# TWO YEAR FINE AND ULTRAFINE PARTICLES MEASUREMENTS IN ROME, ITALY

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## ABSTRACT

*Long-term aerosol measurements have been conducted at two sites in Rome, Italy, April 2001 through March 2003, in a traffic-oriented site, and an urban background site, close to the city center. The main objective was to establish validated and consistent data sets of particle number concentrations (PNC) in Rome to be used for epidemiological analyses of cardiovascular health effects. Particle number concentrations were measured by a condensation particle counter (CPC 3022A, TSI). Other pollutants, ($PM_{10}$, $PM_{2.5}$, CO, $NO_2$, NO, NOx, $O_3$) were simultaneously measured at the traffic-oriented site. During the study period, the mean (standard deviation) 24-hr PNC were $4.69x10^4$ ($1.99x10^4$) $cm^{-3}$ and $2.46x10^4$ ($1.10x10^4$) $cm^{-3}$ respectively at the traffic-oriented site and at the urban background site. Mean (standard deviation) 24-hr mass concentration of $PM_{2.5}$ was 23.1 (11.9) $\mu g\ m^{-3}$, while for $PM_{10}$ it was 41.3 (17.9) $\mu g\ m^{-3}$. Higher values for all the pollutants, except ozone, were recorded during the winter period in comparison with the summer period, and a higher variability of the results was also observed during cold months. The comparison between the daily PNC measured at the two sites showed a good correlation (r = 0.74). CO (r = 0.77), NO (r = 0.82) and $NO_X$ (r = 0.83) were all highly correlated with PNC (simultaneous obs. n. 576). Diurnal and seasonal pattern of PNC can be attributed to the combined effect of motor vehicle emissions and meteorological conditions.*

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## INTRODUCTION

Epidemiological research during the last decade has indicated that exposure to air pollution at the levels presently measured in European urban environments is associated with an increase in mortality and with a variety of health conditions, including emergency room visits and hospital admissions for respiratory and cardiovascular diseases. Particulate matter (PM) appears to be the air pollutant most consistently associated with adverse health outcomes (Dockery and Pope, 1994; Schwartz et al., 1996; Milligan et al., 1998; Ostro and Chestnut, 1998; Dockery, 2001; Pope et al., 2002; WHO, 2002). With respect to dimension, urban particles are broken down into three groups: ultrafine particles, accumulation mode particles (which together form the fine particle mode) and coarse mode particles. Ultrafine particles contribute very little to the overall mass, but are very high in number, which in episodic events can reach several hundred thousand/$cm^3$ in urban air (Oberdörster, 2001).

Regarding the sources, ultrafine particles in polluted urban environments consist of three main types:

- primary particles originating from road traffic: these particles are directly discharged during combustion processes and are believed to contribute to the majority of the total number of particles in city centers.
- secondary particles (such as ammonium sulfate and nitrate) originating in the atmosphere from oxidation of precursor pollutants ($SO_2$, $NO_x$) followed by neutralisation with gaseous ammonia as well as organic aerosol originating from photochemical induced oxidation of some volatile organics compounds (NMVOCs).
- inflow particles: these particles are known to result from long-range transport as well as from regional energy production and industrial activities (CAFE, 2004).

Motor vehicle emissions usually constitute the most significant source of ultrafine particles in an urban environment. The number of ultrafine particles (0.01 to 0.1 μm, normally expressed as Particle Number Concentration - number per cubic centimetre of atmospheric air) is hypothesised to be of particular concern (Seaton et al., 1995; Oberdörster and Utell, 2002).

The main objective of this study was to establish validated and consistent data sets of particle number concentrations in Rome. These data sets were collected and used in the framework of the research project funded by the European Union: “Health effects of air pollution on susceptible sub-population – traditional air pollutants, ultrafine particles and myocardial infraction: database and health assessment, HEAPSS”. The main objective of this project is to quantify the risk of hospitalisation and death due to air pollution, in particular airborne ultrafine particles, in individuals with coronary heart disease in five European cities. This paper reports the data available after the first two years of continuous monitoring in Rome. The results regarding environmental monitoring (Aalto et al., 2004) and health effects (Lanki et al., 2004) in the five cities have been reported elsewhere.

