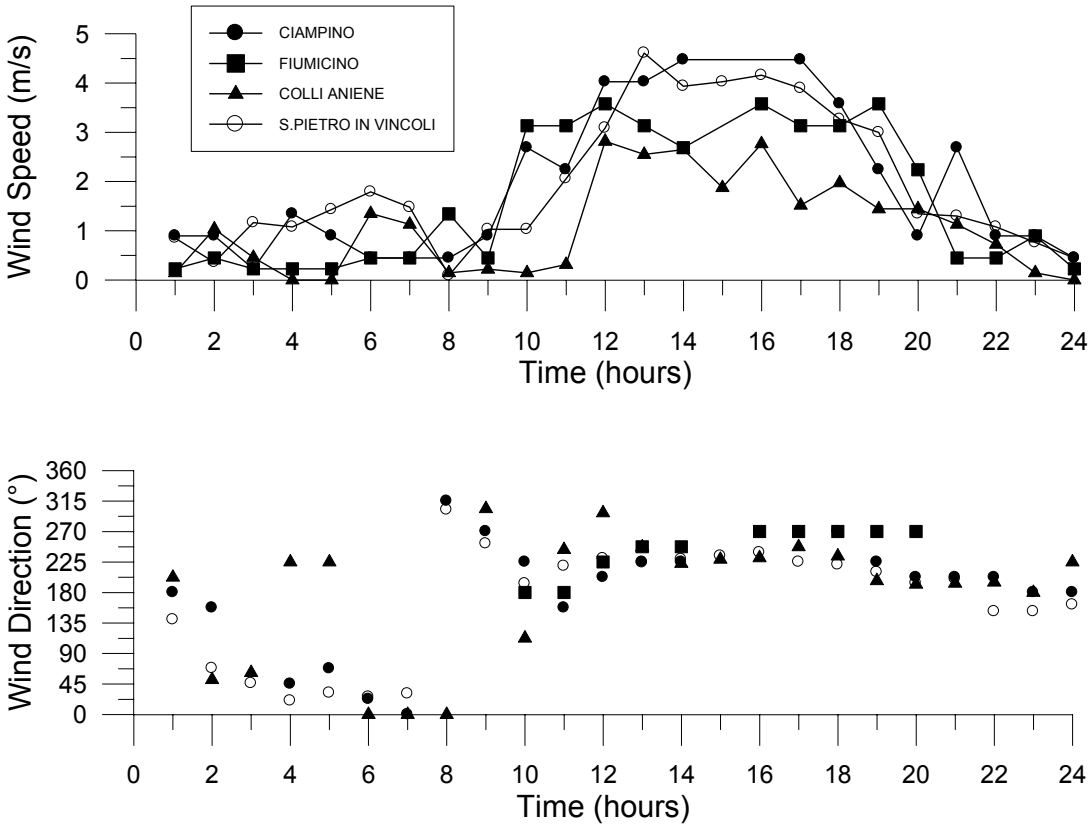


Fig A.4. Comparisons among wind data taken at different weather stations on 14 June 2002.

During night time and in early morning a strong spread of data has been observed for the various stations. On the contrary, after 12.00 LST, when the sea breeze grows, wind directions match pretty-good and the percentage differences between wind velocities decrease. Due to the lower mast height, the observed wind speeds at Colli Aniene are rather low. The example shown is for one single day, but a similar behaviour has been observed on the other days of June. Such conditions are very frequent during summer months in Italy, when strong synoptic winds are absent.

b. Comparison among concentrations

Meteorological data, recorded during individual days of June at different stations, have been alternatively furnished as input to ADMS-Urban. In order to evaluate how the choice of the station affects the model output, resultant concentrations have been compared. The simulation of 14 June 2002 has been considered as an example. The wind input data have been described in the previous paragraph. Cloud amounts and temperatures at different stations have been assumed equal to those measured at Colli Aniene. The pollutant source and the other needed parameters are the same described in the previous section. The results for Fiumicino have been discarded because of the lack of wind direction data. The predicted concentrations have been shown in Fig A.5.

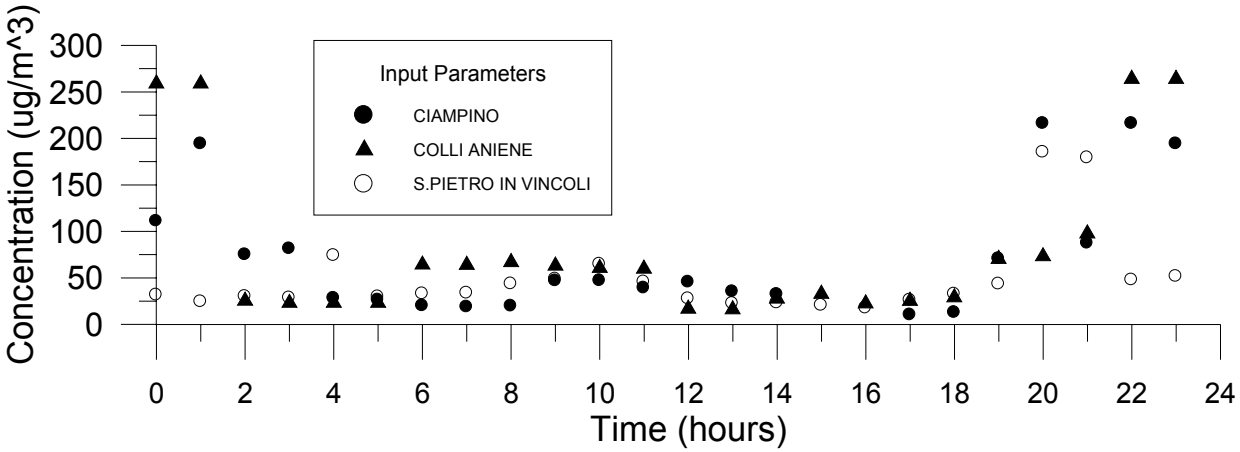


Fig A.5. Comparisons among concentrations calculated by ADMS-Urban, making use of input wind data taken at different weather stations on 14 June 2002.

The spread of input data affects the calculated concentrations. During night time uncertainties in the wind data give more than a tenfold increase in output differences. Such a behaviour is due to a synergic effect of low wind speeds and angles of high sensitivity. As experienced in some other simulations, the freezing effect, exerted by the pre-processor threshold on wind angle, does not seem to improve the results. During the morning the increases of wind speed and angle matching reduce output differences.

2. VERIFICATION UPDATE: INDICATOR 2 RESULTS

Results of the verification phase on the project level are reported in the "Final Verification Report" (D7.1); in the text – chapter 3 - main results and changes regarding the verification activities in Rome were reported. In relation to the Final Verification Report the update presented concerns mainly Indicator 2 where Rome has put additional efforts in performing an adequate model calibration.

The evaluation of the accuracy of roadside description has been carried out in a street canyon located outside the demonstration area described in chapter 3.

All the refining options have been implemented in the chain. Verification results obtained re-running traffic data with the update HEAVEN System are reported

Verification analysis on accuracy of roadside description is performed comparing measured concentration computed by the measurement station located in Via Magna Grecia with concentration computed by the system. In order to give validity to the HEAVEN system, background conditions have been taken into account by means of Villa ADA background measurement station that is one of representative background station of the city of Rome. Therefore, verification of roadside description has been carried out comparing traffic related pollutant concentrations, computed by the HEAVEN system, plus background concentration (ADA) with measured concentration (here after we will refer to computed plus background concentration with "calculated" concentration).

The verification period lasted 12 days from November the 26th to December the 7th. During the monitoring period all traffic and air quality data were collected, and both data sets have been validated in order to take into account only correct reference data.

A brief summary of statistical properties of measured and calculated concentrations (12 days x 24 hourly concentrations) is reported in the table.

Tab. A.2: statistical properties of measured and calculated pollutant concentrations (Via Magna Grecia)

Via Magna Grecia	CO		Benzene		Nox		PM10	
	measured	calculated	measured	calculated	measured	calculated	measured	calculated
average	2,819	1,941	16,612	8,716	95,324	58,042	65,181	24,464
max	10,789	9,123	72,670	58,763	177,151	190,855	199,519	77,132
min	0,690	0,933	0,470	1,828	50,757	26,195	11,250	0,327
standard dev.	1,489	0,356	10,089	1,840	22,896	8,336	31,420	13,962
NMD	0,311		0,475		0,391		0,625	
Corr. Index	0,859		0,707		0,879		0,660	

NMD: Normalised Mean Difference [(measured - calculated)/measured]
Avg Corr. Index: Average Correlation Index

Verification success criteria and results obtained are reported in Tab. A.3.

This table shows that during the evaluation period the success criteria is reached for all the pollutant CO (computed for 8 hours periods), C_6H_6.(computed for the whole evaluation period) and NO_x (computed for 1 hour periods). Success criterion is not reached only for PM_{10} (computed for 24 hours) concentration comparison; it is due to the difficulty of having adequate emission factors for motorcycles that represent an high percentage of the vehicular fleet. Benzene has been computed over the 12 days verification period.

Tab. A.3: Via Magna Grecia. Roadside evaluation criteria and results

POLLUTANT	EVALUATION PERIOD	SUCCESS CRITERIA	VALUE	SUCCESS
CO (8 hours)	26/11/01 - 7/12/01	$\Delta C < 50$ %	$\Delta C =$ - 23,56 %	yes
		$\Delta C_{abs} < 50$ %	$\Delta_{Cabs} = 26,69$ %	yes
C_6H_6 (annual) (*)	26/11/01 - 7/12/01	$\Delta C < 50$ %	$\Delta C =$ - 46,30 %	yes
		$\Delta C_{abs} < 50$ %	$\Delta C_{abs} = 46,30$ %	yes
NO_x (1 hour)	26/11/01 - 7/12/01	$\Delta C < 50$ %	$\Delta C =$ - 37,23 %	yes
		$\Delta C_{abs} < 50$ %	$\Delta C_{abs} = 37,23$ %	yes
PM_{10} (24 hours)	26/11/01 - 7/12/01	$\Delta C < 50$ %	$\Delta C =$ - 57,71 %	no
		$\Delta C_{abs} < 50$ %	$\Delta C_{abs} = 57,71$ %	no

(*) analysis performed over the verification period

Key:

$$\Delta C = \frac{\sum \frac{(C_{calculated} - C_{measured})}{C_{measured}}}{n} \quad ; \quad \Delta C_{abs} = \frac{\sum \frac{|C_{calculated} - C_{measured}|}{C_{measured}}}{n}$$

In the following paragraphs a detailed description of verification results obtained using the "refined" methodology is reported.

2.1 CO analysis

In this section results obtained from CO analysis are reported.

In Fig. A.6 and Fig. A.7calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

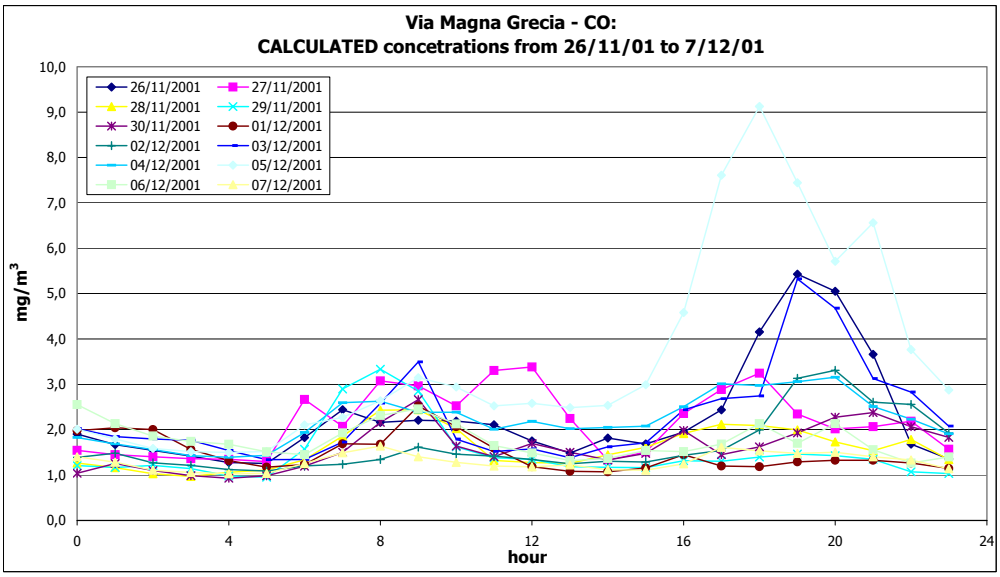


Fig. A.6. Via Magna Grecia: calculated CO daily trends

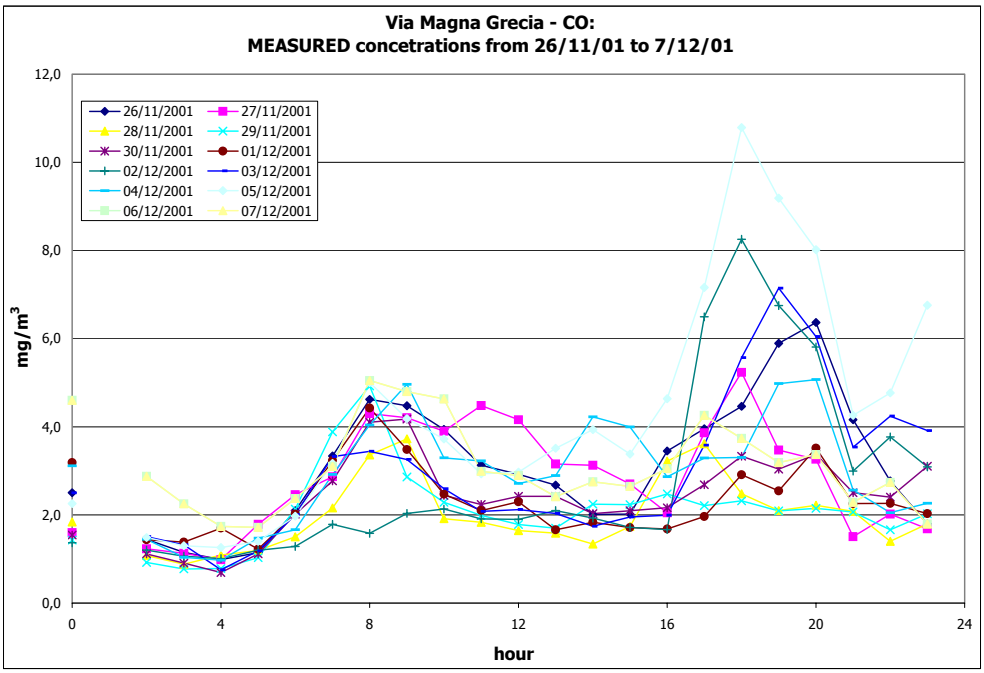
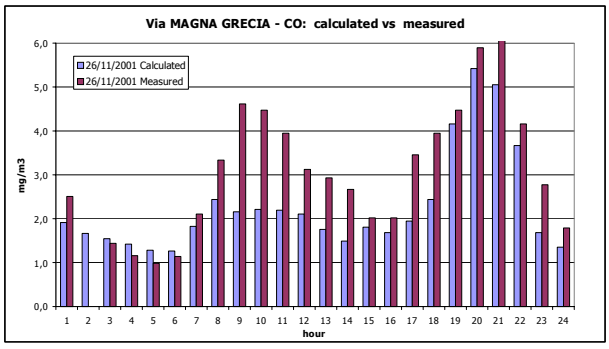
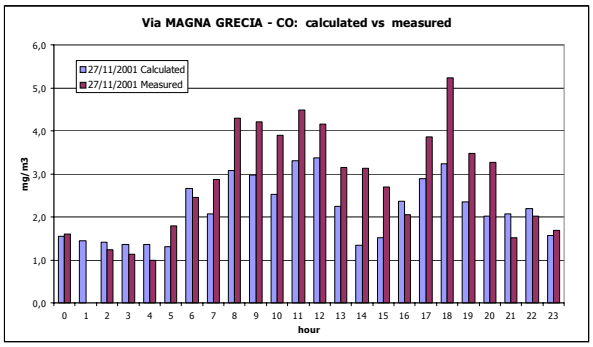
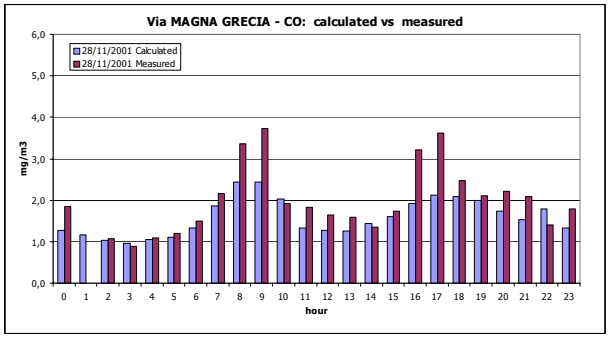


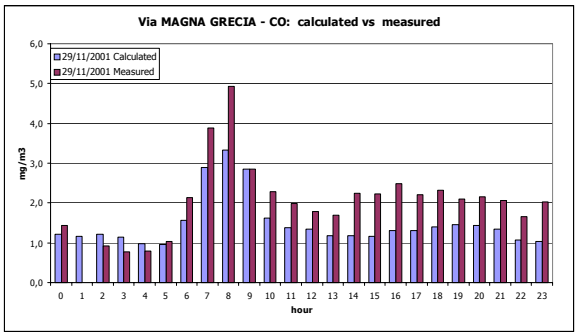
Fig. A.7. Via Magna Grecia: measured CO daily trends

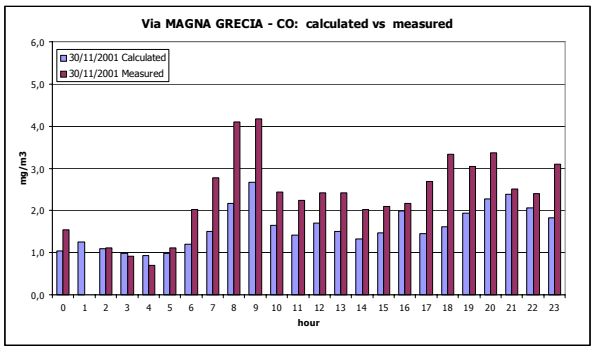
A detailed analysis of measured versus calculated concentrations is shown in the following; the comparison is carried out on a day-by-day basis for the whole verification period. These diagrams show both a good fitting, over the different hours of the day and over the different days, between computed and measured concentrations also if an under estimation of concentration computed by the HEAVEN is generally highlighted.

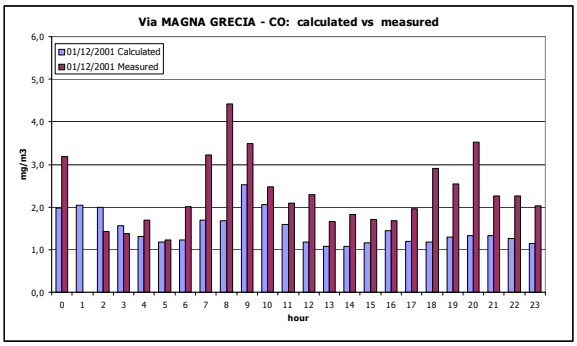


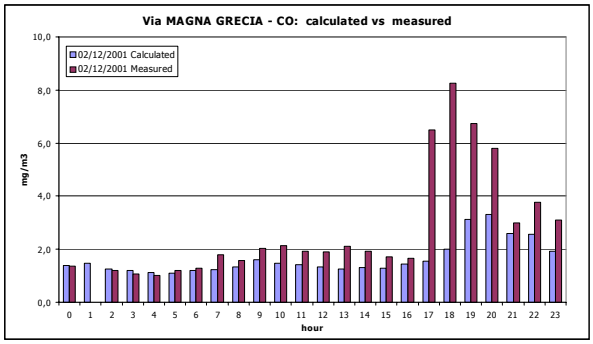












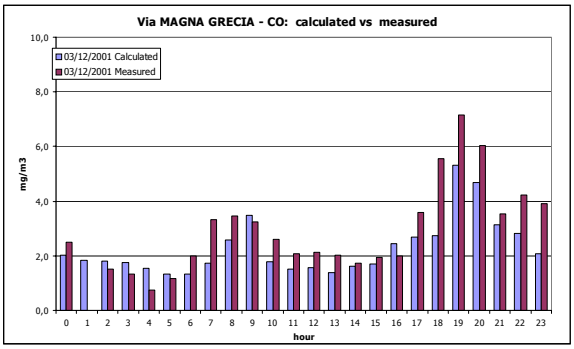
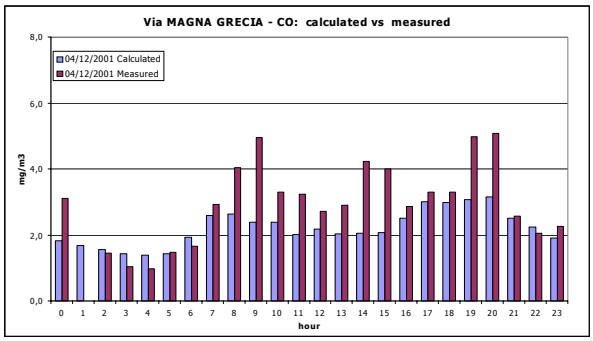
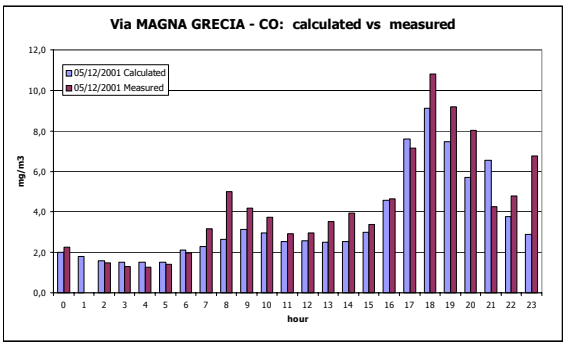


Fig. A.8. Via Magna Grecia: CO day-by-day comparison calculated – measured





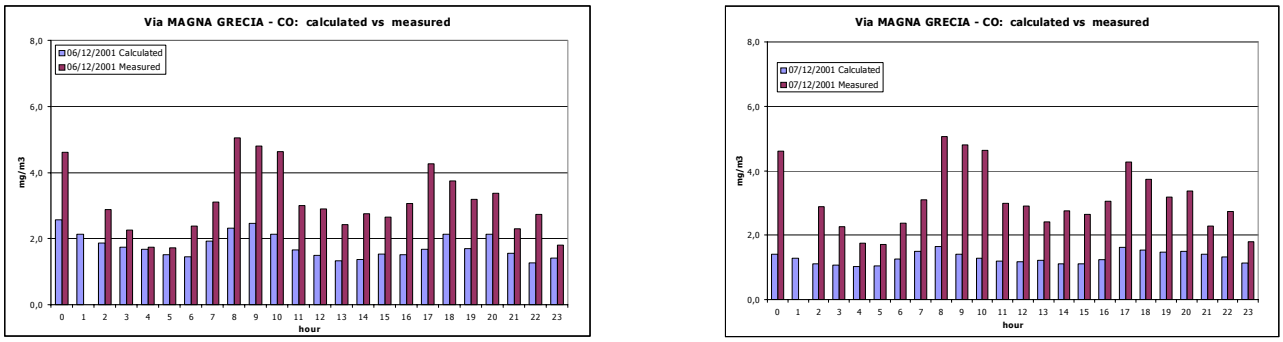


Fig. A.9. Via Magna Grecia: CO day-by-day comparison calculated – measured

The comparison of average calculated and measured CO concentrations, computed over the verification period, is shown in Fig. A.10. The results obtained are coherent with the ones obtained form the day-by-day analysis: CO concentrations are generally under estimated by the HEAVEN system.

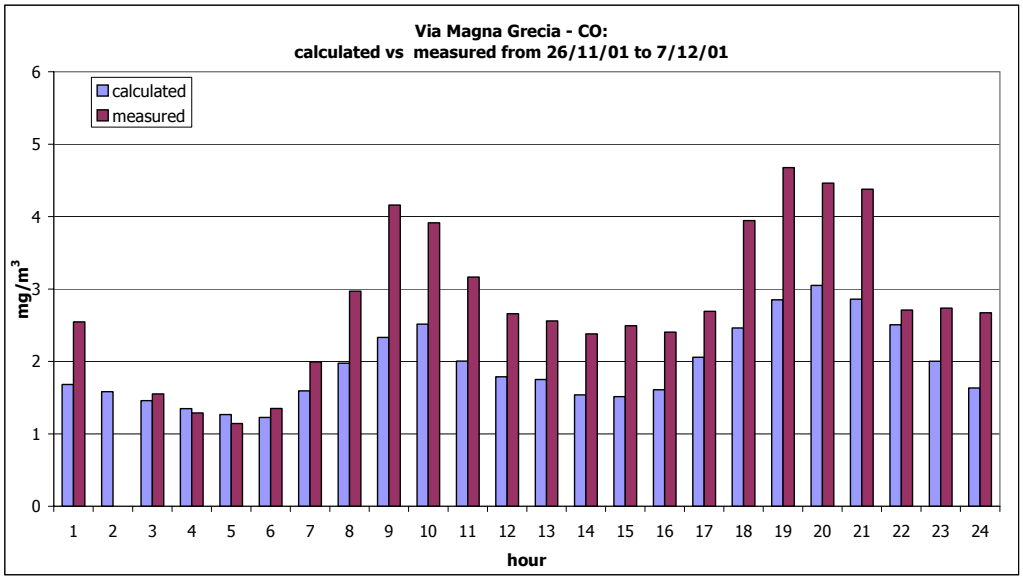


Fig. A.10. Via Magna Grecia: average CO concentrations: comparison calculated – measured

In Fig. A.11 and Fig. A.12 scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.859 and 0.594. These values show that there is a good correlation between measured and calculated CO concentrations.

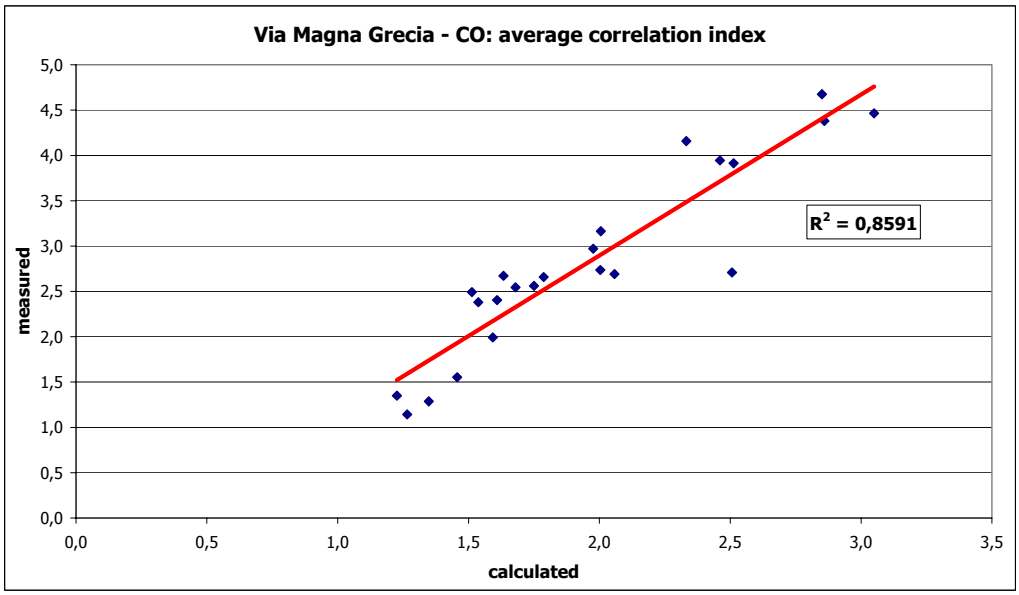


Fig. A.11. Via Magna Grecia: average CO correlation index

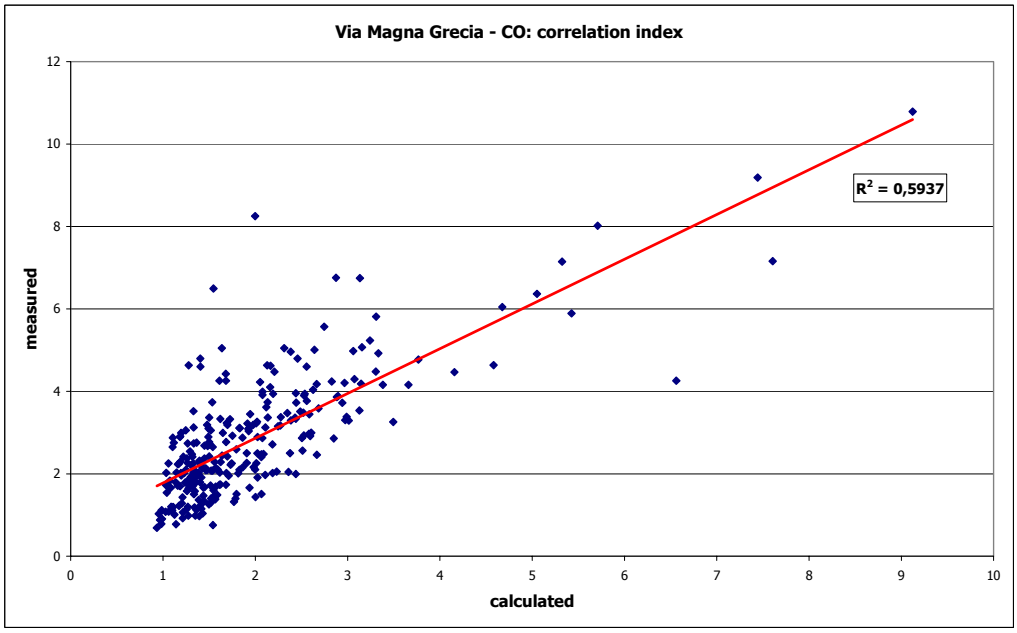


Fig. A.12. Via Magna Grecia: CO correlation index

2.2 C_6H_6 analysis

In this section results obtained from C_6H_6 analysis are reported.

In Fig. A.13 and Fig. A.14 calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

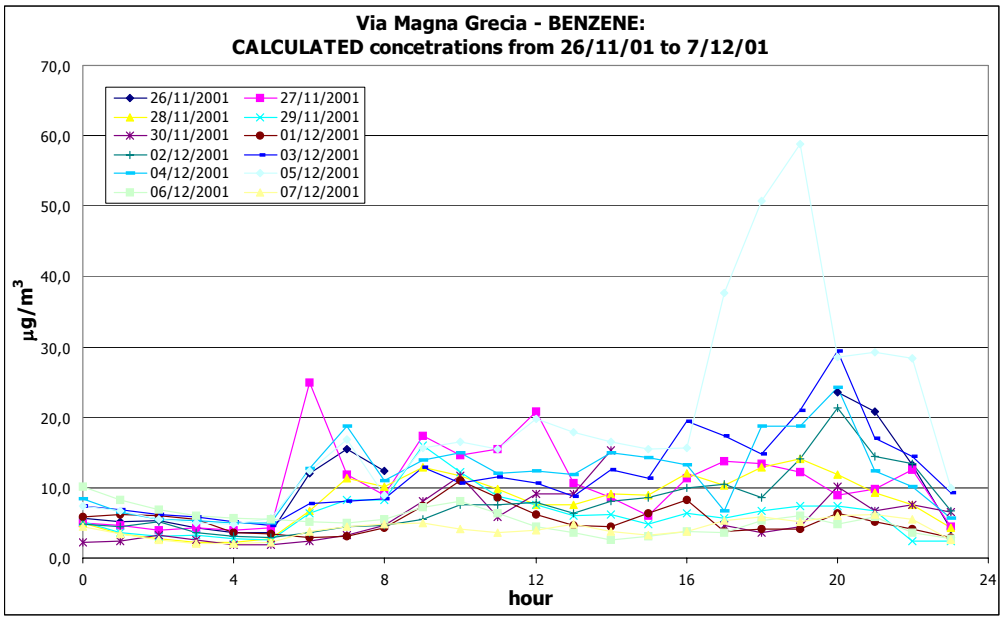


Fig. A.13. Via Magna Grecia: calculated BENZENE daily trends

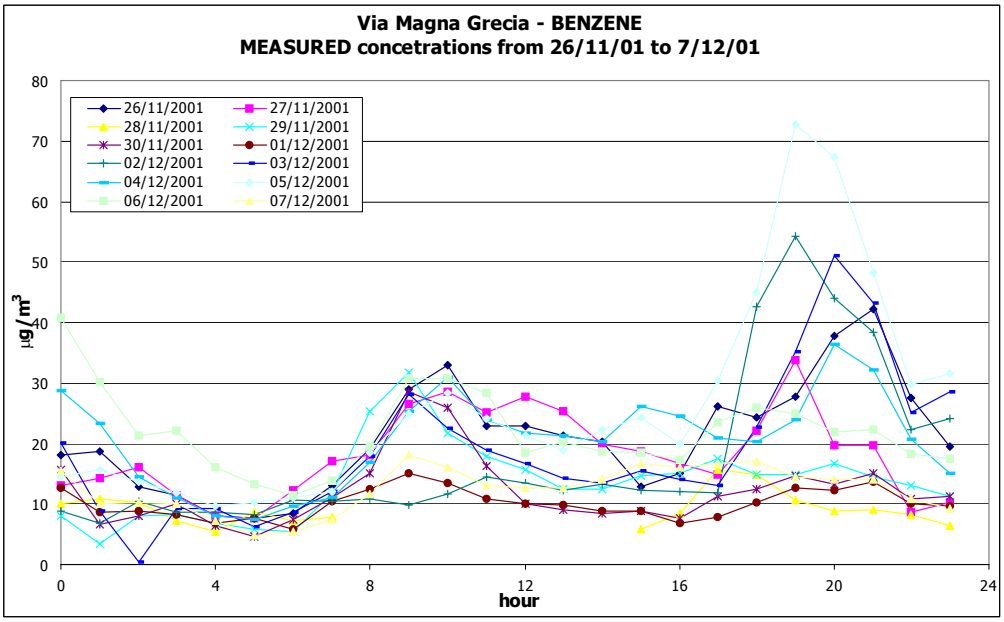


Fig. A.14. Via Magna Grecia: measured BENZENE daily trends

A detailed analysis is shown in the following picture; the comparison is carried out on a day-by-day basis for the whole verification period.

Due to a malfunctioning of Villa Ada background measurement station, two gaps of calculated concentration are present on November 26th and 30th for the period of time lasting, respectively, from 9 am to 7 pm and from 3 pm to 4 pm.

Moreover, due to an incorrect detection of benzene concentration measured data are not reported for the period of time lasting from 8 am to 2 pm of November the 28th.

These diagrams show a general under estimation of benzene concentrations computed by the HEAVEN system over the different hours of the day; this trend is more evident at peak hours.

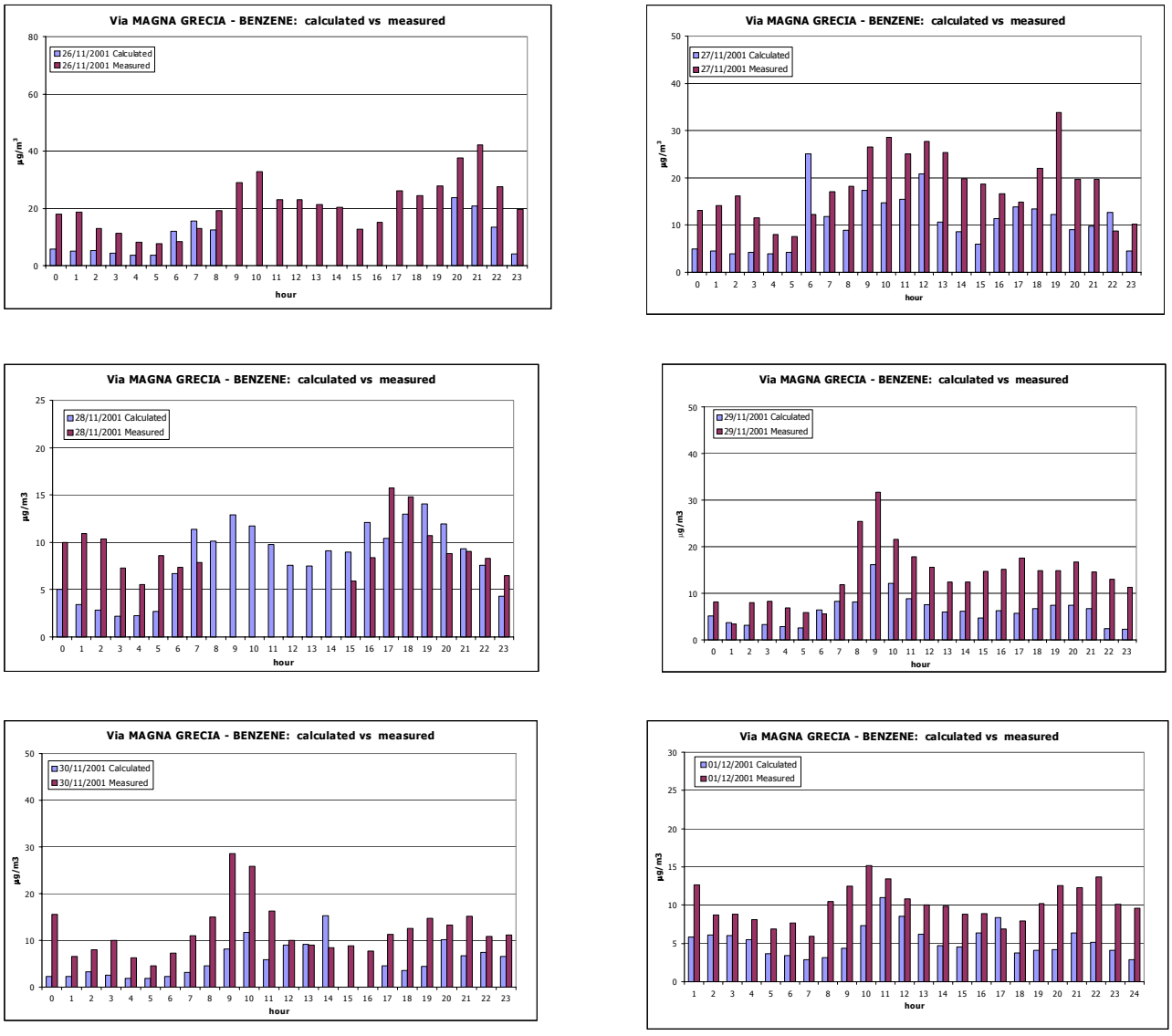


Fig. A.15. Via Magna Grecia: BENZENE day-by-day comparison calculated – measured

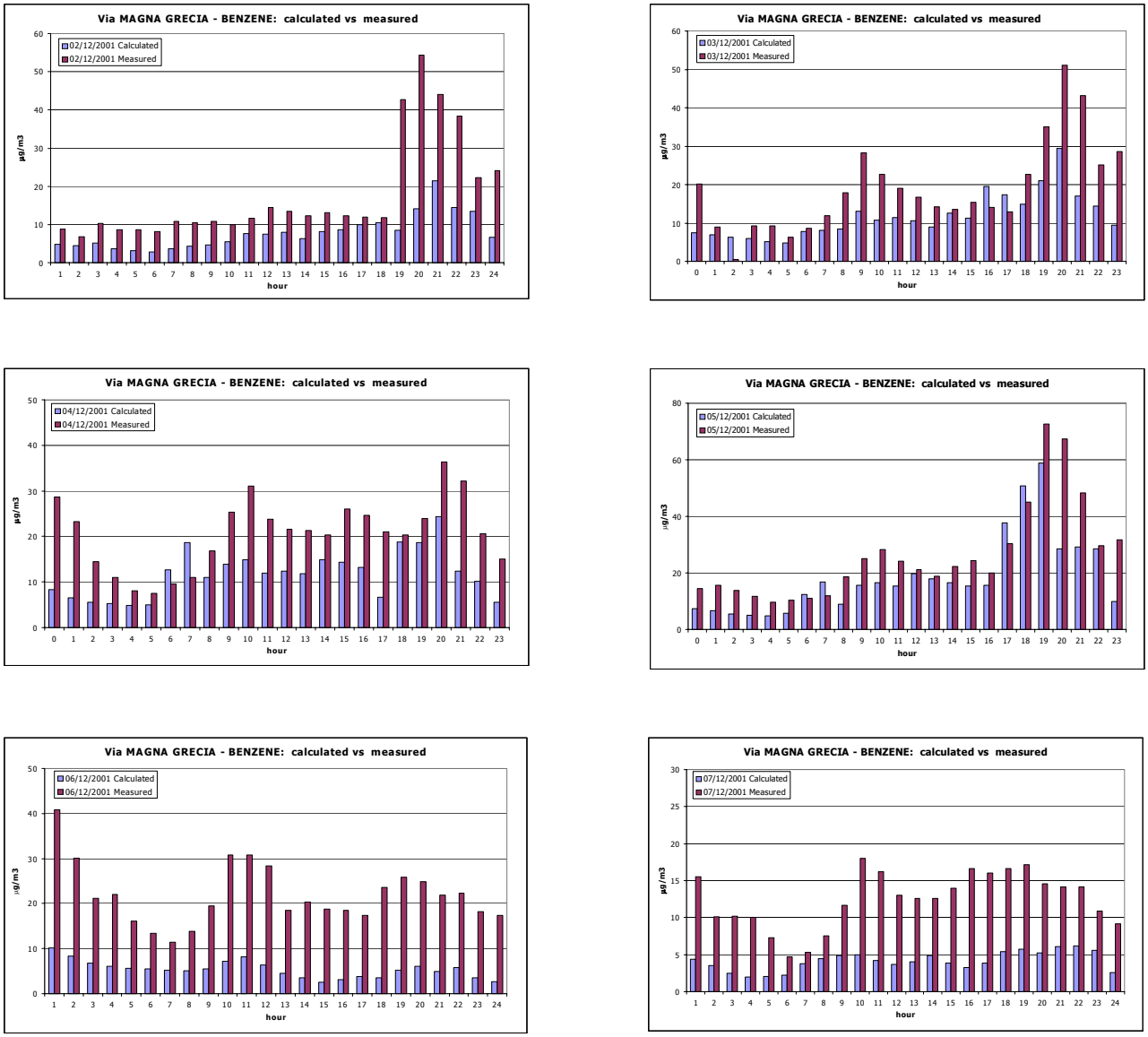


Fig. A.16. Via Magna Grecia: BENZENE day-by-day comparison calculated – measured

HH: As in other cases the figure numbers are not consistent. Fig 15 is reference two times.

The comparison of <u>average</u> calculated and measured C_6H_6 concentrations, computed over the verification period, is shown in the following picture. The results obtained are coherent with the ones obtained form the day-by-day analysis: benzene concentrations are generally under estimated by the HEAVEN system.

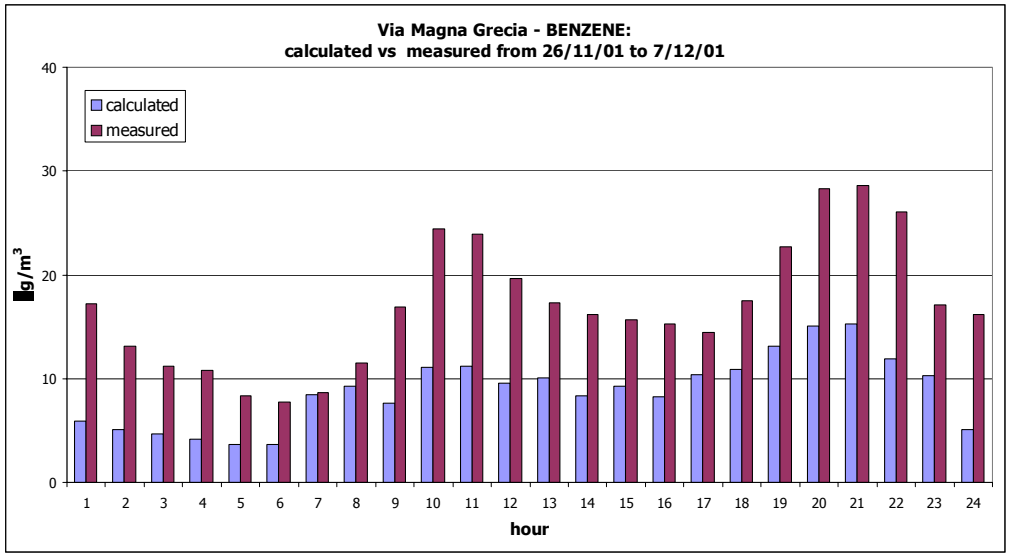


Fig. A.17. Via Magna Grecia: average BENZENE concentrations: comparison calculated – measured

In the following scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.707 and 0.488. These values show that there is a good correlation between average measured and calculated C_6H_6 concentrations while the correlation decrease analysing the cumulative concentrations values.

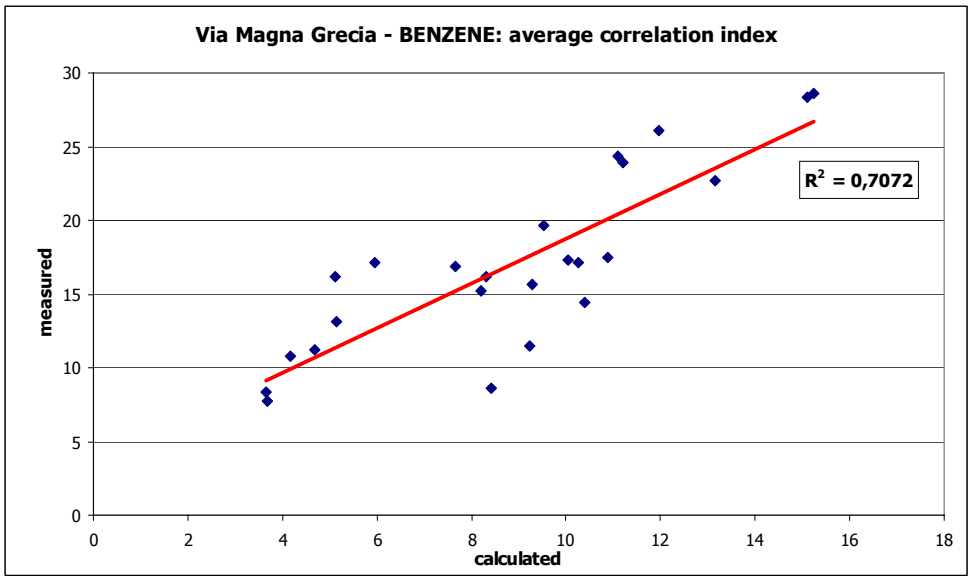


Fig. A.18. Via Magna Grecia: average BENZENE correlation index

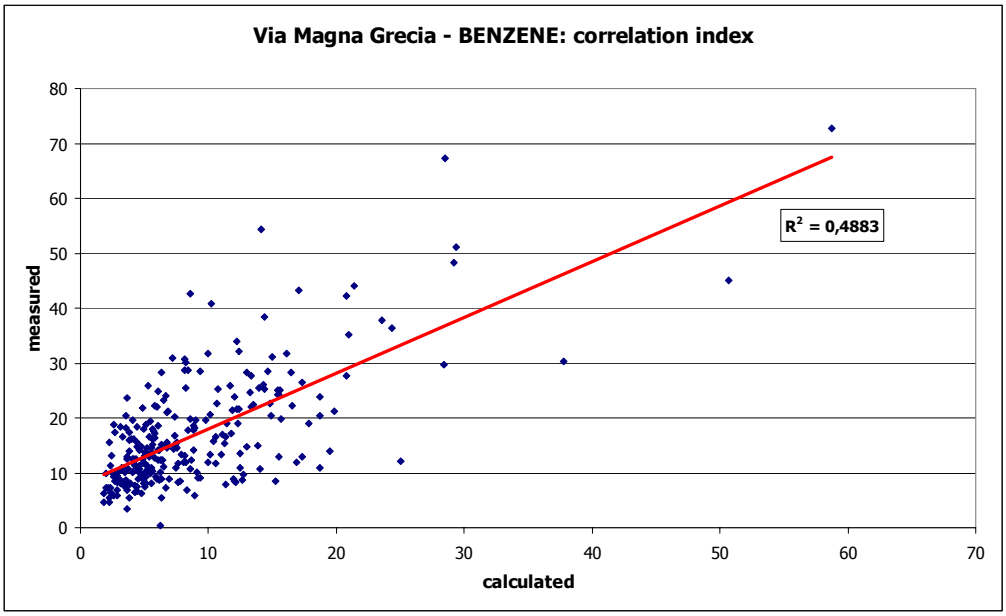


Fig. A.19. Via Magna Grecia: BENZENE correlation index

2.3 NO_x analysis

In this section results obtained from NO_x analysis are reported.

Calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

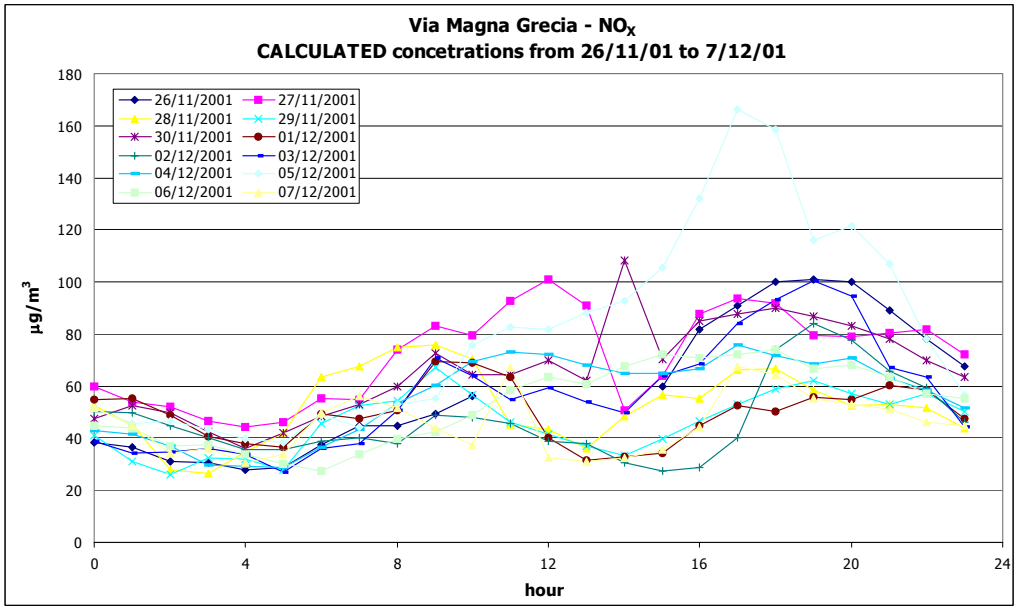


Fig. A.20. Via Magna Grecia: calculated NO_x daily trends

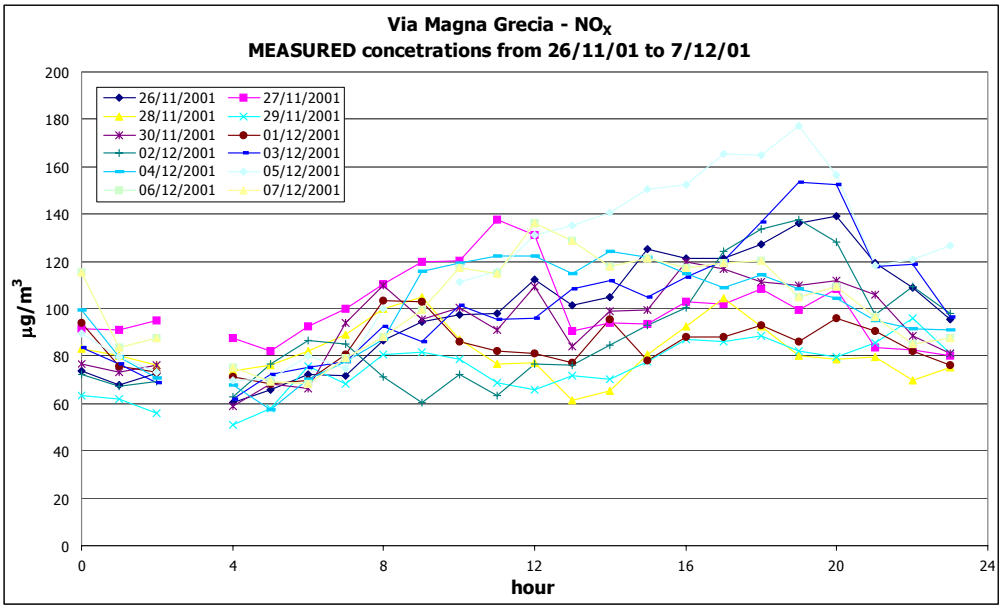


Fig. A.21. Via Magna Grecia: measured NO_x daily trends

A detailed analysis of measured versus calculated concentrations is shown in Fig. XX; the comparison is carried out on a day-by-day basis for the whole verification period.