## EXPERIMENTAL METHODS

The data reported in this study are relative to the period from 4/2001 to 3/2003. Rome is a large metropolitan area, with about 3.000.000 inhabitants. In the metropolitan area very high traffic concentrations are reported, in many roads, especially from 7 to 9 a.m. and from 6 to 8 p.m. The ratio of diesel to gasoline cars circulating in the town is about 1:4. The residential heating season usually lasts five months; fuels are mostly natural gas and heating oil. In the last few years $SO_2$ and lead concentrations decreased significantly in ambient air due to the decreasing content of sulphur compounds and lead tetralchile in fuels.

### *Sampling sites*

In our study we have used data from two separate measurement locations, in the urban area of Rome, Italy (Figure 1).

### *Primary site*

The primary site is located 2 km east of the city center on the front yard of the Italian National Institute of Health (INIH). Inlets for particle measurements were at about 8 m from the curb and about 20 m from the street, Viale Regina Elena, and approximately 3 m from the ground. A flow of 25000 cars/day was estimated, constant throughout the year except for August. Traffic intensity was presumed to be roughly intermediate between the center and suburban areas. The area is not subject to industrial emissions. This site could be considered as a traffic-oriented site.

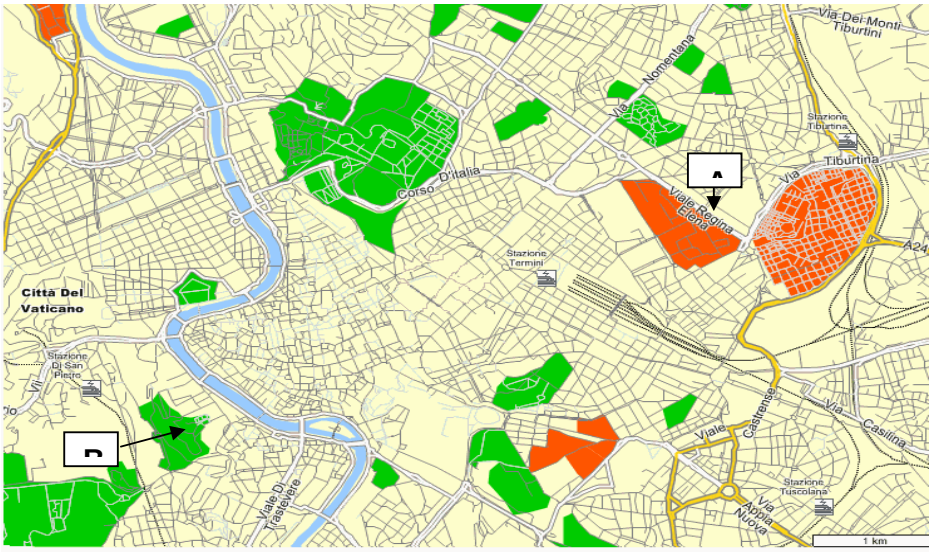


Figure 1. Measurement locations. A: INIH - primary site, traffic-oriented; B: Botanical garden - secondary site, urban background.

***Secondary site***

The secondary site is located in a park (botanical garden) situated in the area surrounding the center of town. From the sampling site, at the east side there is a little hill (Gianicolo) characterized by a large variety of plants and trees. At the south side there is the famous district of Trastevere (about 400 meter from the sampling point), which is a limited traffic area (only for residents). The closest traffic street is located about 400 meters from the sampling point. So we can consider this an urban background site.

For the purpose of this study, the following air samplers were used:

Two low volume samplers, model SKYPOST PM (TCR Tecora - Italy); one operating at 1 $m^3$/h, equipped with an omnidirectional aerosol inlet designated as reference for $PM_{10}$ by the United States Environmental Protection Agency (US-EPA) and a WINS impactor to separate the particles into the "fine" size fraction ($PM_{2.5}$). The second operating at 2.3 $m^3$/h, equipped with an omnidirectional aerosol inlet designated as reference for the thoracic fraction ($PM_{10}$) according to CEN standard EN 12341 (1998).

PM was collected daily on 47-mm diameter glass fiber filter (Pall Corporation, USA). The use of this type of filters was considered a satisfactory compromise between advantages (reduced cost, low hygroscopicity, lower friability with respect to quartz filters) and disadvantages (the potential occurrence of artifacts, e.g. sulphates). Glass fiber filters have been recommended in the recent draft of the European reference method for $PM_{2.5}$ (CEN, 2004).