Due to a malfunctioning of Villa Ada background measurement station, a gap of calculated concentrations is present on November 26th for the period of time lasting from 11 am to 2 pm.

Due to an incorrect detection of NO_x concentration measured data is not reported at 3 am for the whole verification period (see following picture).

These diagrams show a general under estimation of benzene concentrations computed by the HEAVEN system over the different hours of the day; this trend is more evident at peak hours.

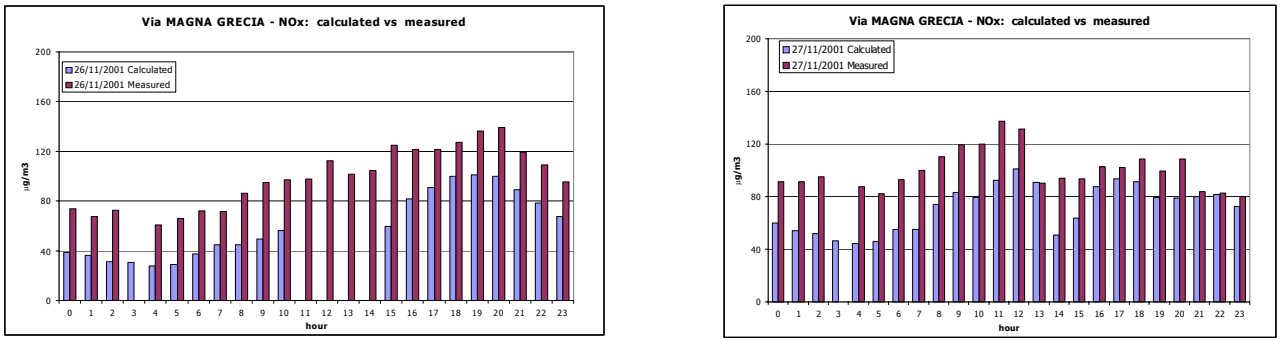
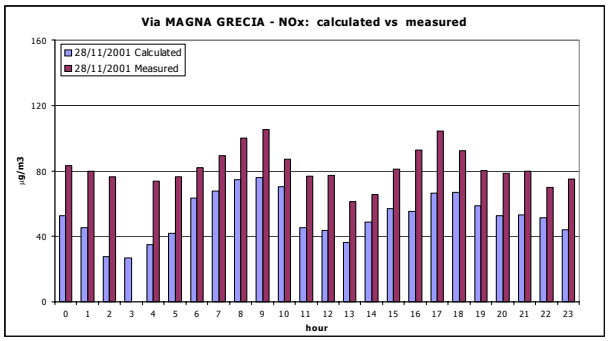
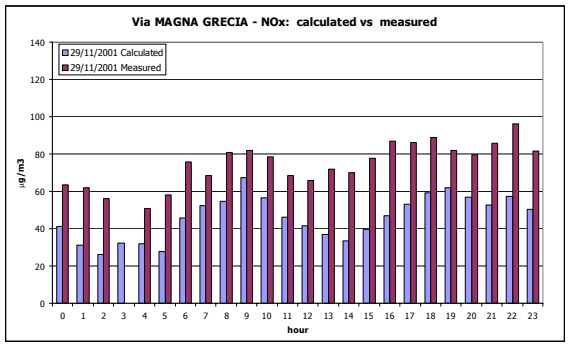
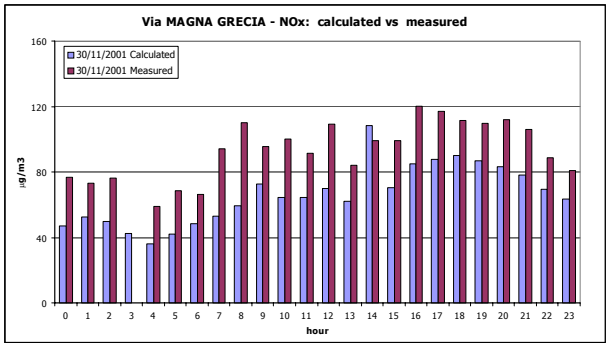
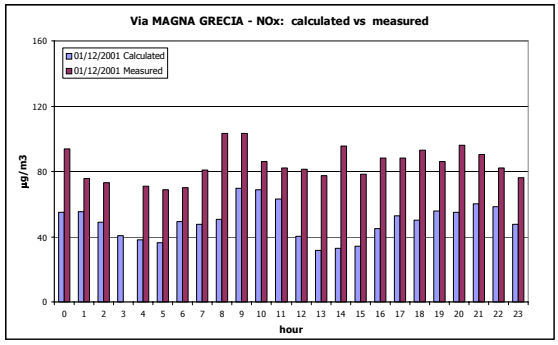


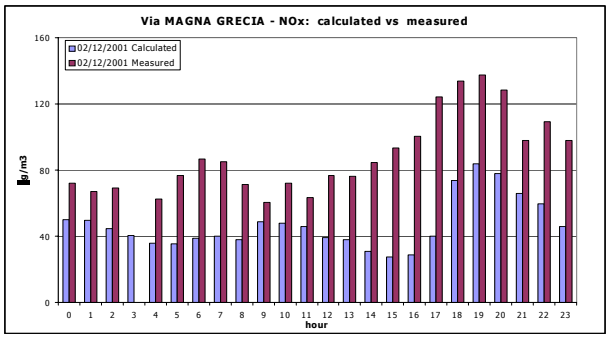
Fig. A.22. Via Magna Grecia: NO_x day-by-day comparison calculated – measured

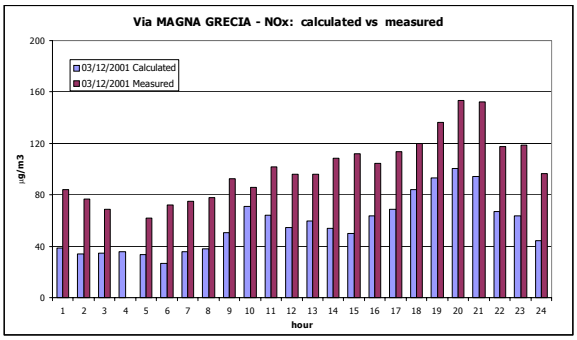


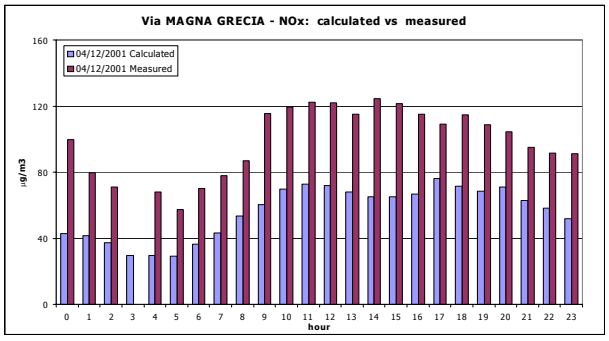












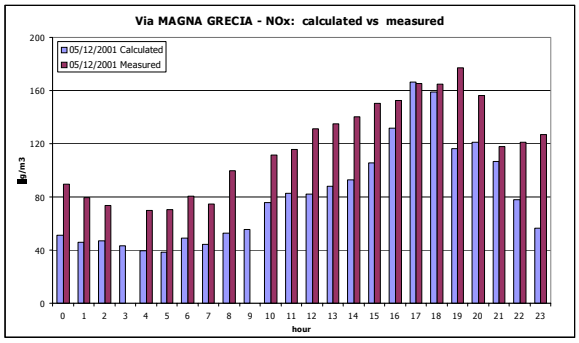


Fig. A.23. Via Magna Grecia: NO_x day-by-day comparison calculated – measured

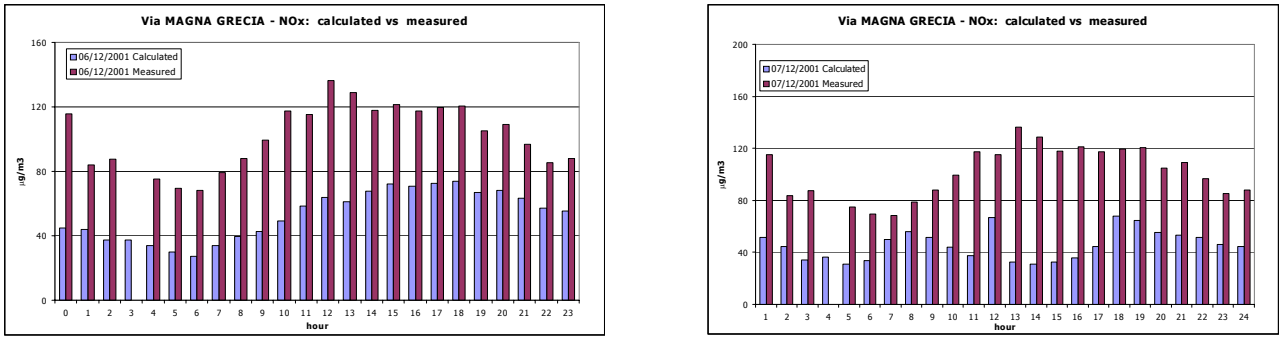


Fig. A.24. Via Magna Grecia: NO_x day-by-day comparison calculated – measured

The comparison of <u>average</u> calculated and measured NO_x concentrations, computed over the verification period, is shown in the following picture. The results obtained are coherent with the ones obtained form the day-by-day analysis: NO_x concentrations are generally under estimated by the HEAVEN system.

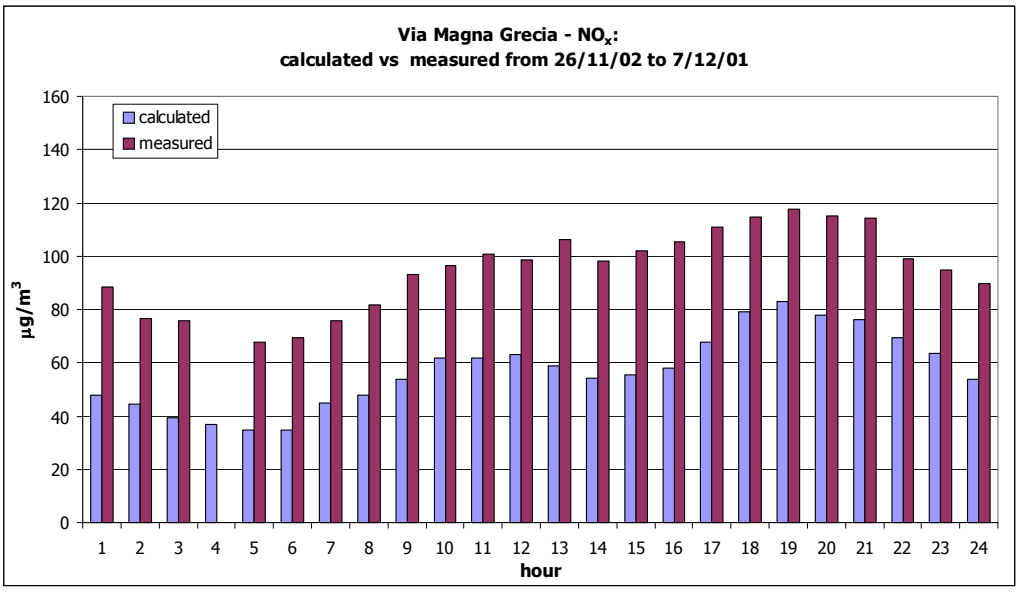


Fig. A.25. Via Magna Grecia: average NO_x concentrations: comparison calculated – measured

In the following scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.879 and 0.56. These values show

that there is a good correlation between average measured and calculated NO_x concentrations while the correlation decrease analysing the cumulative concentrations values.

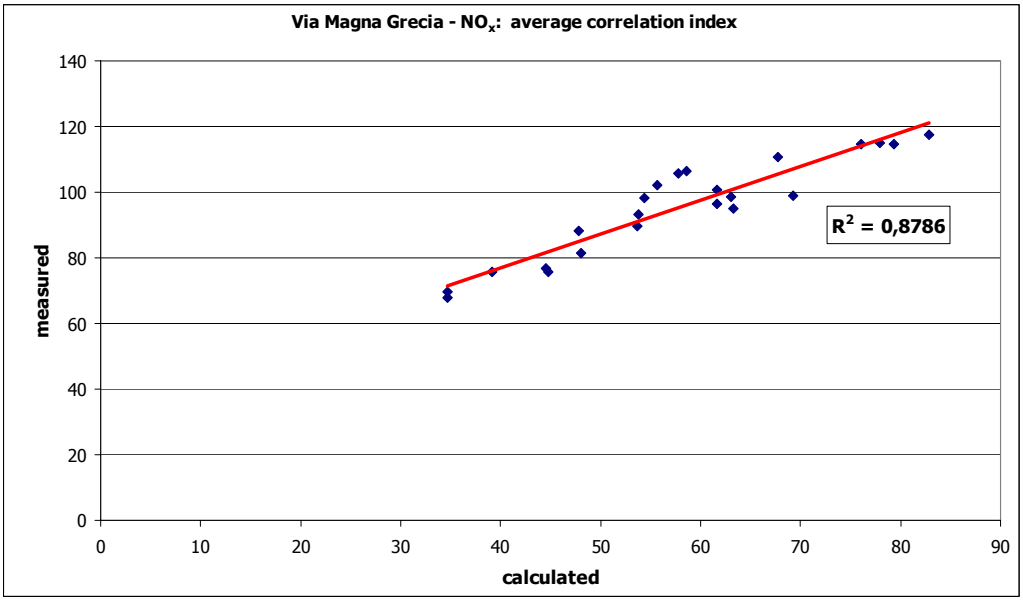


Fig. A.26. Via Magna Grecia: average NO_x correlation index

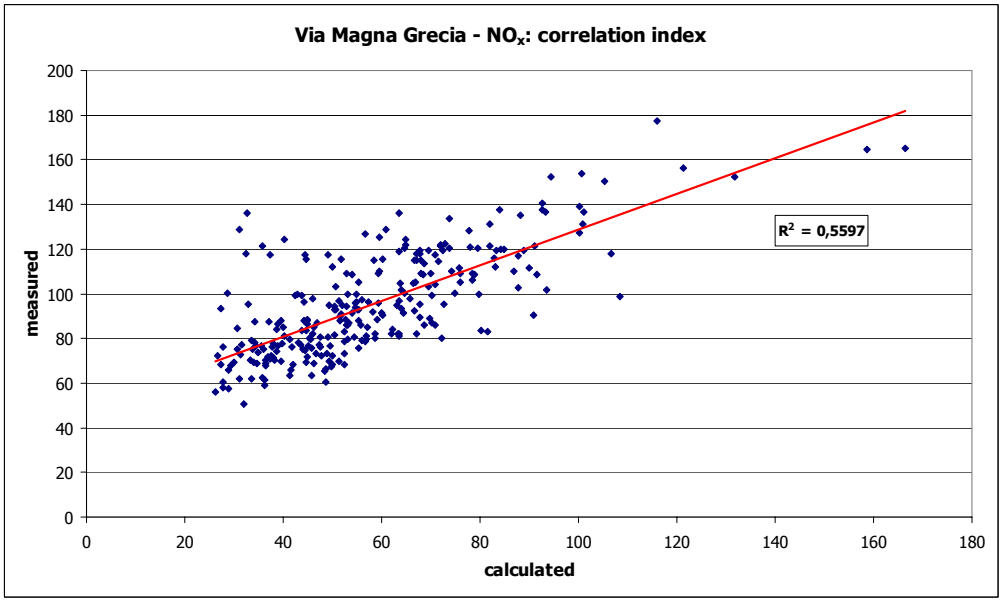


Fig. A.27. Via Magna Grecia: NO_x correlation index

2.4 PM_{10} analysis

In this section results obtained from PM_{10} analysis are reported.

Calculated and measured concentrations' daily trends are reported; those figures show the difficulty of having a correct description of PM_{10} trends related to the difficulty of having adequate emission factors for motorcycles (due of a lackness of the EU regulation) that represent an high percentage of the vehicular fleet.

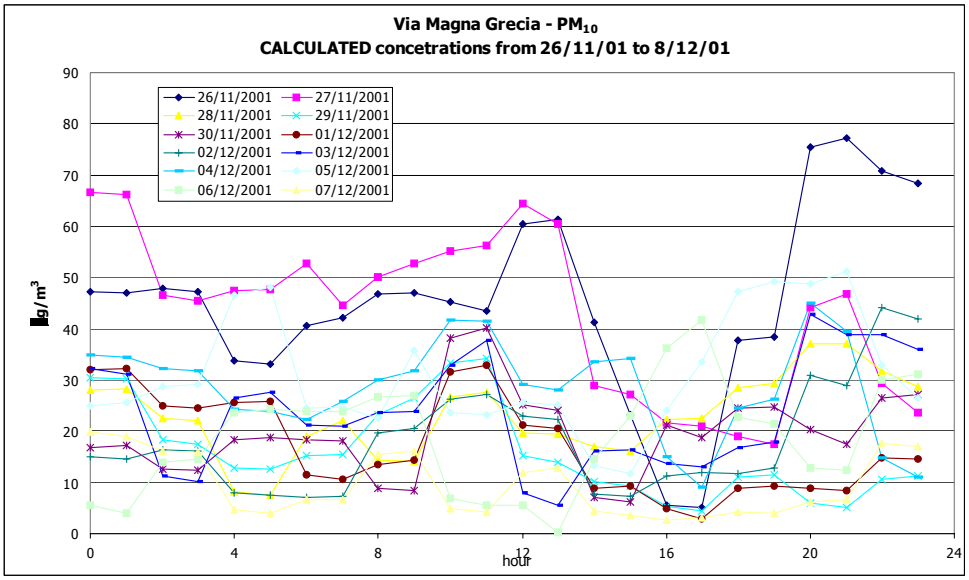


Fig. A.28. Via Magna Grecia: calculated PM_{10} daily trends

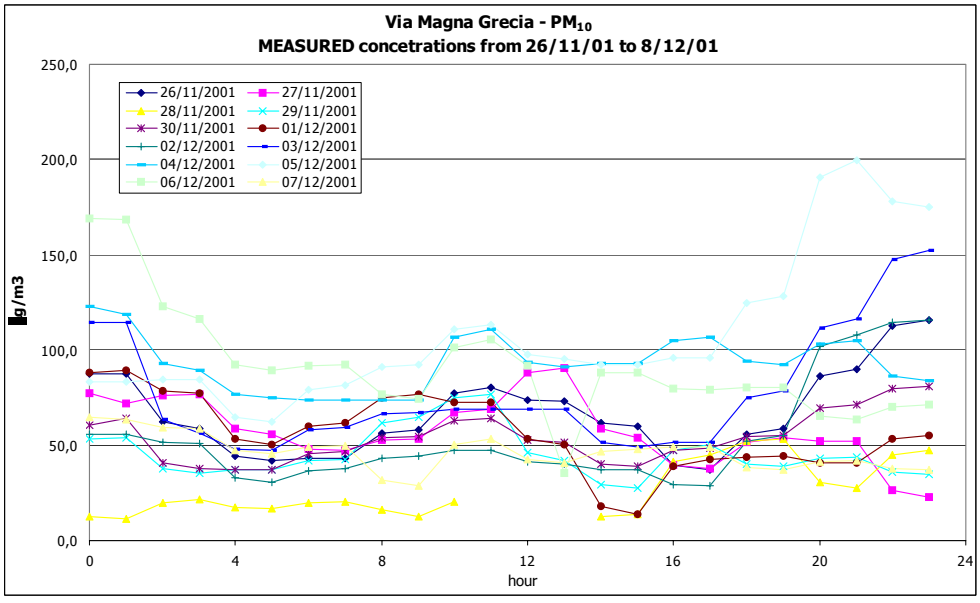


Fig. A.29. Via Magna Grecia: measured PM_{10} daily trends

A detailed analysis of measured versus calculated concentrations is shown; the comparison is carried out on a day-by-day basis for the whole verification period.

Due to an incorrect detection of PM_{10} concentration measured data are not reported for the period of time lasting from 11 am to 1 pm of November the 28th.

These diagrams show a general under estimation of PM_{10} concentrations computed by the HEAVEN system over the different hours of the day.

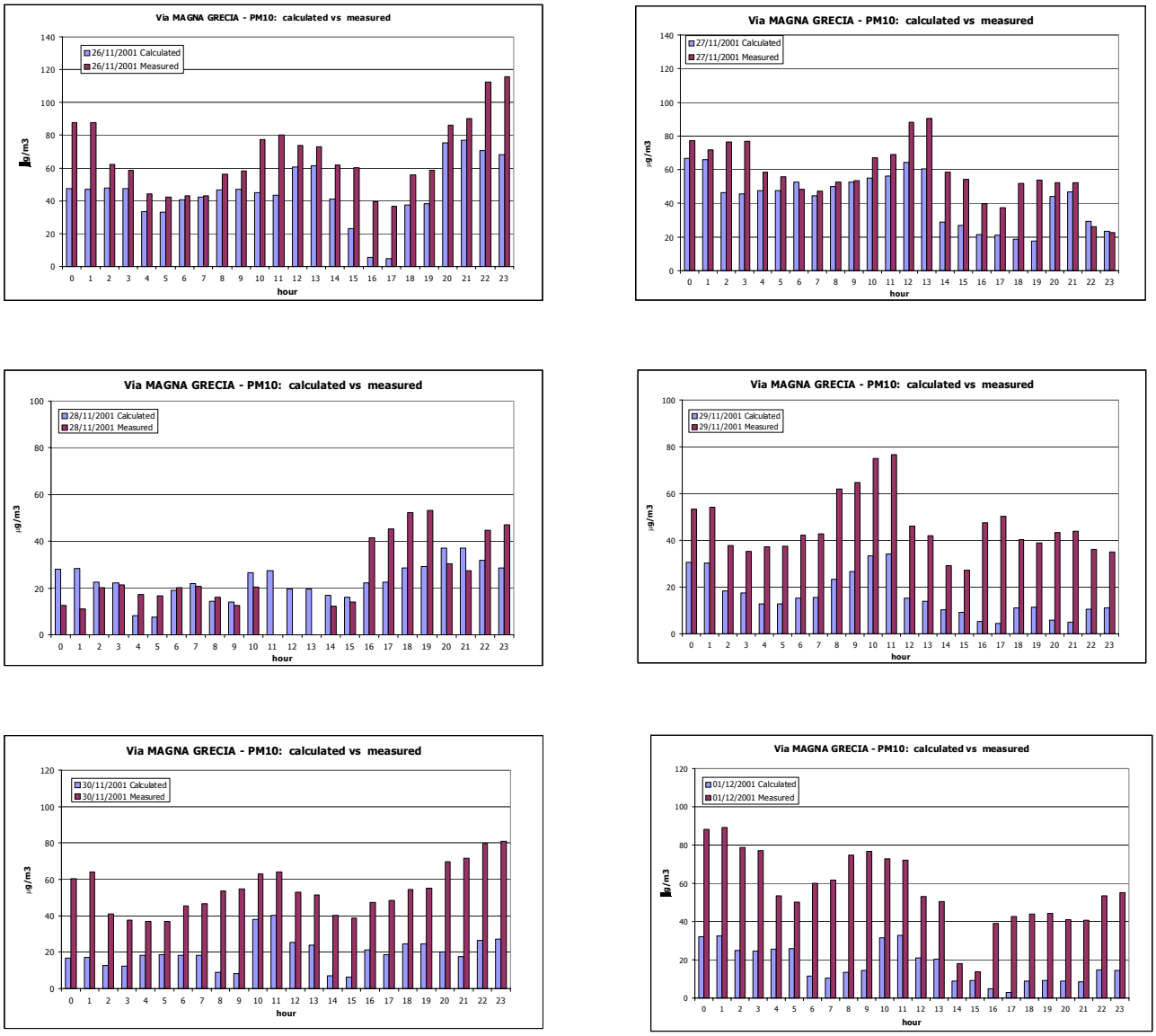


Fig. A.30. Via Magna Grecia: average PM_{10} concentrations: comparison calculated – measured

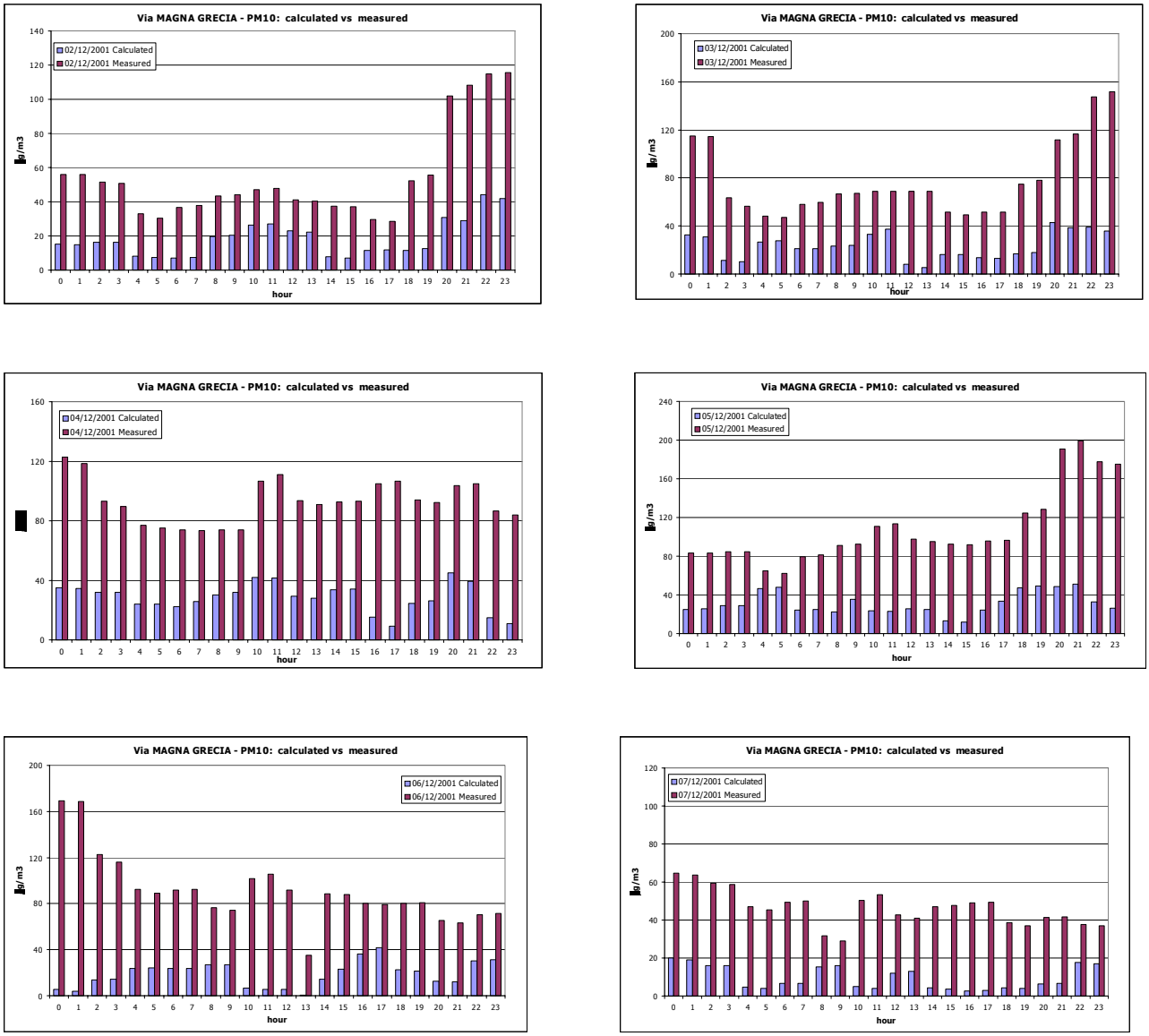


Fig. A.31. Via Magna Grecia: average PM_{10} concentrations: comparison calculated – measured

The comparison of <u>average</u> calculated and measured PM_{10} concentrations, computed over the verification period, is shown in the following picture. The results obtained show that the HEAVEN system under estimated PM_{10} concentrations.

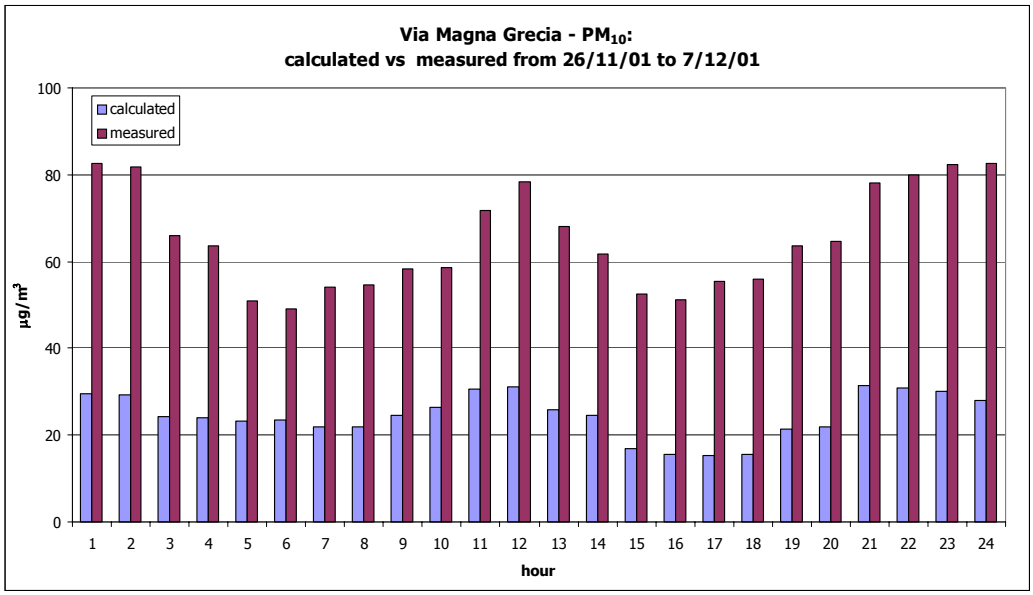


Fig. A.32. Via Magna Grecia: average PM_{10} concentrations: comparison calculated – measured

In the following scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.66 and 0.15. These values show that there is a good correlation between average measured and calculated NO_x concentrations while the correlation decrease analysing the cumulative concentrations values.

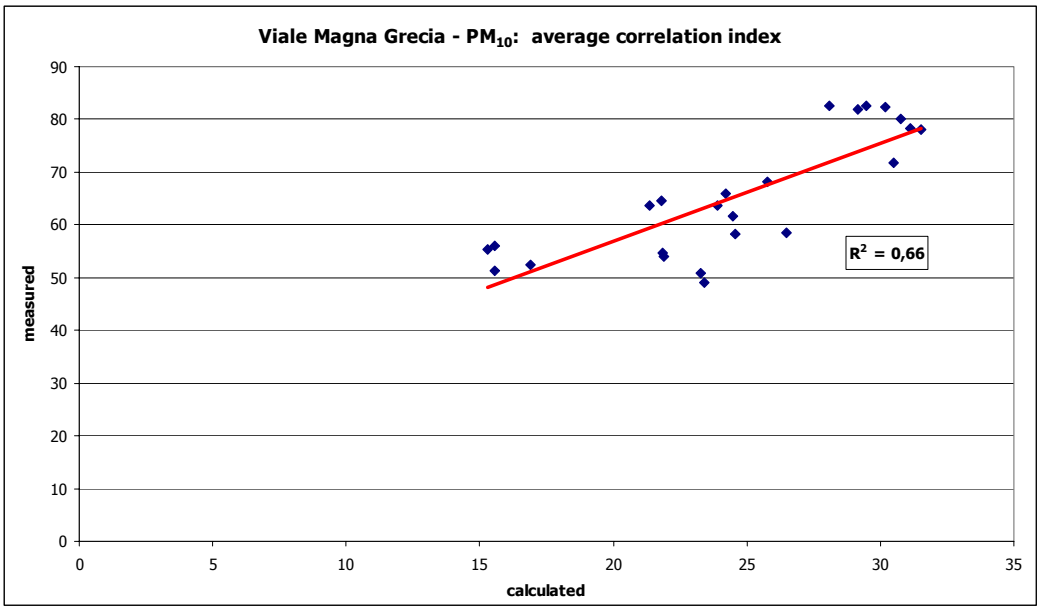


Fig. A.33. Via Magna Grecia: average PM_{10} correlation index

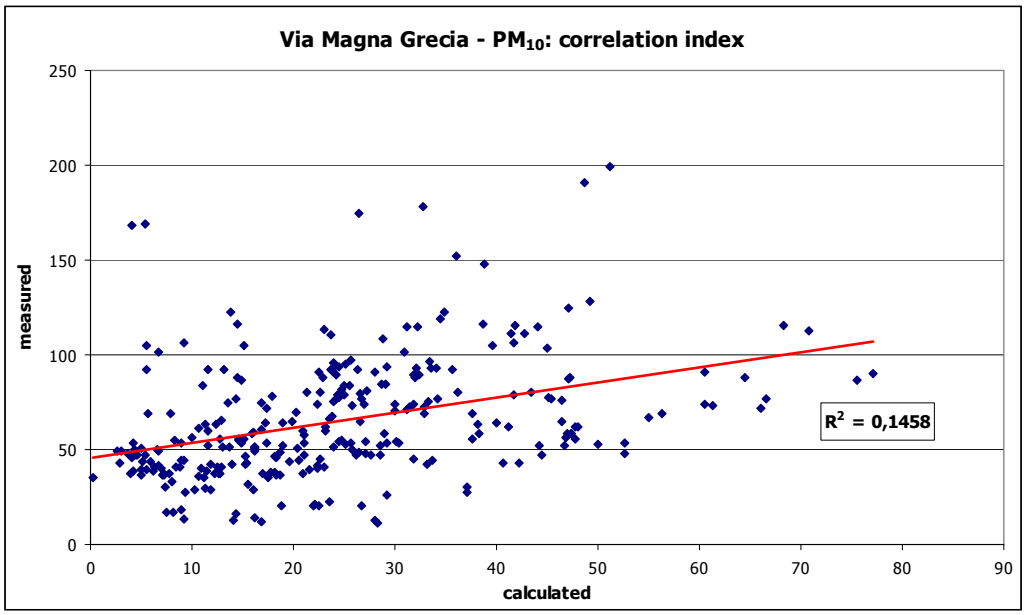


Fig. A.34. Via Magna Grecia: PM_{10} correlation index

3. EVALUATION PHASE: DETAILED RESULTS.

3.1 Evaluation in Viale Libia

3.1.1 Viale Libia: CO analysis

In this section results obtained from CO analysis are reported.

In the following pictures calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown in the next picture where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show both a good fitting, over the different hours of the day and over the different days, between computed and measured concentrations but an under estimation of concentration computed by the HEAVEN system at peak hours is highlighted.

Such results are mainly related to Viale Libia traffic flow composition where two wheels represent a high ratio of the total vehicular fleet. More in details, the under estimation of CO concentration is due to the following factors:

- An under estimation of two wheels on the link, that gets higher at peak hours, due to the not feasibility of detecting this vehicular class with traffic detectors. Consequentially, the correction algorithm, that performs the O/D matrixes update with traffic counts, is not able to consider the real percentage of two wheels on the link. For this reason, the O/D matrixes use the standard ratio of two wheels defined to describe the average Rome's fleet composition.
- The un-possibility of having the real split between catalyzed and not catalyzed two wheels. At present, standard prediction selling trends are used to estimate the current percentage of catalyzed vehicles but this kind of models do not guarantee an 100% correspondence with real situation.

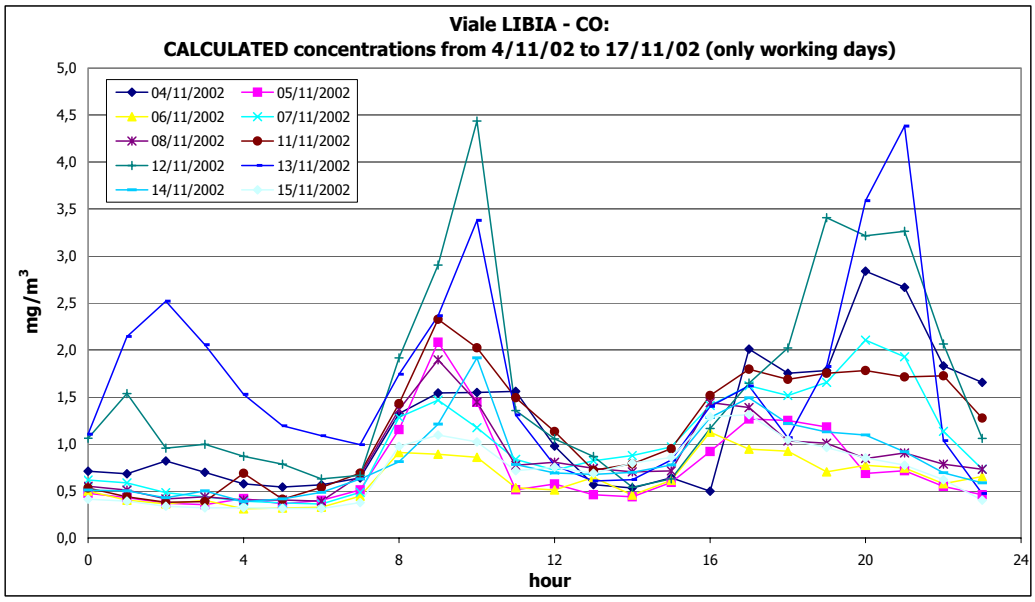


Fig. A.35. Viale Libia: calculated CO daily trends

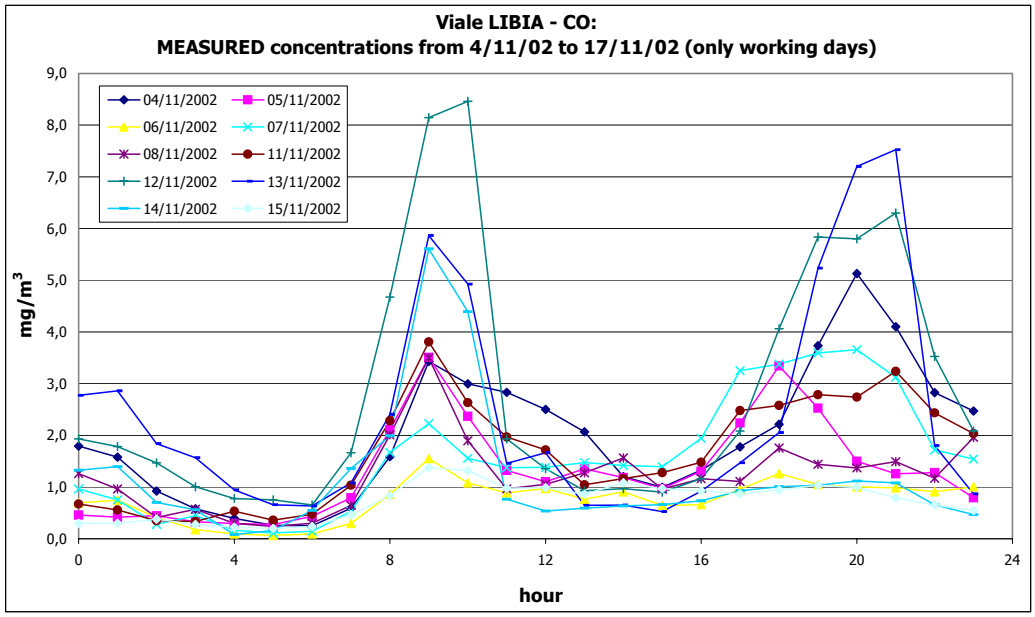


Fig. A.36. Viale Libia: measured CO daily trends

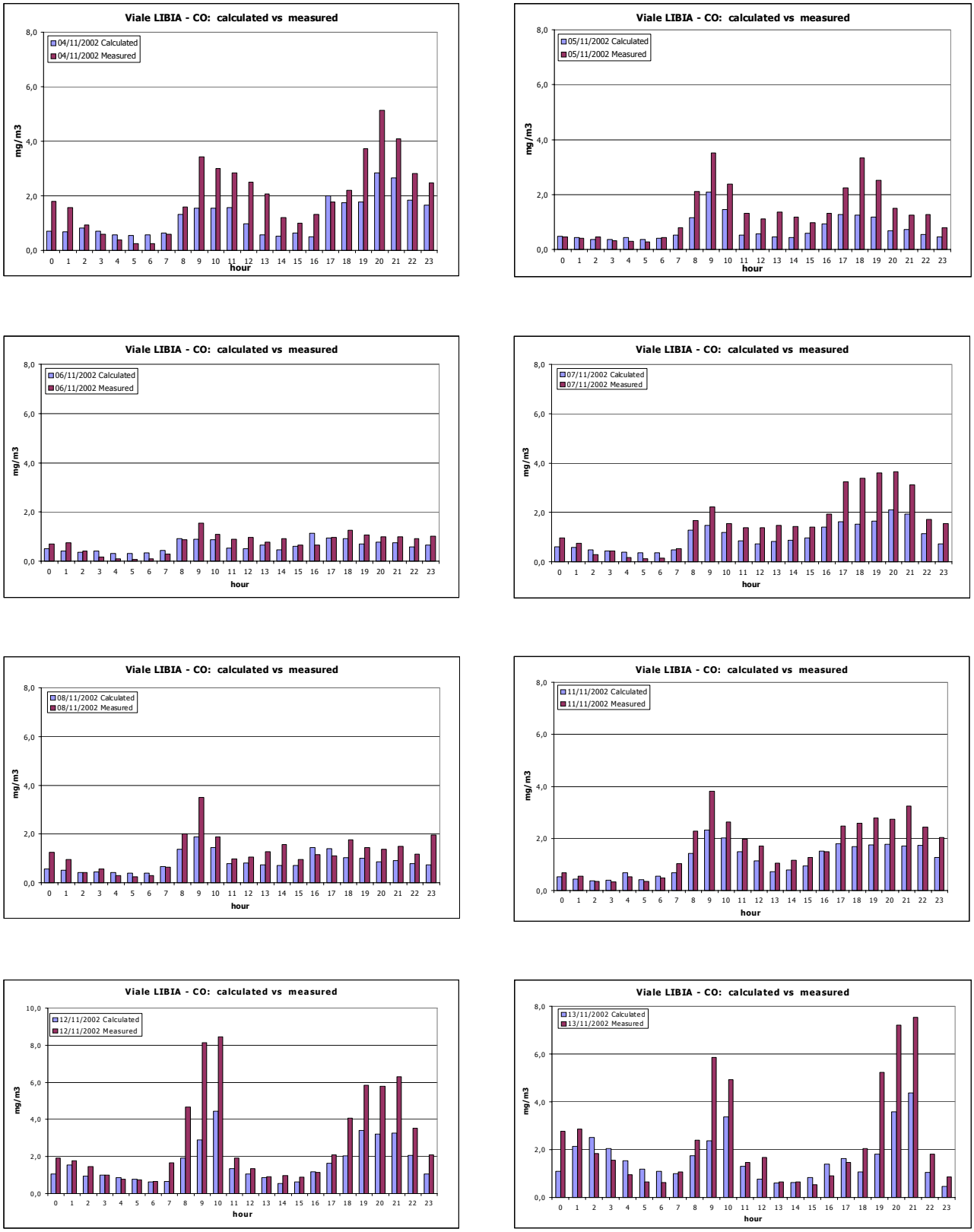


Fig. A.37. Viale Libia: CO day-by-day comparison calculated – measured

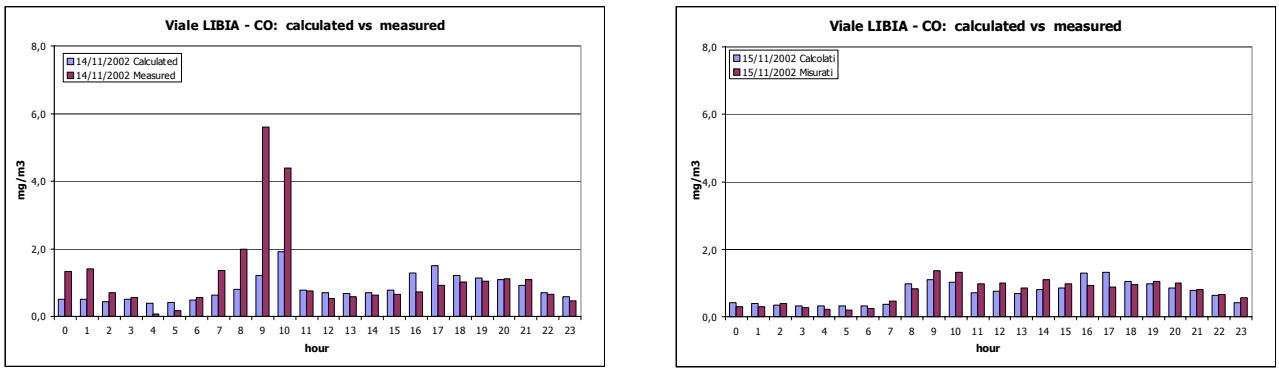


Fig. A.38. Viale Libia: CO day-by-day comparison calculated – measured

The comparison of average calculated and measured CO concentrations, computed over the two weeks evaluation period, is shown in the following pictures. The results obtained are coherent with the ones obtained form the day-by-day analysis: the HEAVEN system under estimated CO concentrations at peak hours.

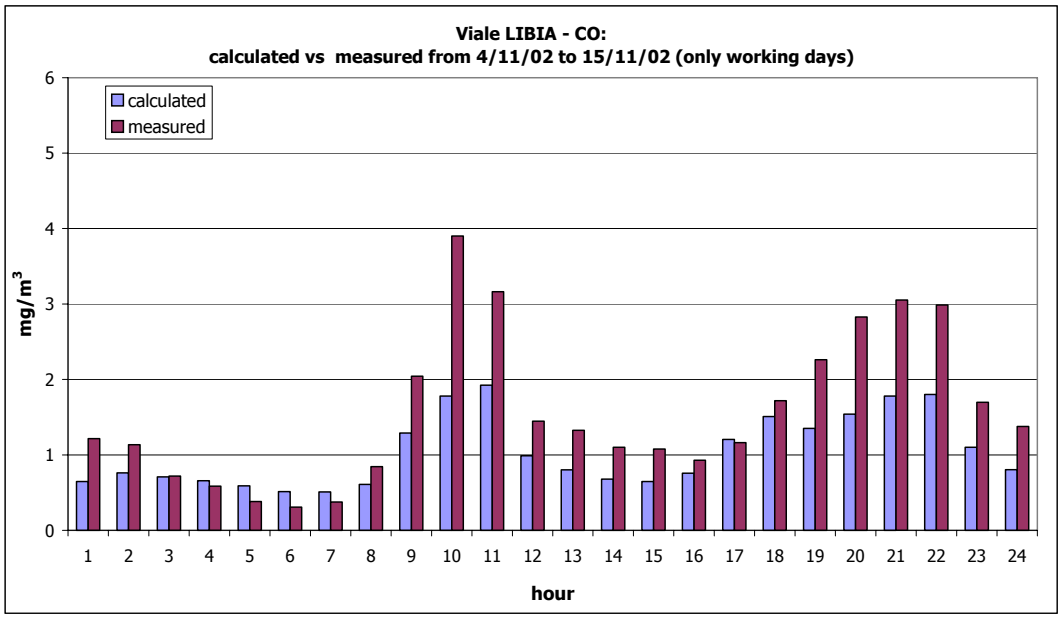


Fig. A.39. Viale Libia: average CO concentrations: comparison calculated – measured

In the following scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.878 and 0.791. These values show that there is a good correlation between measured and calculated CO concentrations.

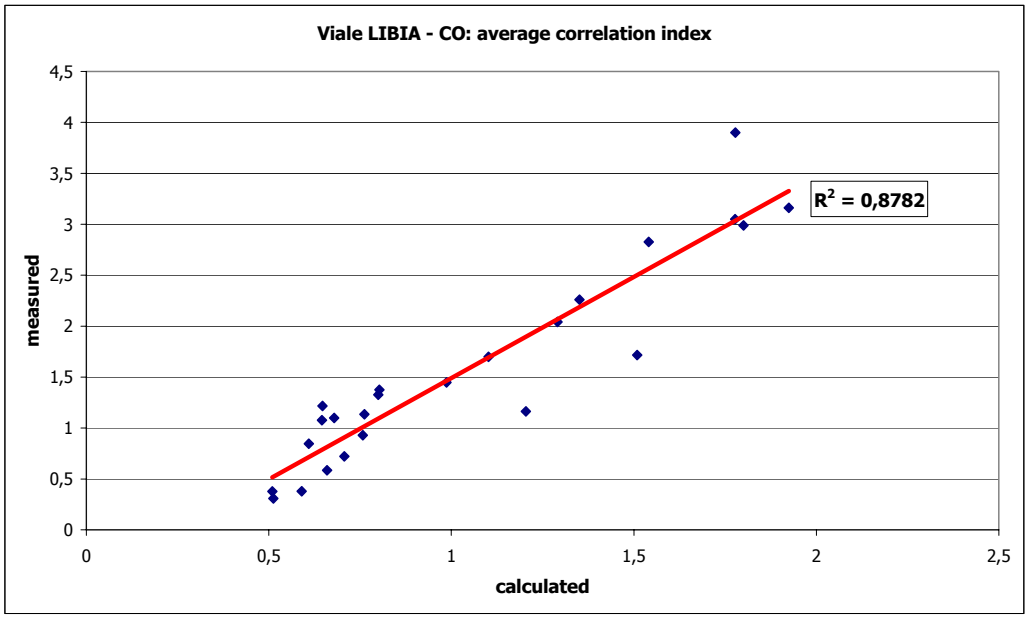


Fig. A.40. Viale Libia: average CO correlation index

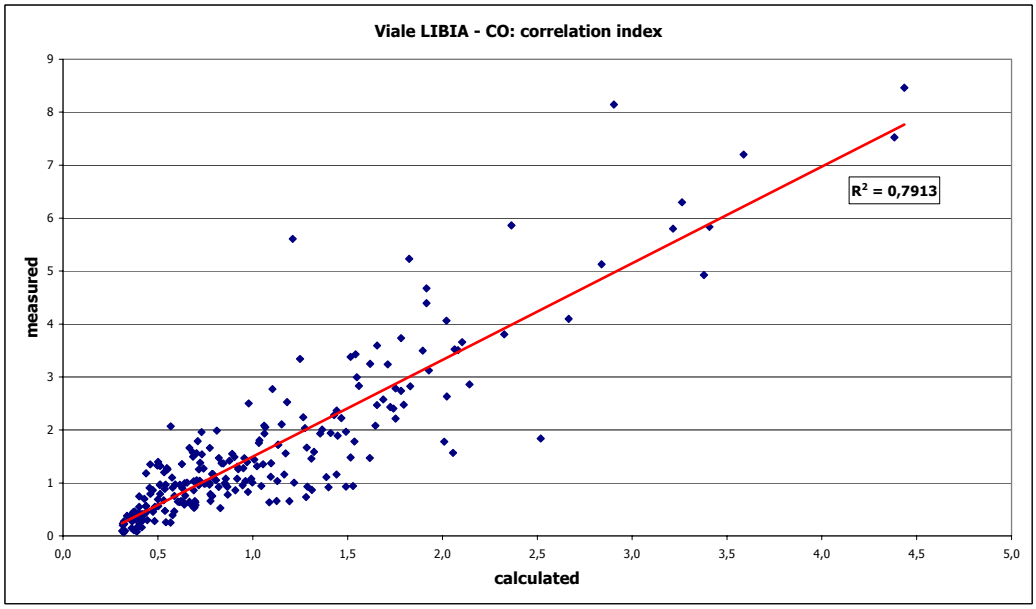


Fig. A.41. Viale Libia: CO correlation index

3.1.2 Viale Libia: C_6H_6 analysis

In this section results obtained from C_6H_6 analysis are reported.

Calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show a general under estimation of benzene concentrations computed by the HEAVEN system over the different hours of the day; this trend is more evident at peak hours.

Such results are mainly related to Viale Libia traffic flow composition where two wheels represent a high ratio of the total vehicular fleet. More in details, the under estimation of C_6H_6 concentration is due to the following factors:

- An under estimation of two wheels on the link, that gets higher at peak hours, due to the not feasibility of detecting this vehicular class with traffic detectors. Consequentially, the correction algorithm, that performs the O/D matrixes update with traffic counts, is not able to consider the real percentage of two wheels on the link. For this reason, the O/D matrixes use the standard ratio of two wheels defined to describe the average Rome's fleet composition.
- Difficulty of having "real" two wheels benzene emissions factors especially for not catalyzed vehicles.
- The un-possibility of having the real split between catalyzed and not catalyzed two wheels. At present, standard prediction selling trends are used to estimate the current percentage of catalyzed vehicles but this kind of models do not guarantee an 100% correspondence with real situation.

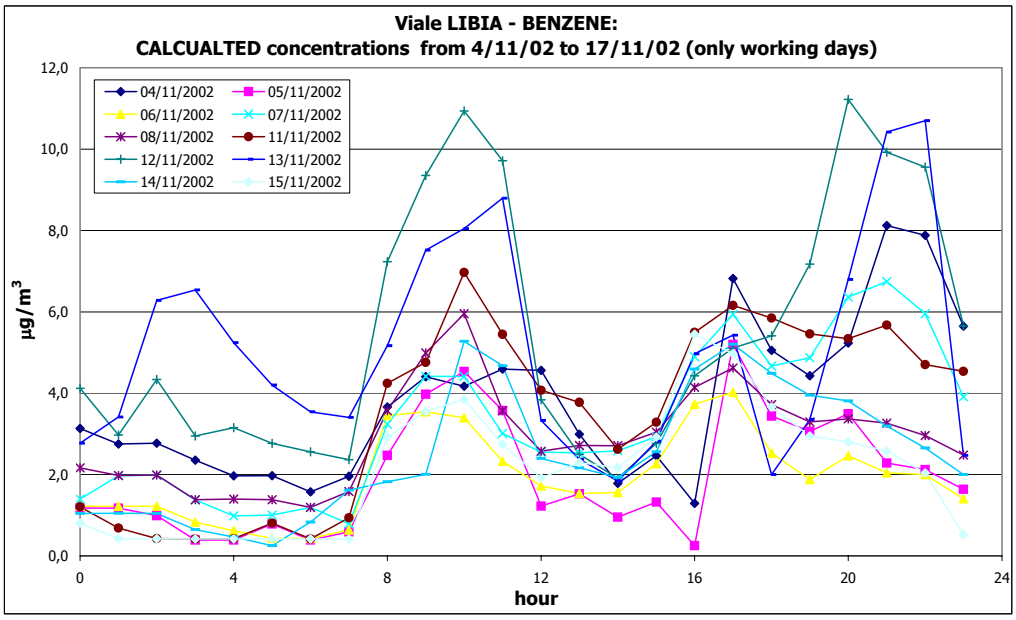


Fig. A.42. Viale Libia: calculated C_6H_6 daily trends

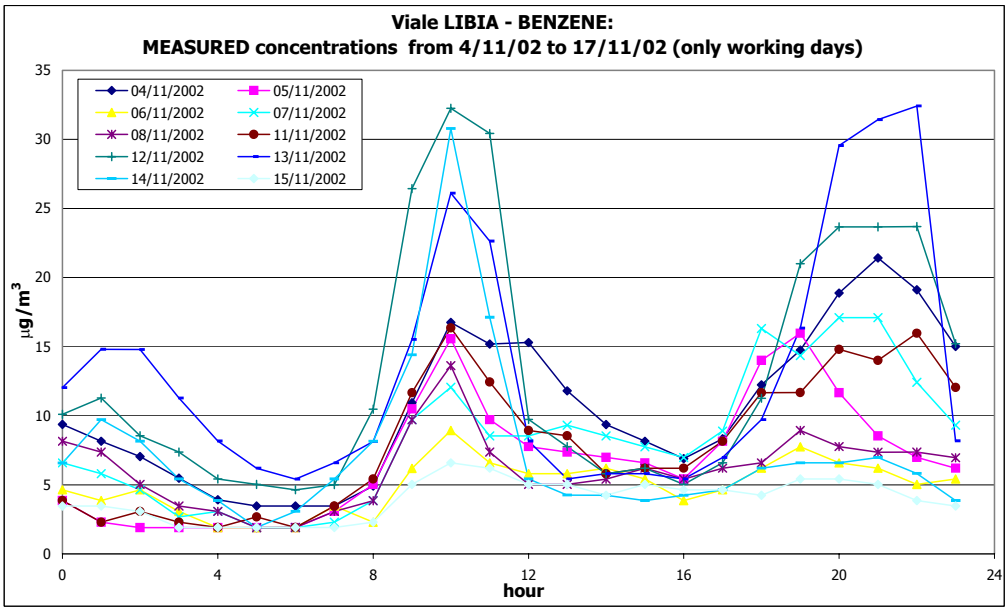
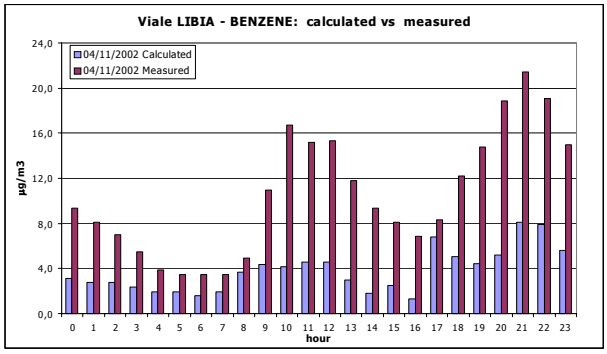
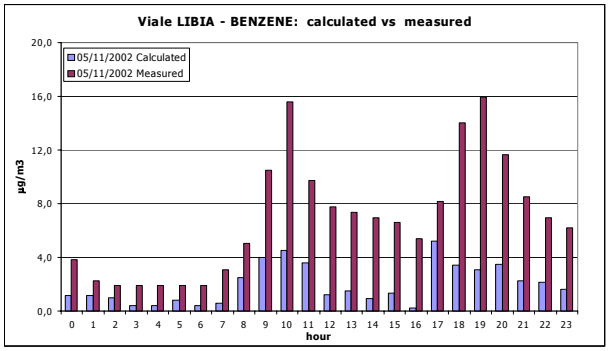
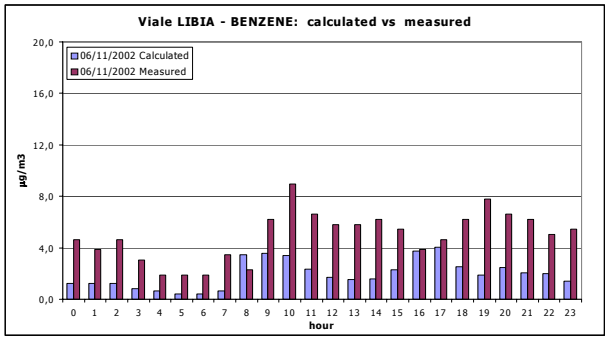
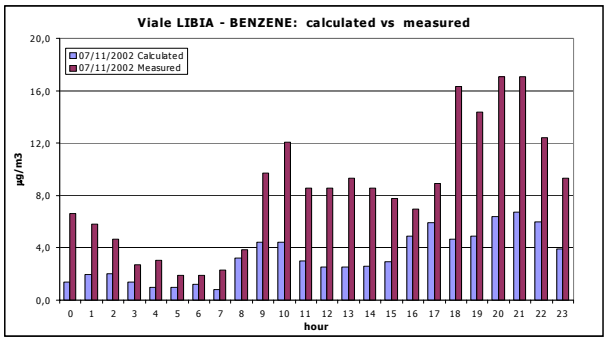


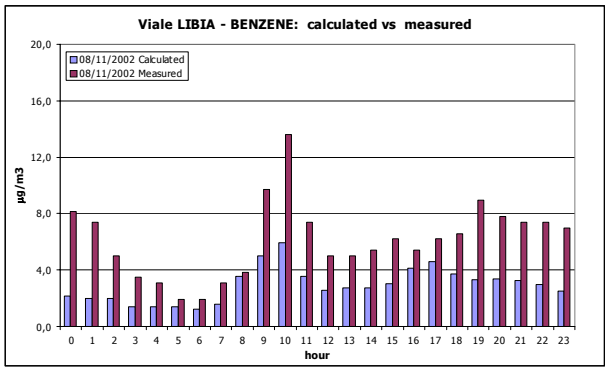
Fig. A.43. Viale Libia: calculated C_6H_6 daily trends

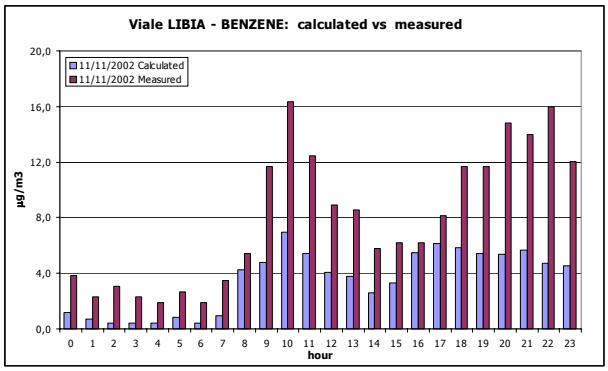


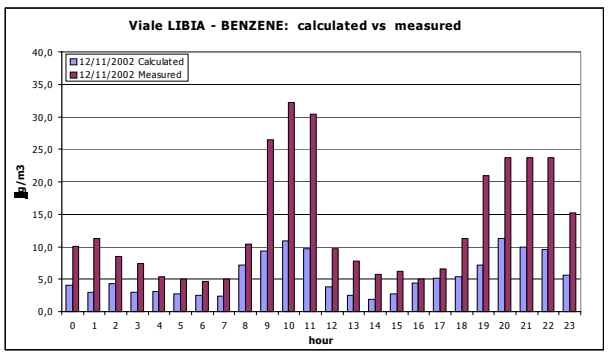












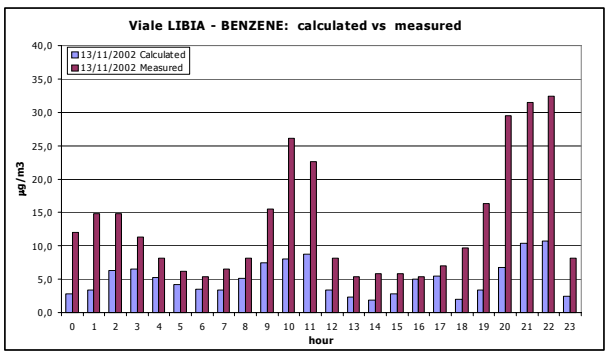


Fig. A.44. Viale Libia: C_6H_6 day-by-day comparison calculated - measured

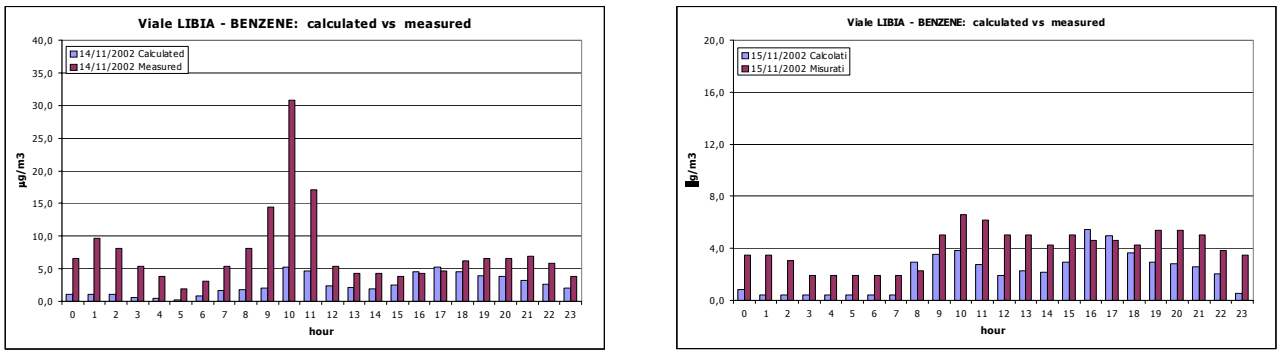


Fig. A.45. Viale Libia: C_6H_6 day-by-day comparison calculated - measured

The comparison of average calculated and measured C_6H_6 concentrations, computed over the two weeks evaluation period, is shown in the following picture. The results obtained are coherent with the ones obtained form the day-by-day analysis: the HEAVEN system under estimated C_6H_6 concentrations and this trend is more evident at peak hours where the difference between calculated and measured is higher.

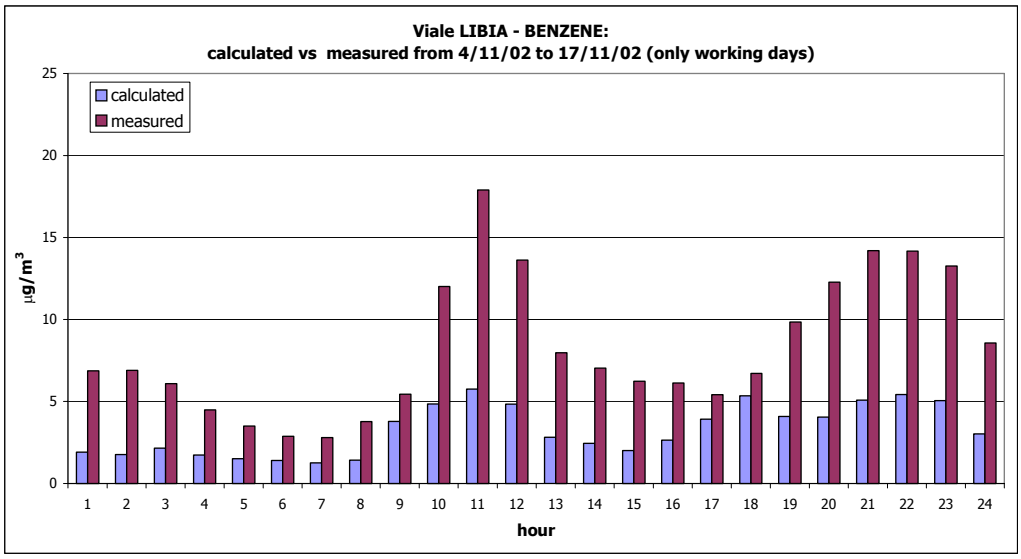


Fig. A.46. Viale Libia: average C_6H_6 comparison calculated - measured

In the following scartergrams are reported both for average concentration and and for cumulative concentration values; R^2 values obtained are respectively 0.711 and 0.634. These

values show that there is a good correlation between measured and calculated benzene concentrations.

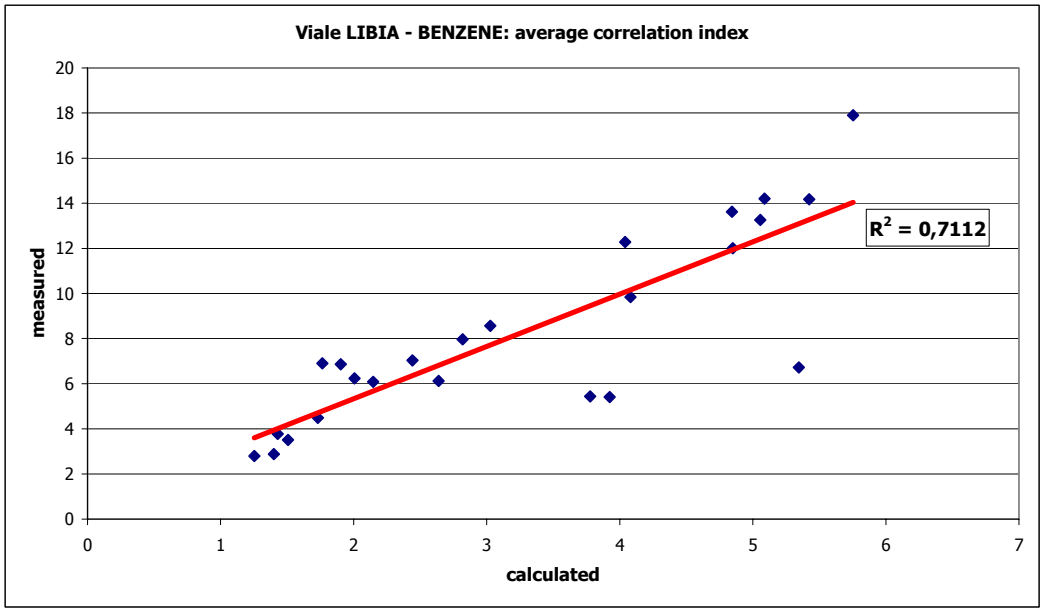


Fig. A.47. Viale Libia: average C_6H_6 correlation index

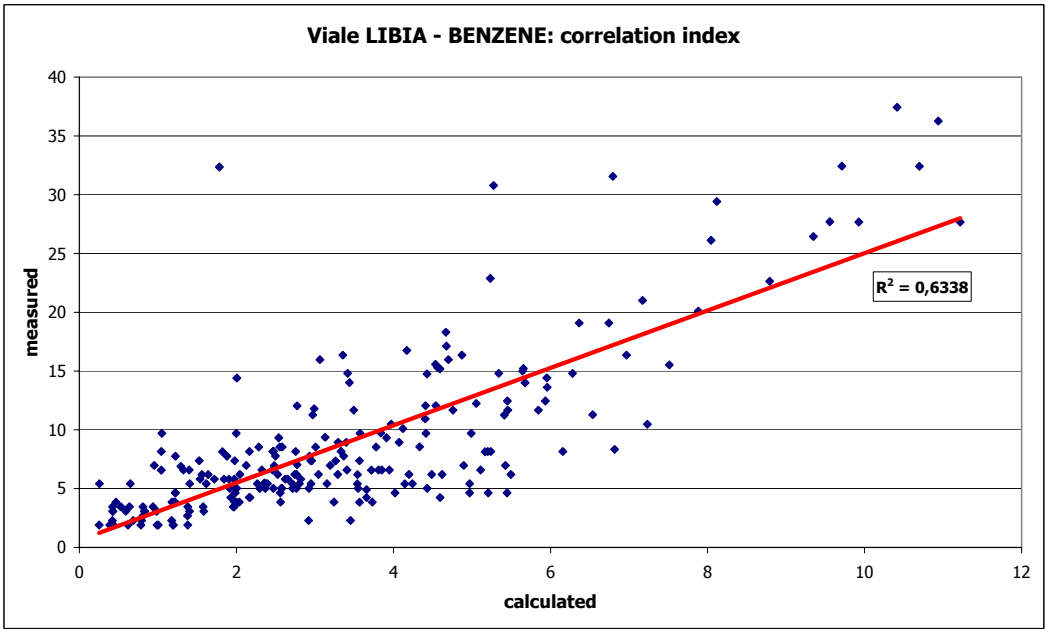


Fig. A.48. Viale Libia: C_6H_6 correlation index

3.1.3 Viale Libia: NO_x analysis

In this section results obtained from NO_x analysis are reported.

In the following pictures calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown in the next picture where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show a general under estimation of NO_x concentrations computed by the HEAVEN system over the different hours of the day; this trend is more evident at peak hours.

Such results are mainly related to Viale Libia traffic flow composition where two wheels represent a high ratio of the total vehicular fleet. More in details, the under estimation of CO concentration is due to the following factors:

- The system calculates NO_2 concentrations while measurement stations detect NOx concentrations; it has been assumed that the percentage of NO_2 becoming NO_x in the short term is equal to the 7%. This assumption is probably too restrictive.
- An under estimation of two wheels on the link, that gets higher at peak hours, due to the not feasibility of detecting this vehicular class with traffic detectors. Consequentially, the correction algorithm, that performs the O/D matrixes update with traffic counts, is not able to consider the real percentage of two wheels on the link. For this reason, the O/D matrixes use the standard ratio of two wheels defined to describe the average Rome's fleet composition.
- The un-possibility of having the real split between catalyzed and not catalyzed two wheels. At present, standard prediction selling trends are used to estimate the current percentage of catalyzed vehicles but this kind of models do not guarantee an 100% correspondence with real situation.

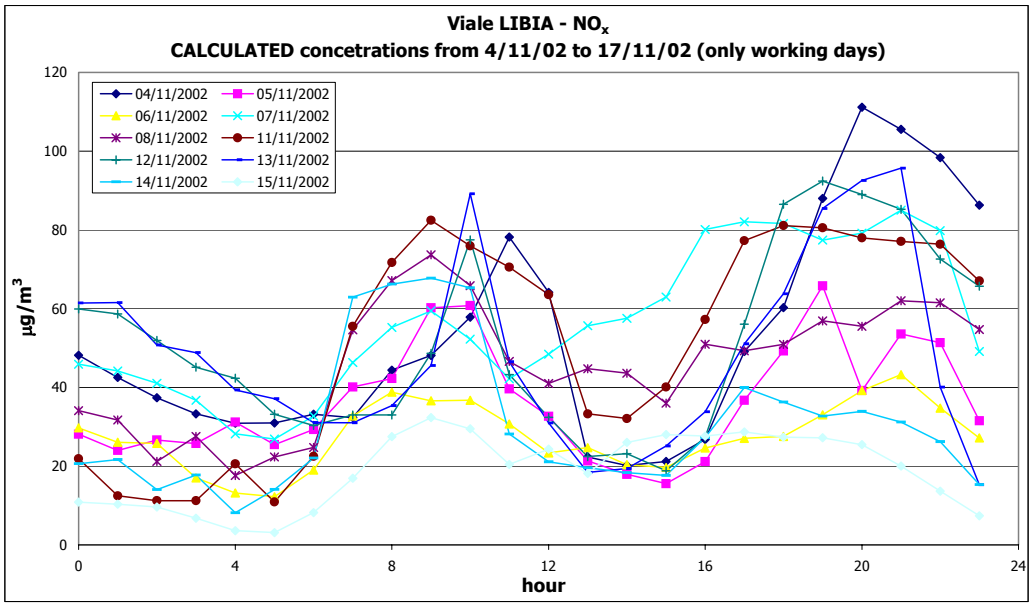


Fig. A.49. Viale Libia: calculated NO_x daily trends

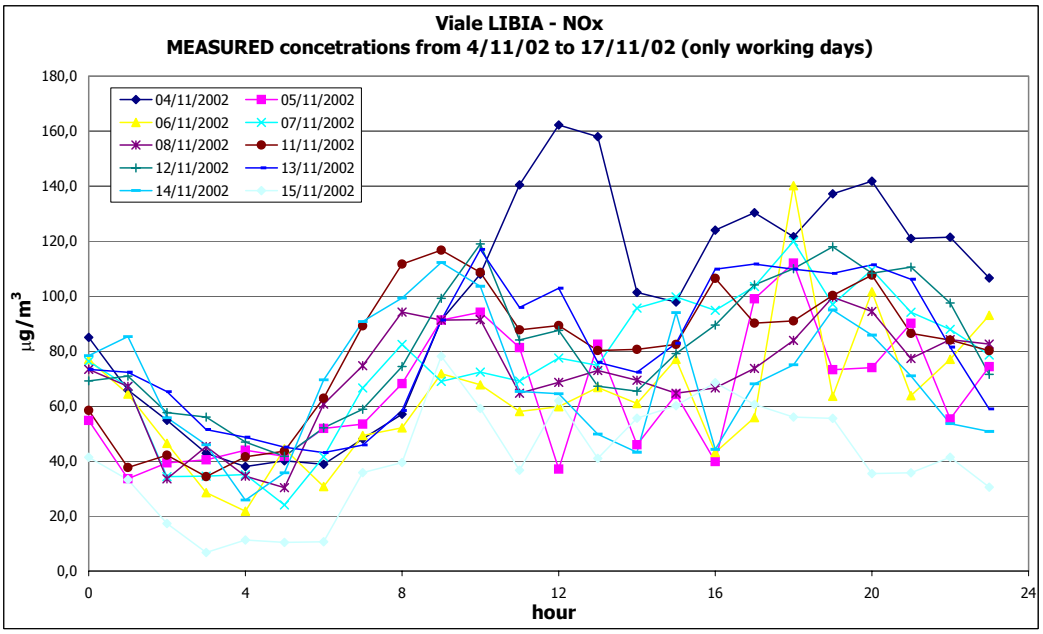
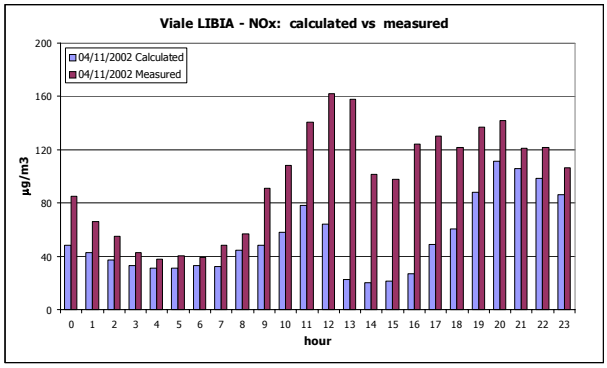
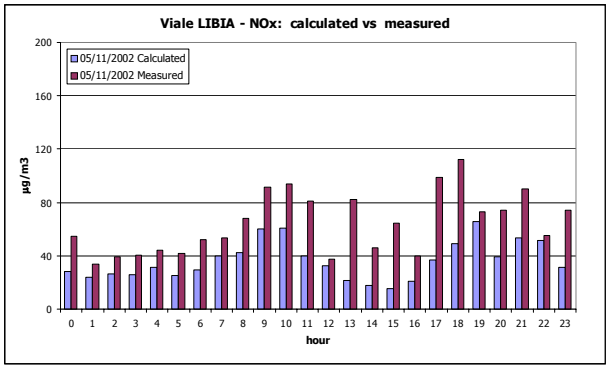
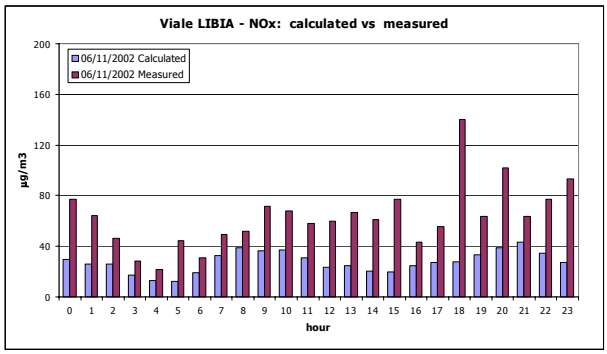
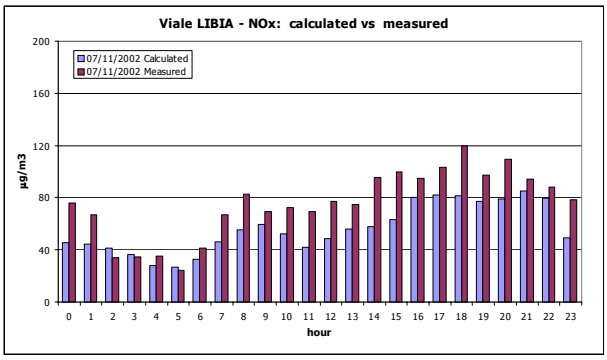


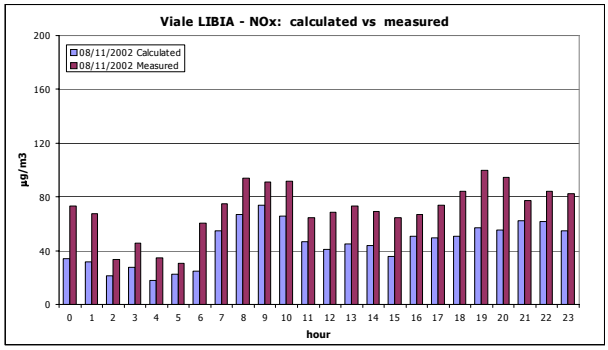
Fig. A.50. Viale Libia: calculated NO_x daily trends

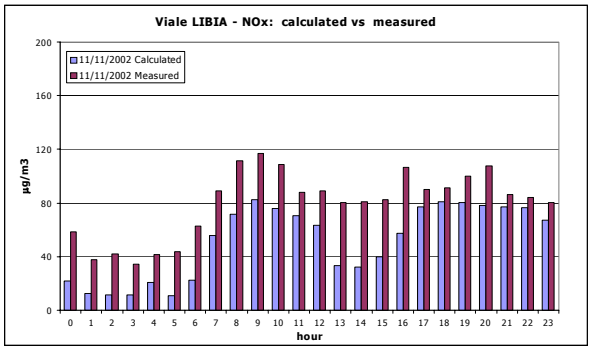


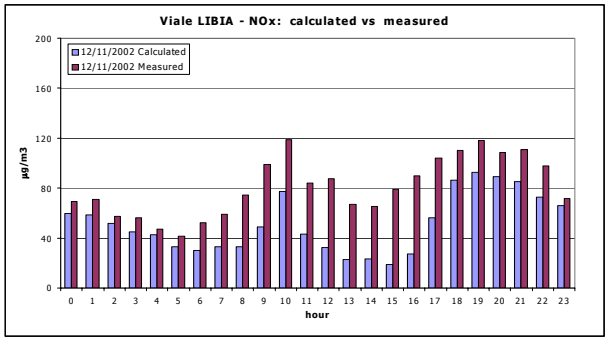












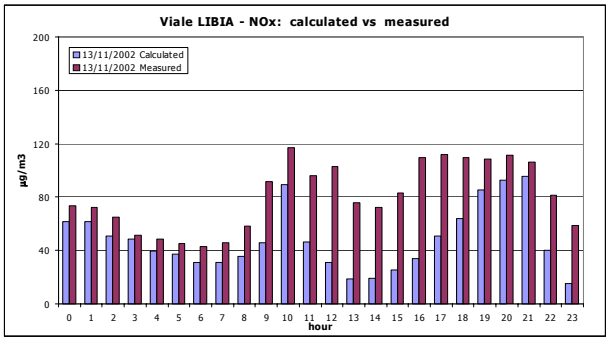


Fig. A.51. Viale Libia: NO_x day-by-day comparison calculated – measured

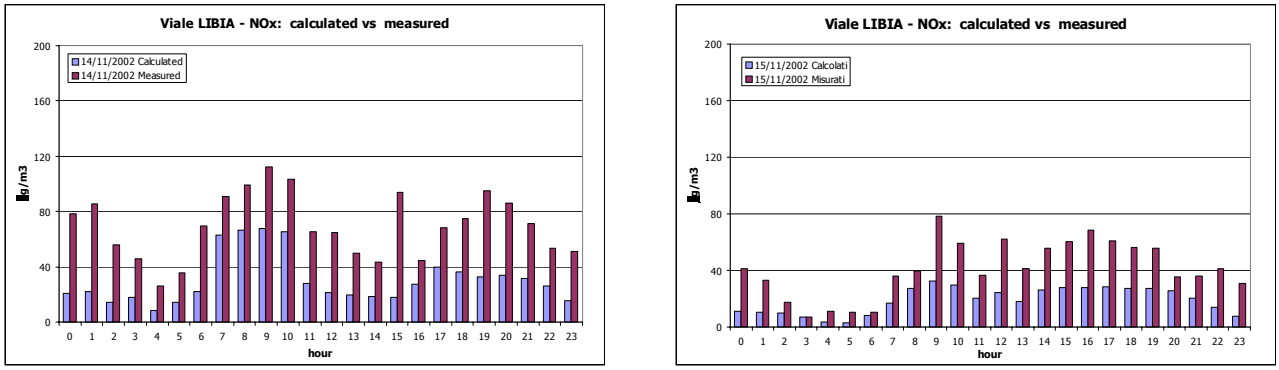


Fig. A.52. Viale Libia: NO_x day-by-day comparison calculated - measured

The comparison of average calculated and measured NO_x concentrations, computed over the two weeks evaluation period, is shown in the following picture. The results obtained are coherent with the ones obtained form the day-by-day analysis: the HEAVEN system generally under estimated NO_x concentrations.

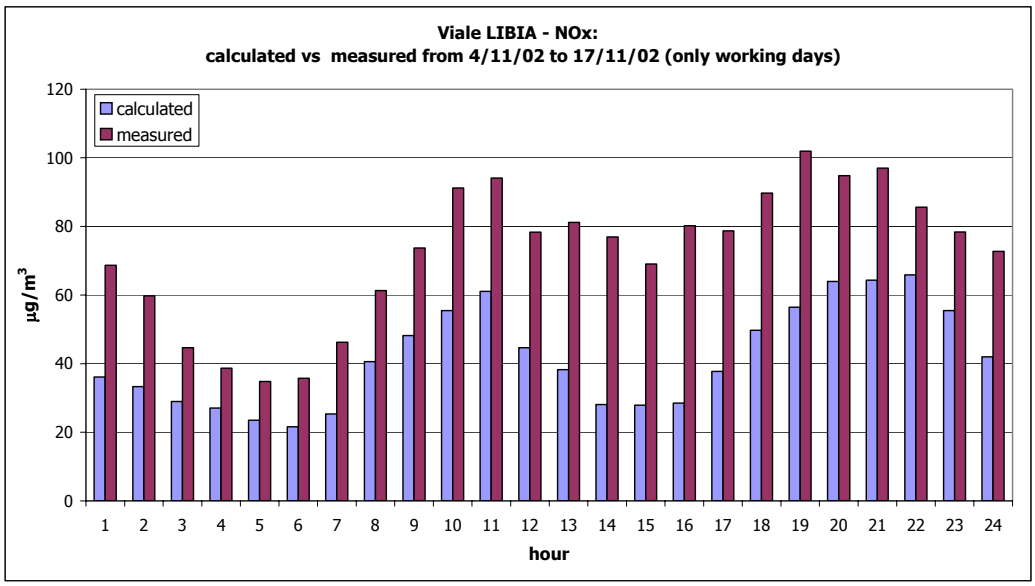


Fig. A.53. Viale Libia: average NO_x comparison calculated - measured

In in the following scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.668 and 0.506. These values show that there is a good correlation between measured and calculated NO_x concentrations.

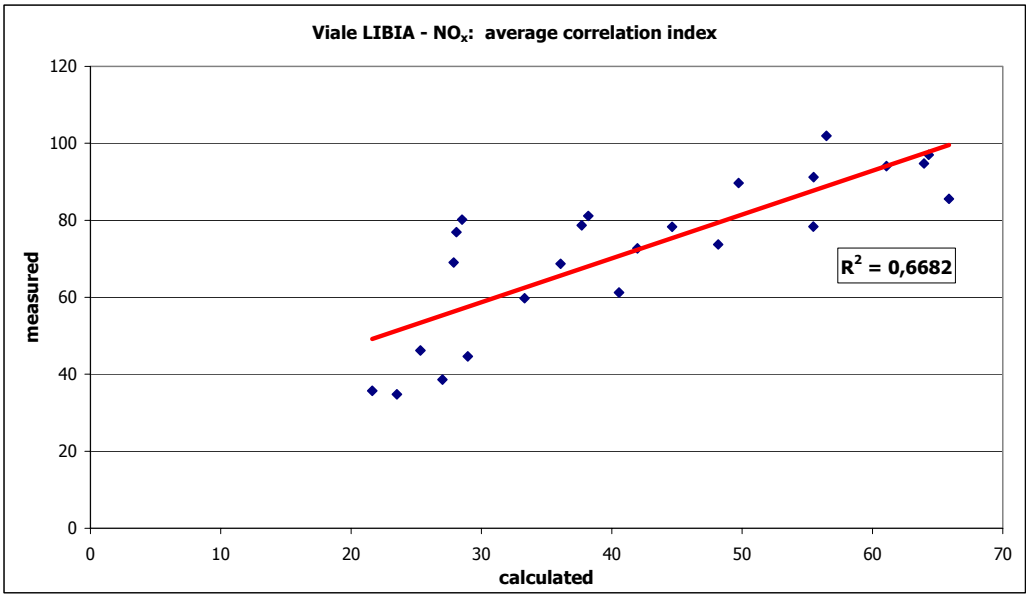


Fig. A.54. Viale Libia: average NO_x correlation index

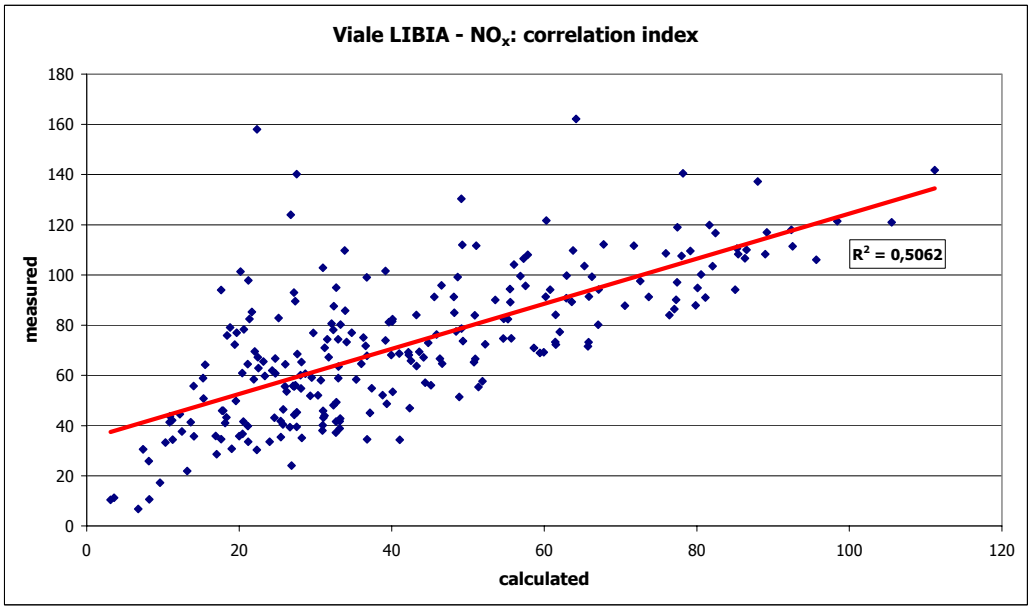


Fig. A.55. Viale Libia: NO_x correlation index

3.1.4 Viale Libia: PM_{10} analysis

In this section results obtained from PM_{10} analysis are reported.

PM_{10} calculated concentrations' daily trends are reported fro the whole evaluation period. In this section are presented only the results obtained from the HEAVEN system and not comparison with measured concentration has been carried out because the measurement station located in Piazza S. Emerenziana does not detect PM_{10} concentrations.

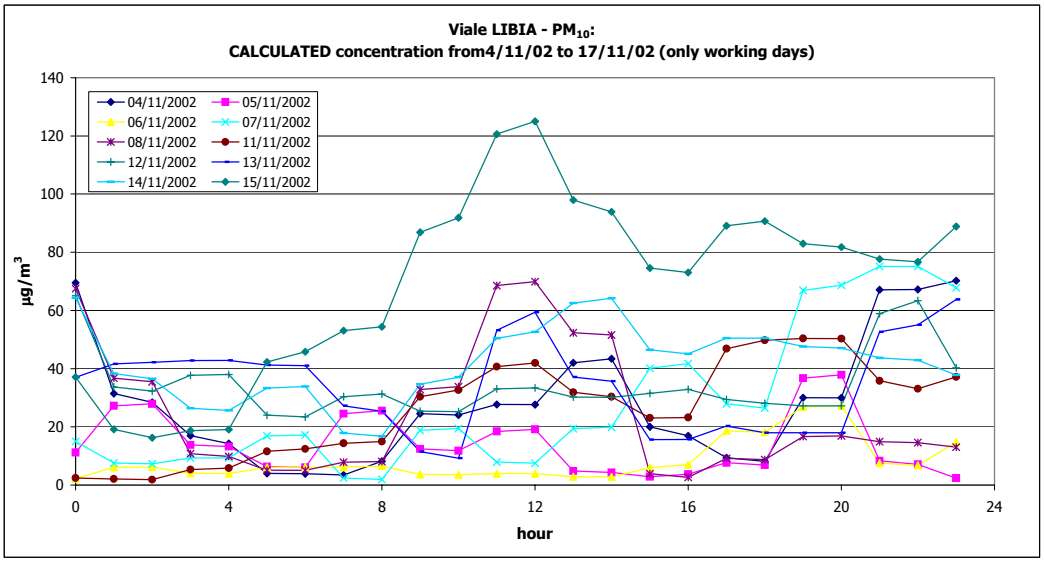


Fig. A.56. Viale Libia: calculated PM_{10} daily trends

In order to evaluate the attendency of calculated PM_{10} concentration trends results obtained from 4 different measurement station located in the Rome's area (Arenula, Fermi, Magna Grecia and Ada) are reported. Measured PM_{10} concentrations trends refer to the average day of the year 2001. These results are part of a wider study on Rome's level of pollution carried out in 2001 by the regional authority ARPA.

Comparing those curves with the one obtained from the system it is possible to evaluate that calculated PM_{10} concentration trends are coherent with the measured PM_{10} trends referring to the average day of year 2001.

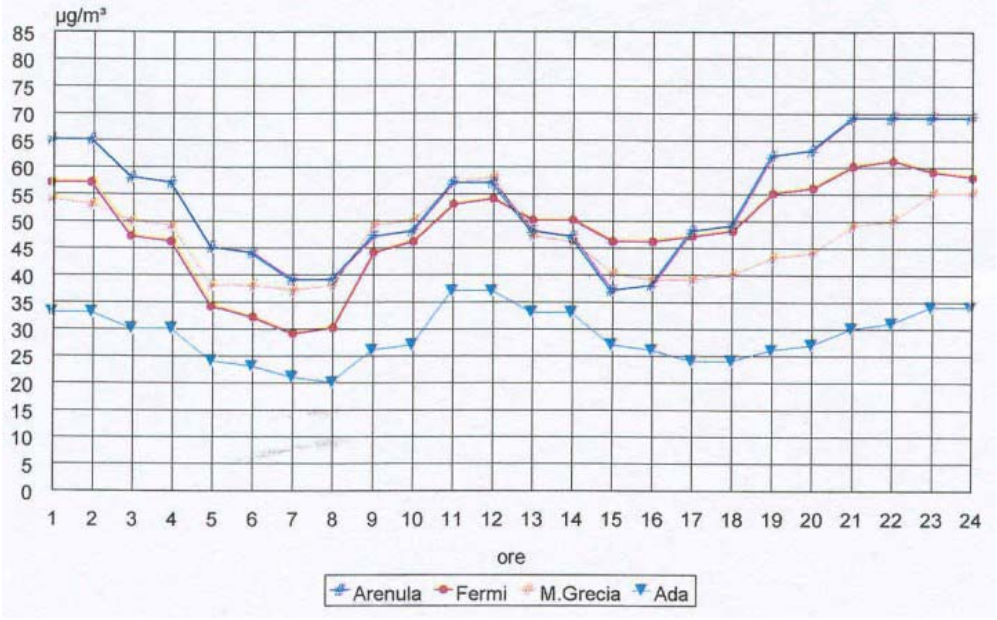


Fig. A.57. PM_{10} average day (2001) - measured trends

3.2 Evaluation in Via salaria

3.2.1 Via Salaria: CO analysis

In this section results obtained from CO analysis are reported.

In Fig. A.58 and Fig. A.59 calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown in Fig. A.60 where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show both a good fitting, over the different hours of the day and over the different days, between computed and measured concentrations. It is not possible to define, within this specific location, a general trend for the concentration computed by HEAVEN system: under or over estimation of CO concentrations are highlighted from the day-by-day comparison.

Such results are mainly related to the difficulty of having a one to one transposition between local conditions of Via Salaria and of Via Tiburtina. The correction factor α has been introduced to have comparable data concentrations and to take into account the different boundary conditions of the locations. However, this factor is not able to perfectly reproduce local fluctuations to which the two locations are subject to and that are generally different.

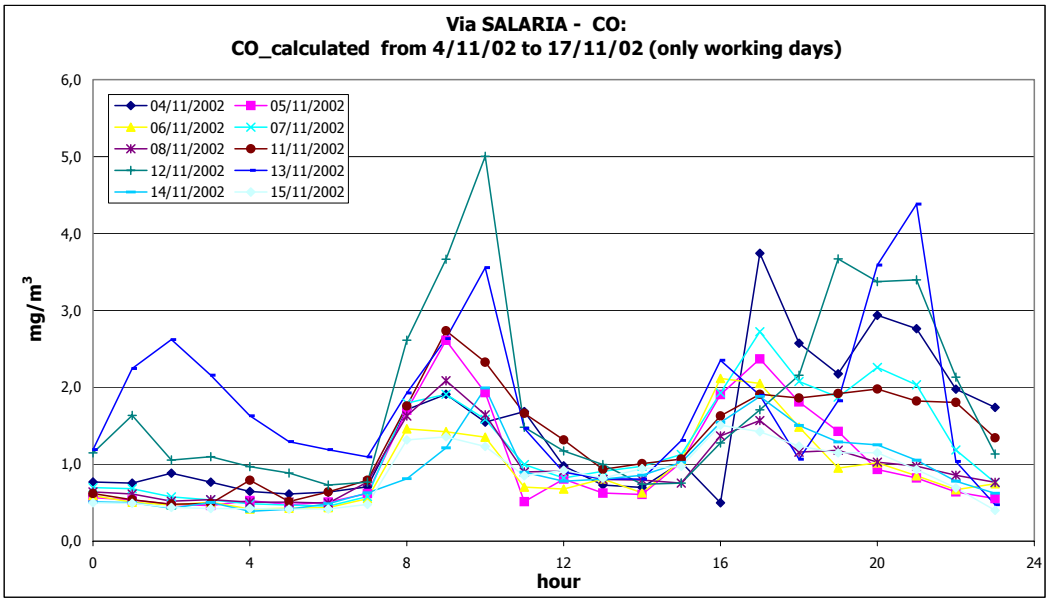


Fig. A.58. Via Salaria: calculated CO daily trends

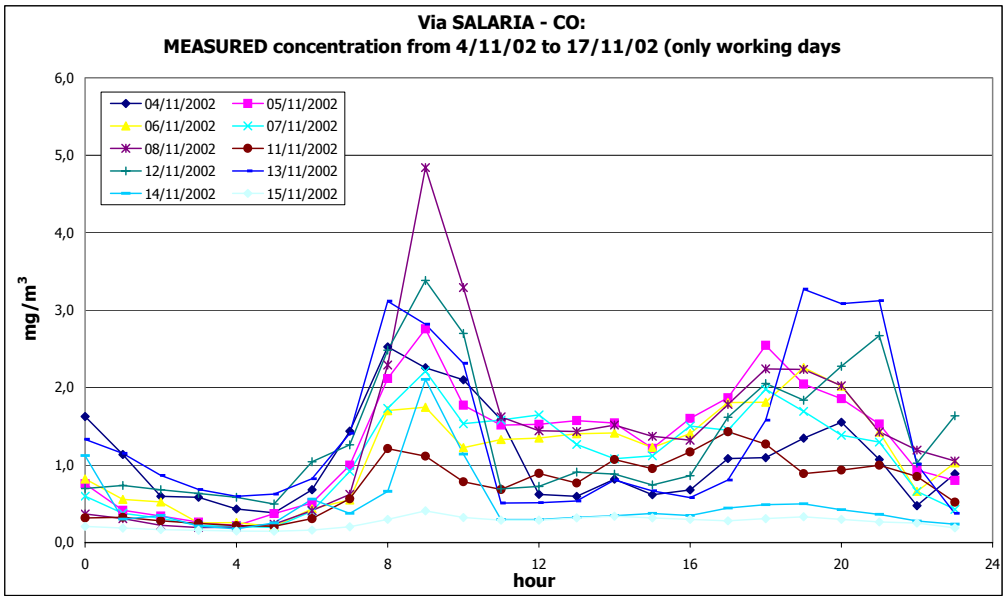


Fig. A.59. Via Salaria: measured CO daily trends

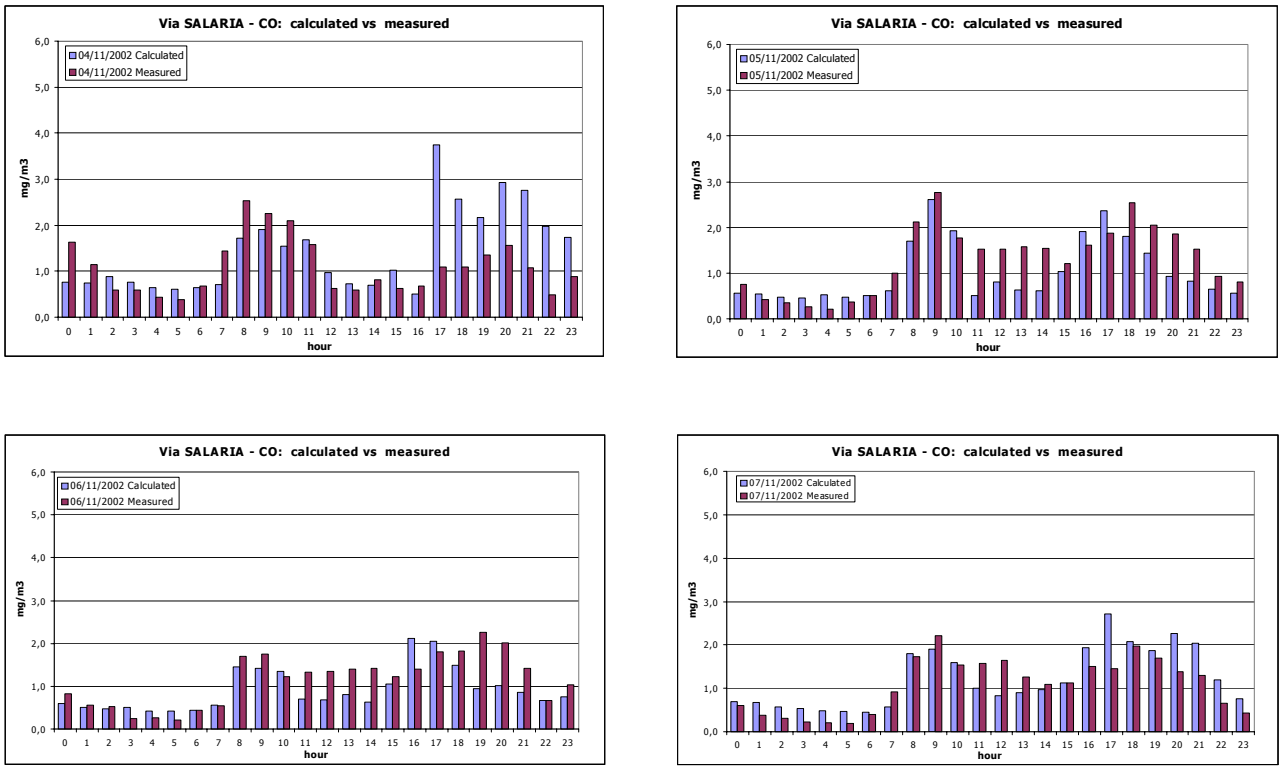


Fig. A.60. Via Salaria: CO day-by-day comparison calculated – measured

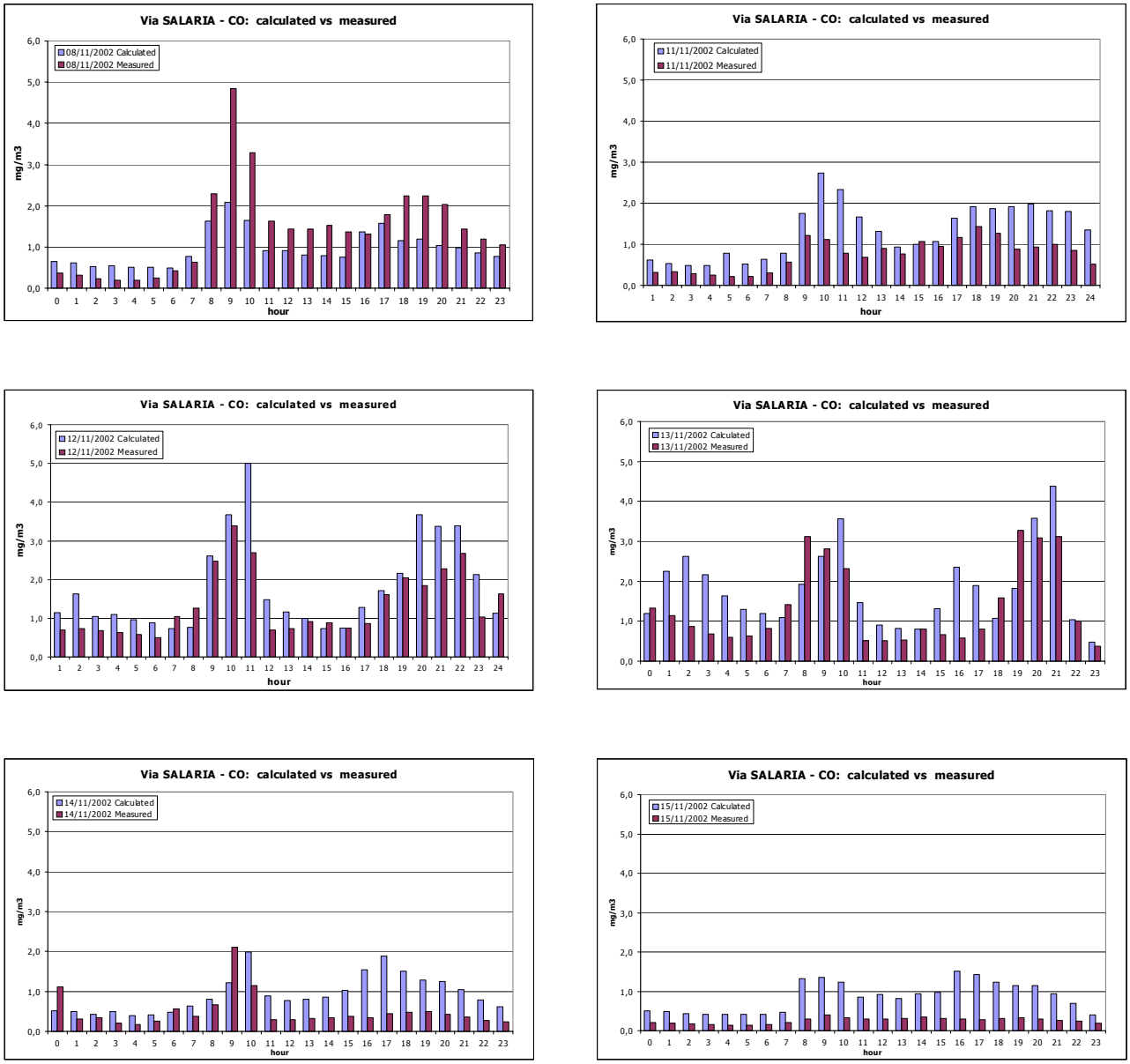


Fig. A.60. Via Salaria: CO day-by-day comparison calculated – measured

The comparison of average calculated and measured CO concentrations, computed over the two weeks evaluation period, is shown in Fig. A.61. The results obtained show that there is a good fitting of average calculated and measured CO concentrations.

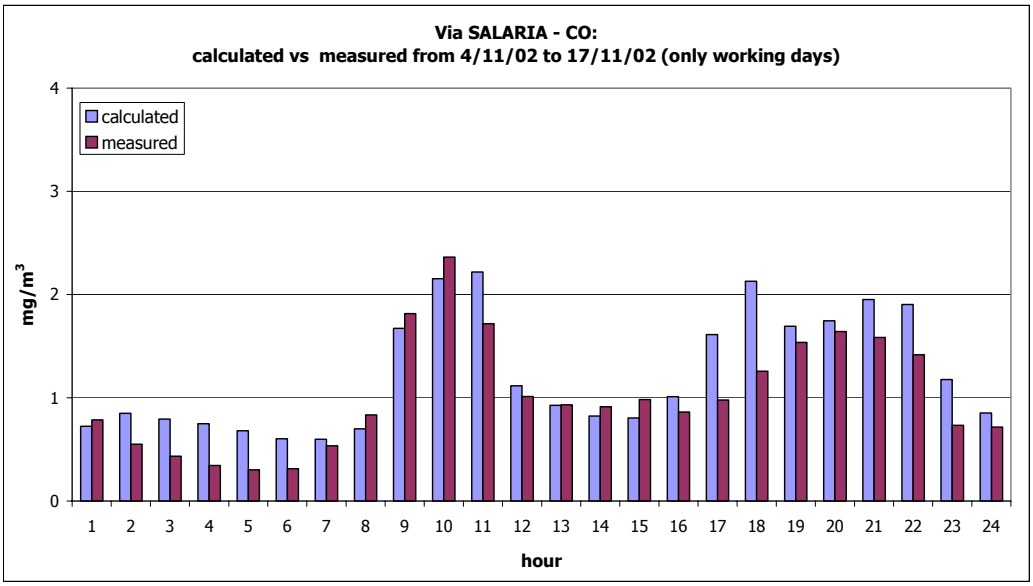


Fig. A.61. Via Salaria: average CO concentrations: comparison calculated – measured

In Fig. A.62 and Fig. A.63 scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.762 and 0.371. These values show that there is a good correlation between average measured and calculated CO concentrations while the correlation decrease analysing the cumulative concentrations values.

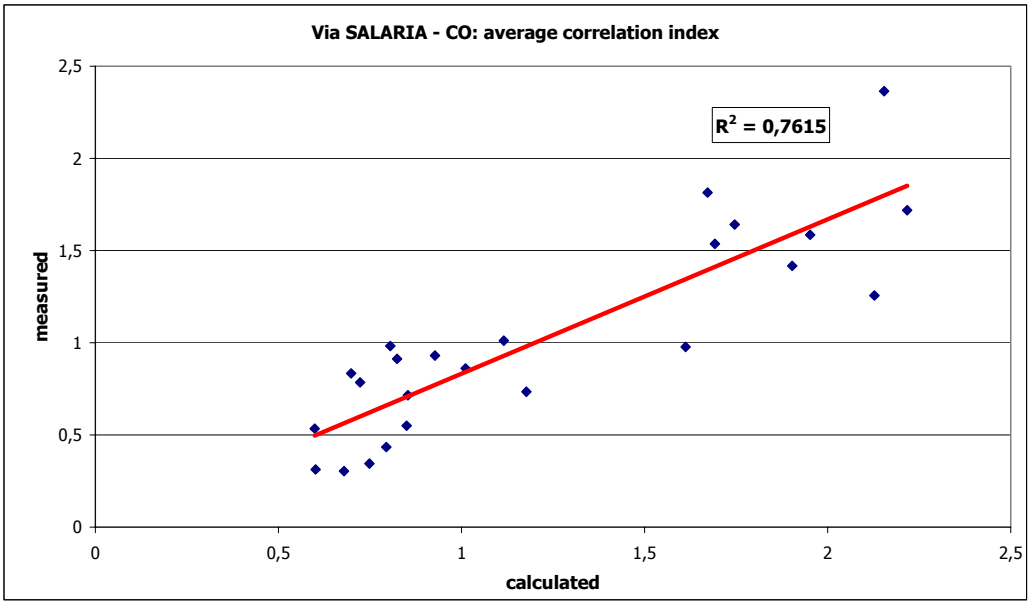


Fig. A.62. Via Salaria: average CO correlation index

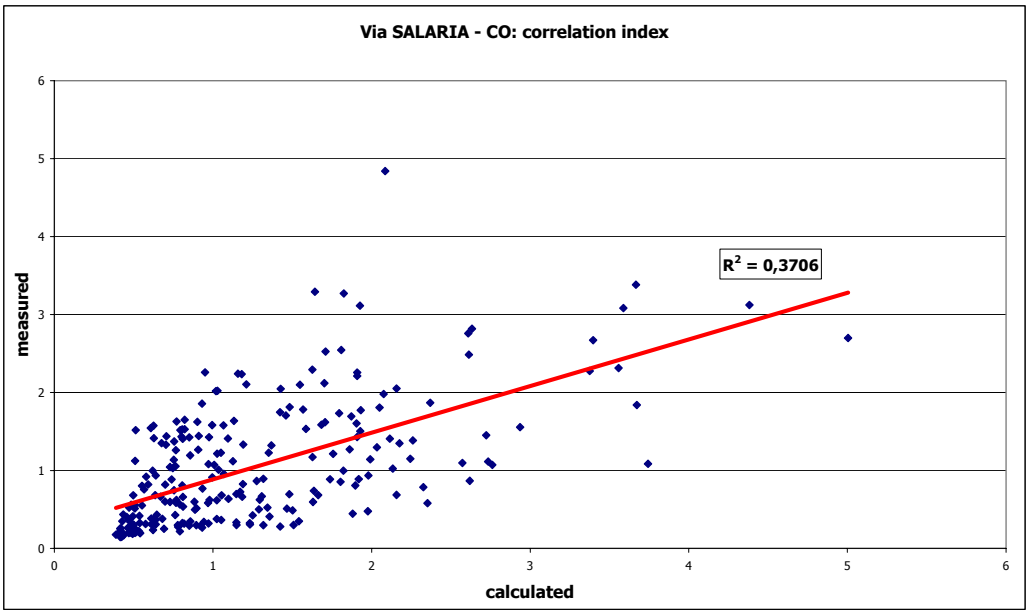


Fig. A.63. Via Salaria: CO correlation index

3.2.2 Via Salaria: C_6H_6 analysis

In this section results obtained from C_6H_6 analysis are reported.

In Fig. A.64 and Fig. A.65 calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown in Fig. A.66 where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show both a good fitting, over the different hours of the day and over the different days, between computed and measured concentrations. It is not possible to define, within this specific location, a general trend for the concentration computed by HEAVEN system: under or over estimation of C_6H_6 concentrations are highlighted from the day-by-day comparison.

Such results are mainly related to the difficulty of having a one to one transposition between local conditions of Via Salaria and of Via Tiburtina. The correction factor α has been introduced to have comparable data concentrations and to take into account the different boundary conditions of the locations. However, this factor is not able to perfectly reproduce local fluctuations to which the two locations are subject to and that are generally different.

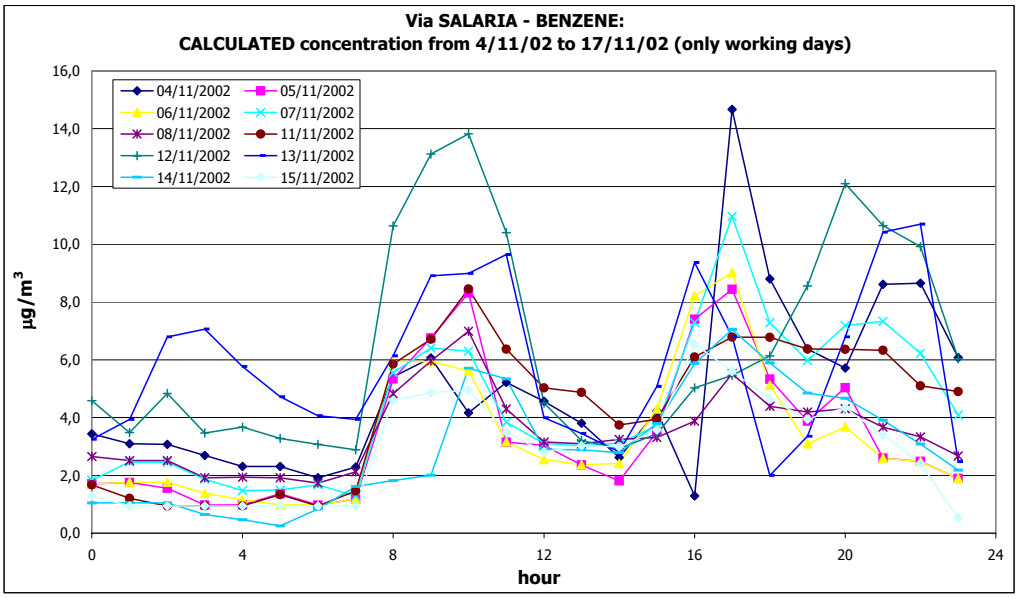


Fig. A.64. Via Salaria: calculated C_6H_6 daily trends

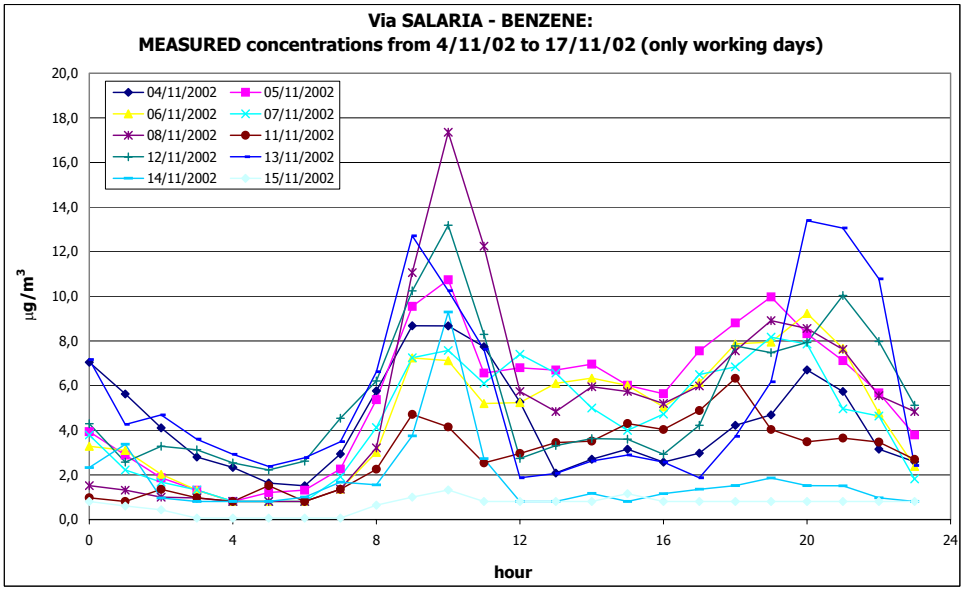
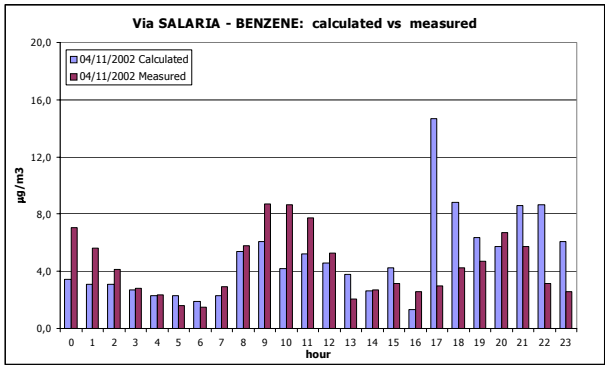
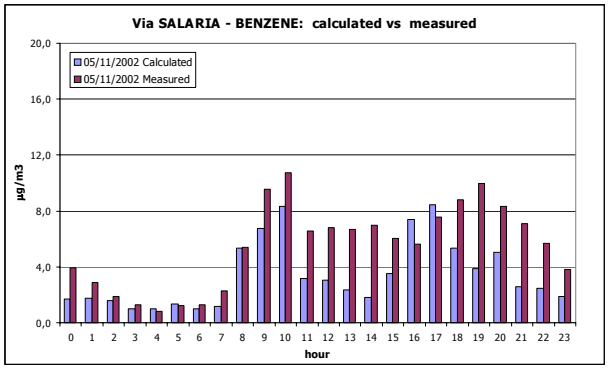
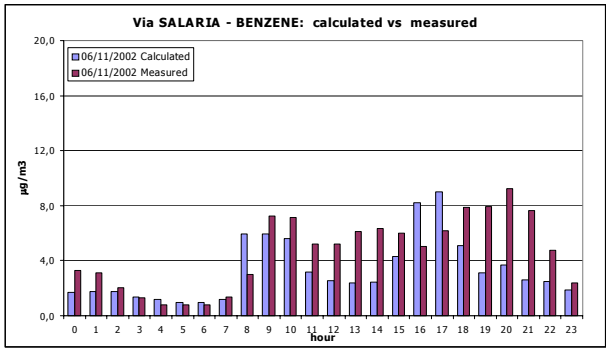
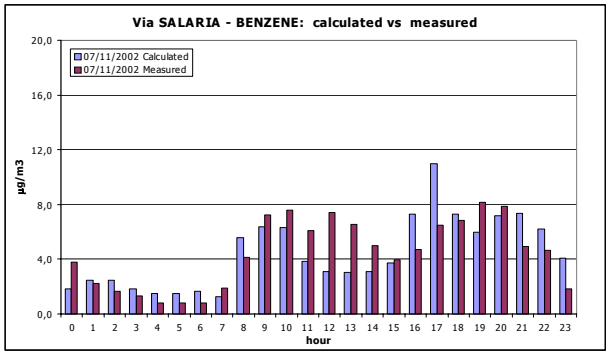


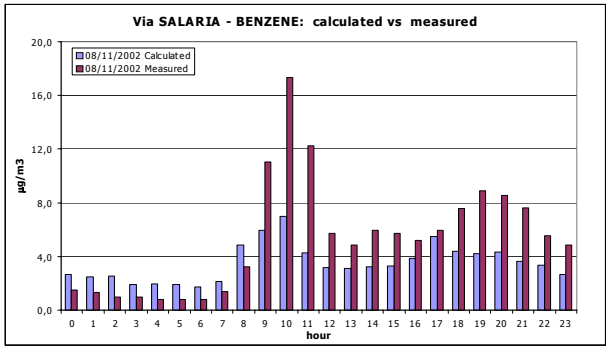
Fig. A.65. Via Salaria: calculated C_6H_6 daily trends

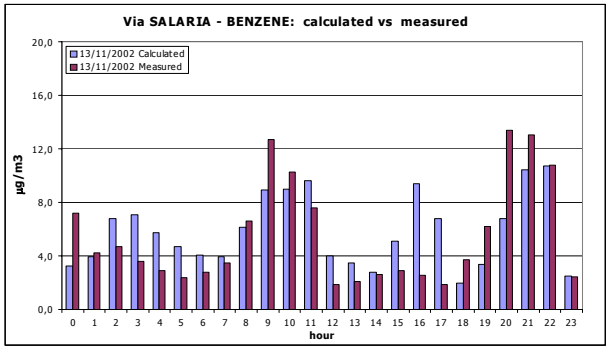


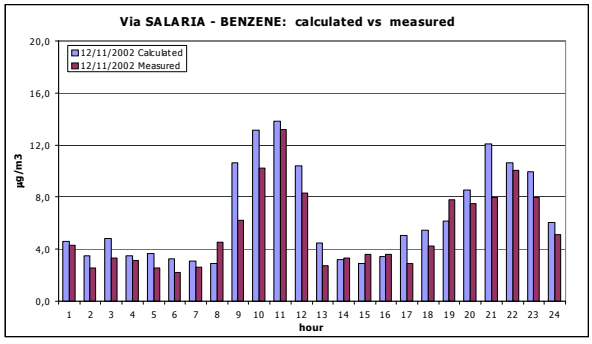












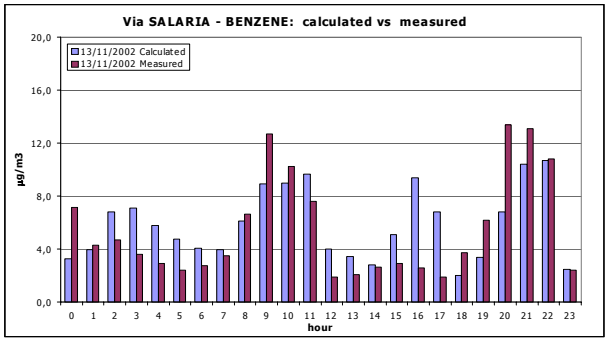


Fig. A.66. Via Salaria: C_6H_6 day-by-day comparison calculated - measured

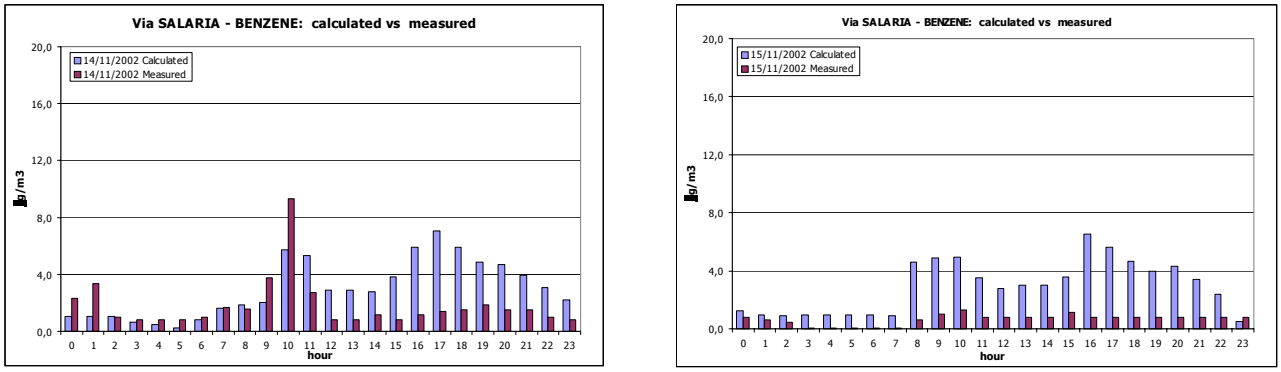


Fig. A.66. Via Salaria: C_6H_6 day-by-day comparison calculated - measured

The comparison of average calculated and measured C_6H_6 concentrations, computed over the two weeks evaluation period, is shown in Fig. A.67. The results obtained show that there is a good fitting of average calculated and measured C_6H_6 concentrations; an over estimation of computed benzene concentration is evident at 5 and 6 pm.

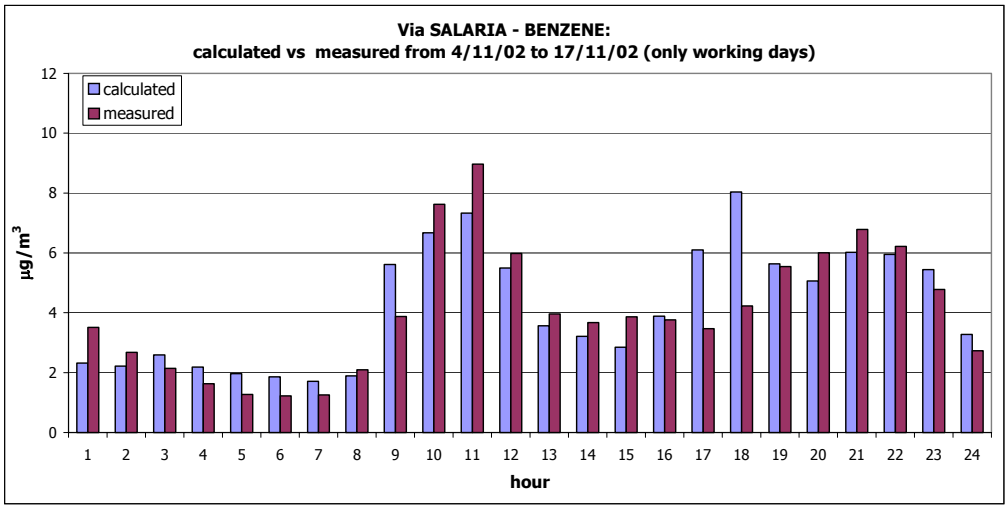


Fig. A.67. Via Salaria: average C_6H_6 comparison calculated - measured

In Fig. A.68 and Fig. A.69 scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.673 and 0.332. These

values show that there is a good correlation between average measured and calculated C_6H_6 concentrations while the correlation decrease analysing the cumulative concentrations values.

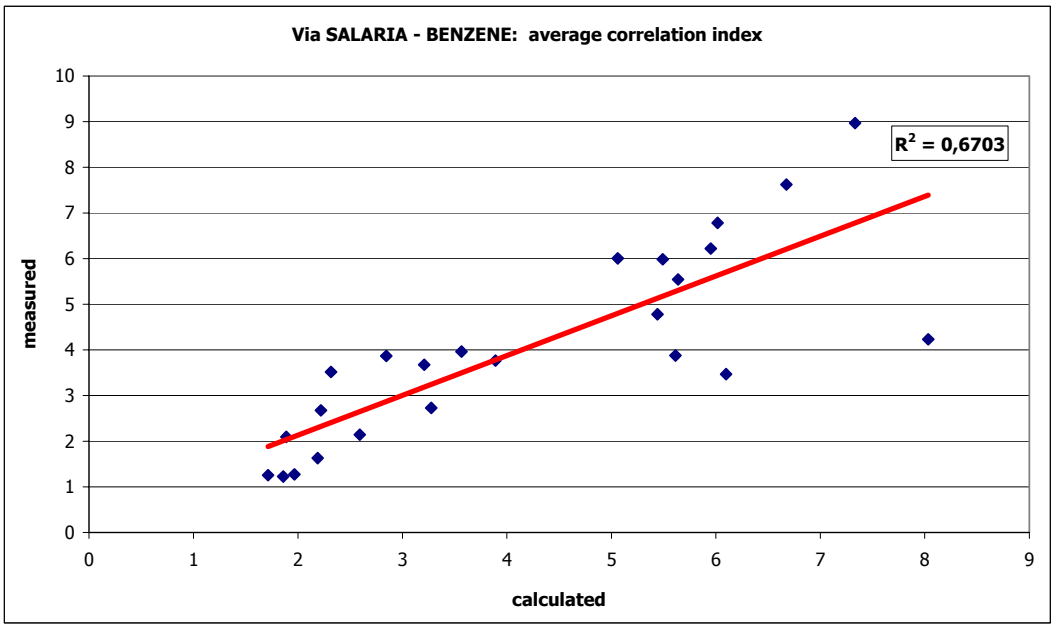


Fig. A.68. Via Salaria: average C_6H_6 correlation index

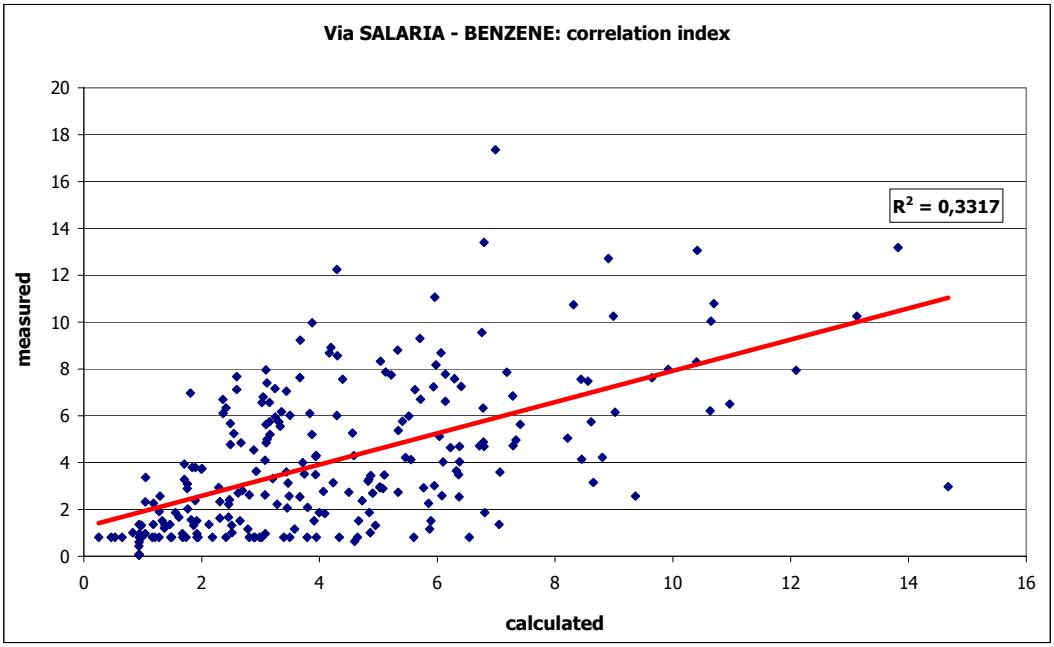


Fig. A.69: Via Salaria: C_6H_6 correlation index

3.2.3 Via Salaria: NO_x analysis

In this section results obtained from NO_x analysis are reported.

In Fig. A.70and Fig. A.71 calculated and measured concentrations' daily trends are reported; those figures show that computed and measured values have similar daily trends.

A detailed analysis is shown in Fig. A.72 where the comparison is carried out on a day-by-day basis for the whole evaluation period. These diagrams show a general under estimation of NO_x concentrations computed by the HEAVEN system over the different hours of the day; this trend is more evident at peak hours.

Such results are mainly related to the following factors:

- The system calculates NO_2 concentrations while measurement stations detect NOx concentrations; it has been assumed that the percentage of NO_2 becoming NO_x in the short term is equal to the 7%. This assumption is probably too restrictive.
- The difficulty of having a one to one transposition between local conditions of Via Salaria and of Via Tiburtina. The correction factor α has been introduced to have comparable data concentrations and to take into account the different boundary conditions of the locations. However, this factor is not able to perfectly reproduce local fluctuations to which the two locations are subject to and that are generally different.

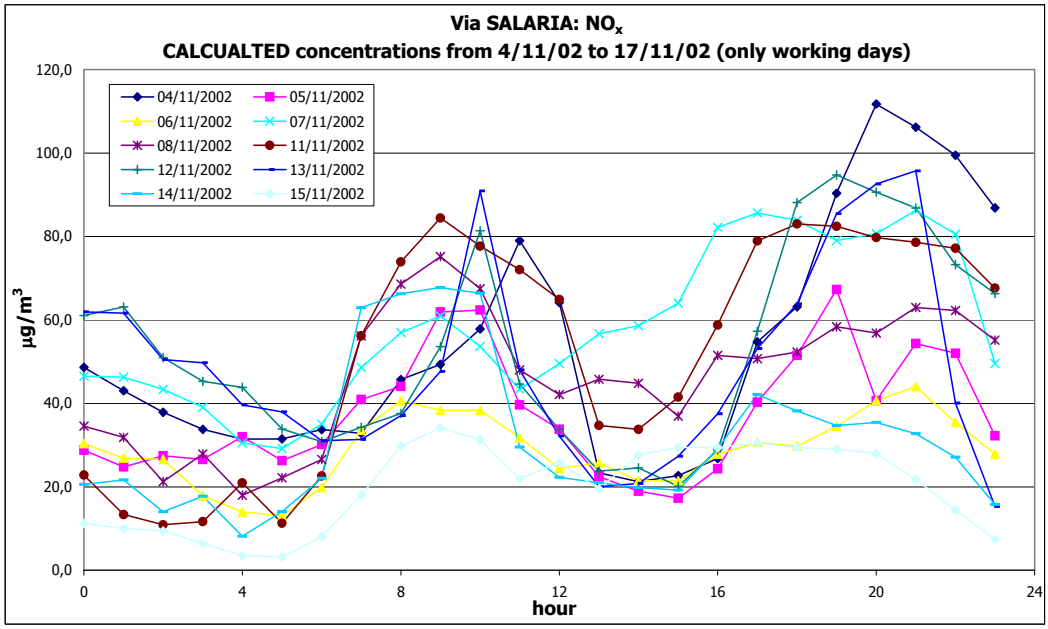


Fig. A.70. Via Salaria: calculated NO_x daily trends

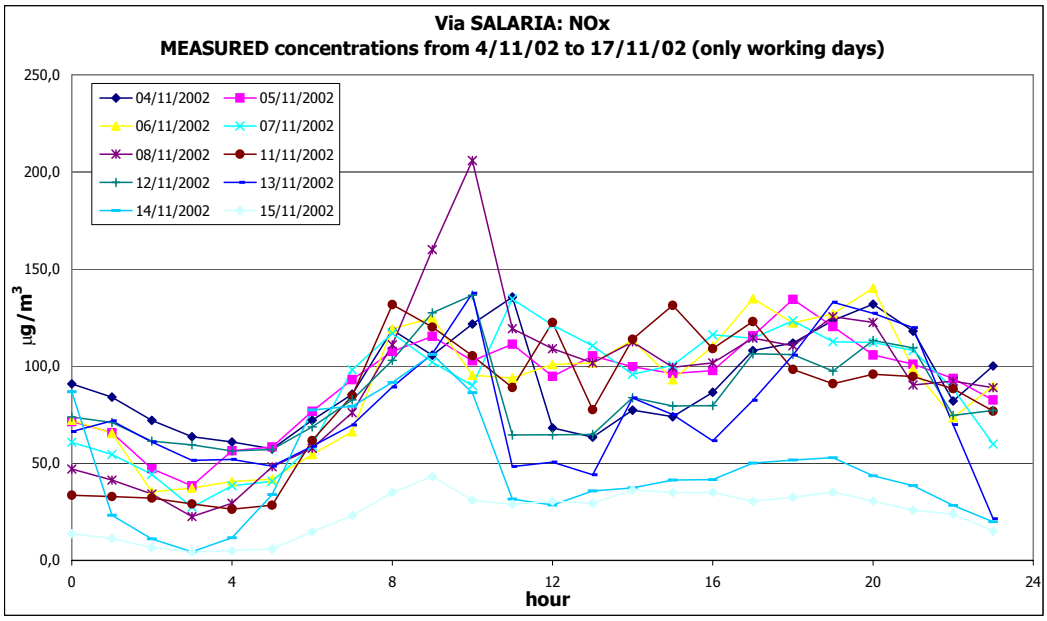


Fig. A.71. Via Salaria: calculated NO_x daily trends

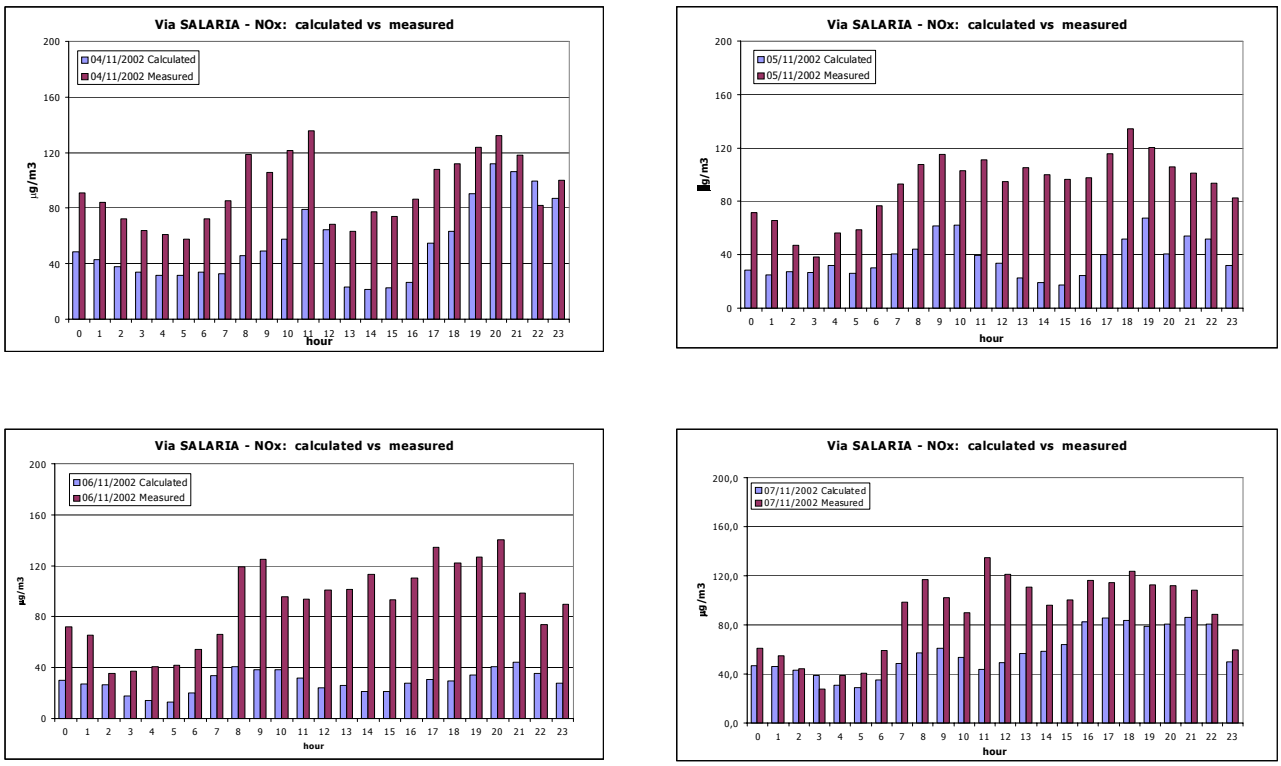


Fig. A.72. Via Salaria: NO_x day-by-day comparison calculated – measured

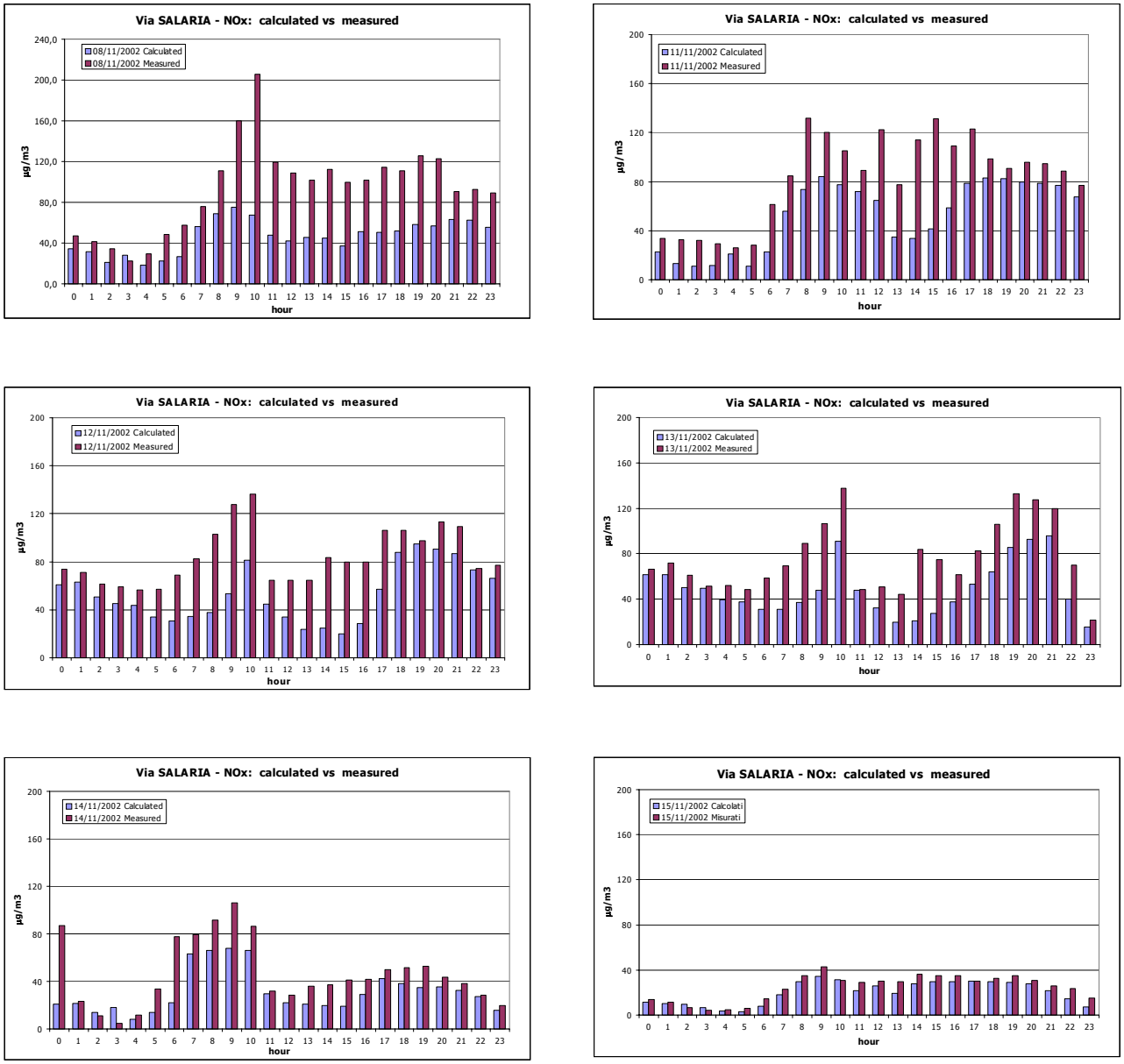


Fig. A.72. Via Salaria: NO_x day-by-day comparison calculated - measured

The comparison of average calculated and measured NO_x concentrations, computed over the two weeks evaluation period, is shown in Fig. A.73. The results obtained are coherent with the ones obtained form the day-by-day analysis: the HEAVEN system generally under estimated NO_x concentrations.

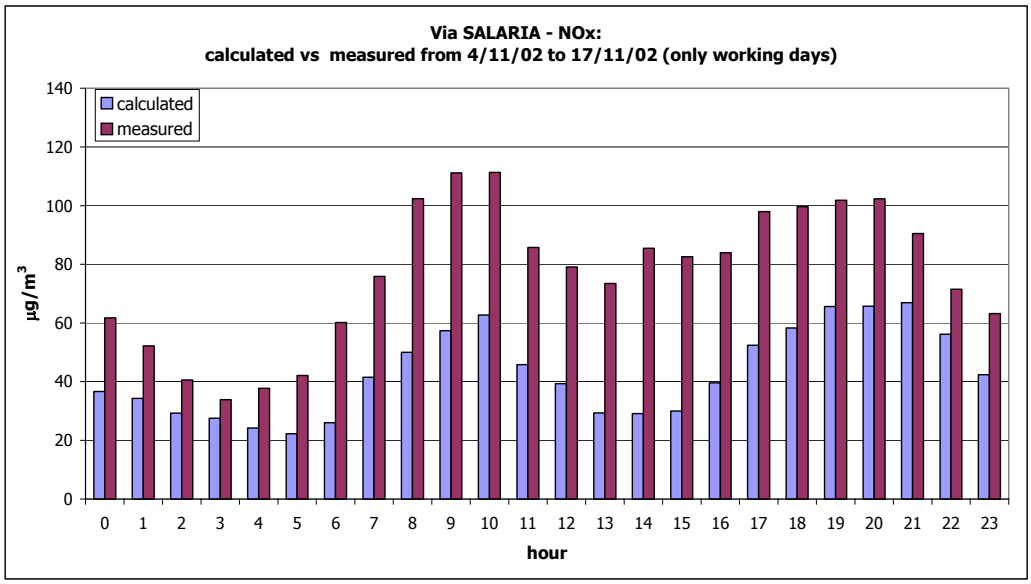


Fig. A.73. Via Salaria: average NO_x comparison calculated - measured

In Fig. A.74 and Fig. A.75 scartergrams are reported both for average concentration and for cumulative concentration values; R^2 values obtained are respectively 0.635 and 0.453. These values show that there is a good correlation between average measured and calculated NO_X concentrations while the correlation decrease analysing the cumulative concentrations values.

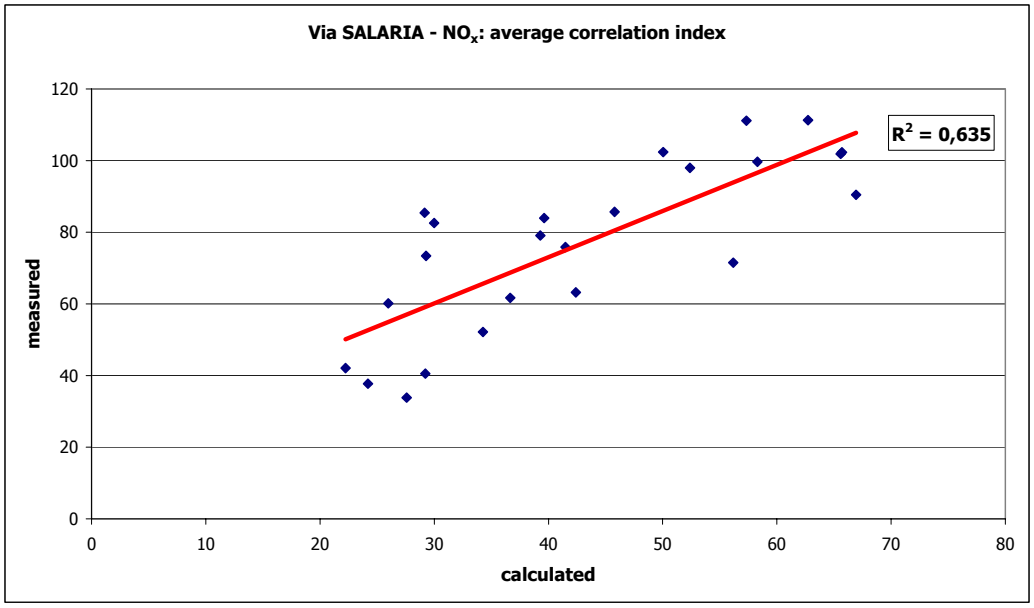


Fig. A.74. Via Salaria: average NO_x correlation index

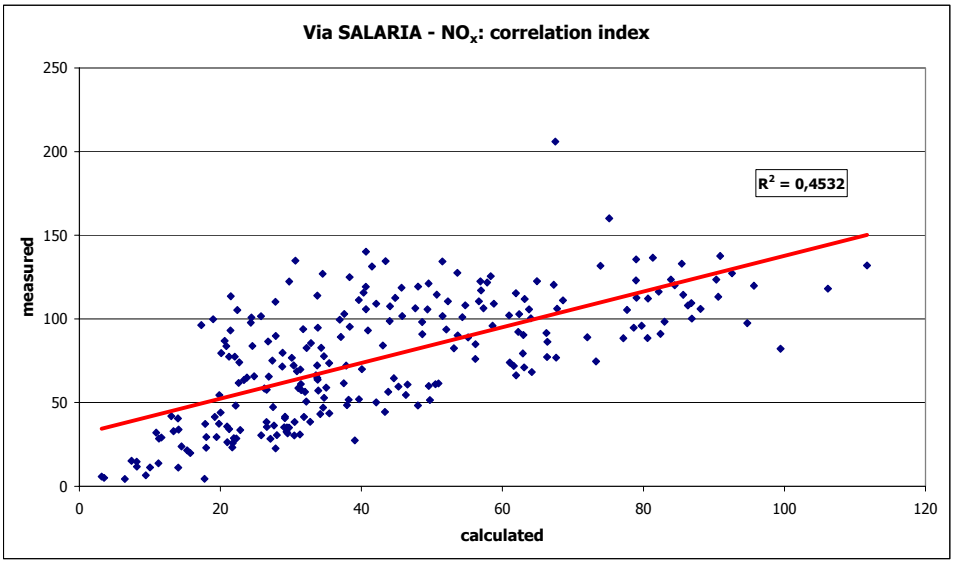


Fig. A.75. Via Salaria: NO_x correlation index

3.2.4 Via Salaria: PM_{10} analysis

In this section results obtained from PM_{10} analysis are reported.

In Fig. A.76 PM_{10} calculated concentrations' daily trends are reported fro the whole evaluation period. In this section are presented only the results obtained from the HEAVEN system and not comparison with measured concentration has been carried out because the measurement station located in via Tiburtina does not detect PM_{10} concentrations.

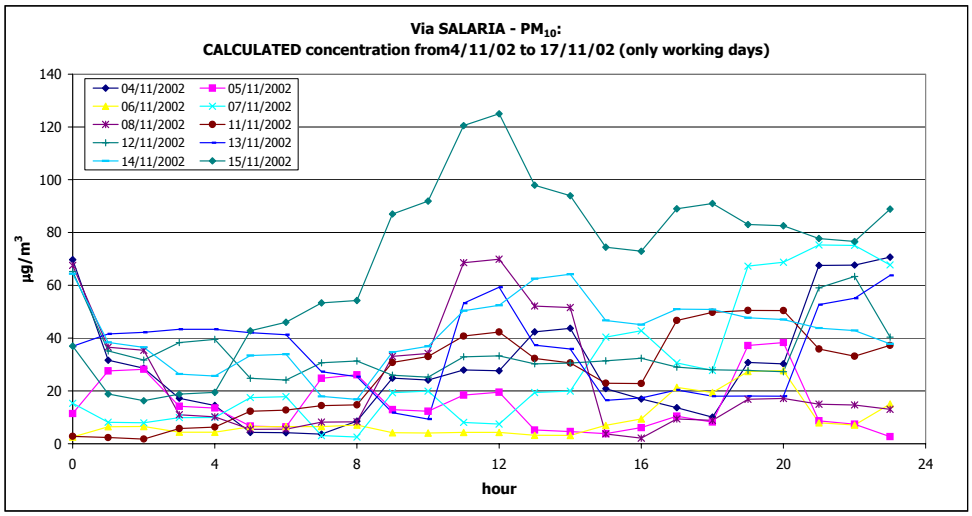


Fig. A.76. Via Salaria: calculated PM_{10} daily trends

In order to evaluate the attendency of calculated PM_{10} concentration trends results obtained from 4 different measurement station located in the Rome's area (Arenula, Fermi, Magna Grecia and Ada) are reported in Fig. A.77. Measured PM_{10} concentrations trends refer to the average day of the year 2001. These results are part of a wider study on Rome's level of pollution carried out in 2001 by the regional authority ARPA.

Comparing those curves with the one obtained from the system it is possible to evaluate that calculated PM_{10} concentration trends are coherent with the measured PM_{10} trends referring to the average day of year 2001.

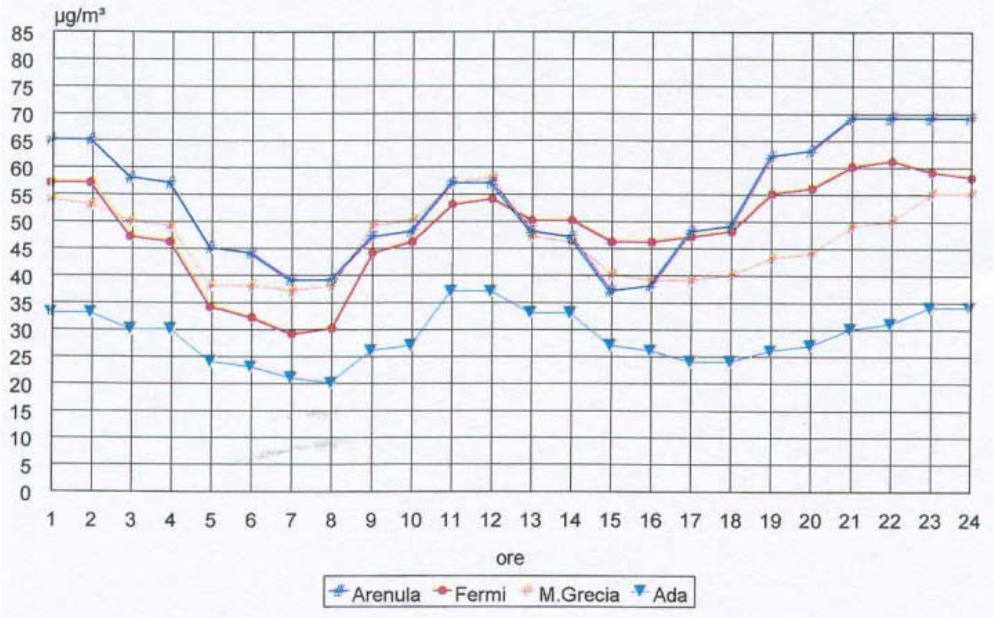


Fig. A.77. PM_{10} average day (2001) - measured trends