Each sixth day, polymethylpentane-ringed, 2.0-µm pore size, 47-mm diameter Teflon filters (Gelman, USA) were used for chemical characterization of collected particles (results not included in this study).

Although the PM samples were collected daily, the number of data (shown in Table 1 and 2) is lower than the data of other pollutants due to instrumental mechanical and electronic problems. Standard filter handling and weighing procedures were adopted in order to minimize errors.

Equilibration and weighing were carried out under controlled conditions. The filters were equilibrated pre- and post-sampling in an air-conditioned room under controlled temperature conditions (20°C ± 1°C) and relative humidity (50% ± 5 %). Conditioning time within the weighing environment was at least 24 hours. Weighing was performed inside the same room, using a Sartorius model M5P 000V001 electrobalance (readability: 0.001 mg).

Table 1. INIH site (traffic-oriented), April 2001 – March 2003: mean of the 24-h average concentrations and descriptive statistics of particle number concentrations, $PM_{2.5}$, $PM_{10}$, CO, NO, $NO_x$, $NO_2$ and $O_3$.

| | Valid N | Mean | S.D. | Min | 25th Perc | Median | 75th Perc | Max |
|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 387 | 24.0 | 12.2 | 4.4 | 16.2 | 21.3 | 29.0 | 87.9 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 389 | 42.0 | 18.7 | 6.7 | 30.2 | 38.6 | 48.5 | 124.9 |
| $PM_{2.5}/PM_{10}$ | 314 | 0.58 | 0.13 | 0.21 | 0.49 | 0.58 | 0.67 | 0.99 |
| CO ($mg\ m^{-3}$) | 659 | 1.4 | 0.8 | 0.3 | 0.8 | 1.2 | 1.7 | 6.3 |
| $NO_X$ ($\mu g\ m^{-3}$) | 661 | 86.8 | 54.7 | 14.4 | 49.6 | 70.7 | 108.5 | 344.9 |
| NO ($\mu g\ m^{-3}$) | 661 | 41.9 | 44.9 | 1.6 | 12.7 | 25.7 | 52.3 | 288.9 |
| $NO_2$ ($\mu g\ m^{-3}$) | 661 | 44.9 | 14.5 | 12.1 | 34.4 | 44.5 | 53.9 | 89.2 |
| $O_3$ ($\mu g\ m^{-3}$) | 688 | 32.8 | 18.1 | 2.9 | 17.3 | 32.9 | 46.8 | 86.2 |
| Particles number ($cm^{-3}$) | 630 | 4.56E+04 | 2.47E+04 | 3.50E+03 | 2.76E+04 | 4.10E+04 | 5.80E+04 | 1.40E+05 |

Table 2. INIH (Primary site, traffic-oriented): averages, standard deviations and Coefficient of Variation for all the pollutants over different period of the 2 years of monitoring - 4/2001-3/2003 - (spring-summer period: April through September; autumn-winter period: October through March).

| Period | | $PM_{2.5}$ ($\mu g\ m^{-3}$) | $PM_{10}$ ($\mu g\ m^{-3}$) | $PM_{2,5}/PM_{10}$ | CO ($mg\ m^{-3}$) | $NO_X$ ($\mu g\ m^{-3}$) | NO ($\mu g\ m^{-3}$) | $NO_2$ ($\mu g\ m^{-3}$) | $O_3$ ($\mu g\ m^{-3}$) | Particles ($cm^{-3}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **N** | **84** | **117** | **78** | **147** | **127** | **127** | **127** | **173** | **153** |
| *4/01-9/01* | mean | 17.7 | 36.5 | 0.51 | 0.96 | 56.5 | 17.8 | 38.7 | 46.6 | 3.65E+04 |
| spring-summer | S.D. | 7.1 | 10.7 | 0.14 | 0.42 | 23.9 | 13.8 | 12.4 | 13.2 | 1.47E+04 |
| | CV% | 39.8 | 29.3 | 27.4 | 43.4 | 42.3 | 77.8 | 32.0 | 28.3 | 40.3 |
| | **N** | **54** | **68** | **54** | **182** | **182** | **182** | **182** | **150** | **181** |
| *10/01-3/02* | mean | 32.2 | 50.3 | 0.61 | 2.02 | 122.3 | 72.2 | 50.1 | 17.8 | 6.15E+04 |
| autumn - winter | S.D. | 18.5 | 24.2 | 0.12 | 0.93 | 60.0 | 53.7 | 11.1 | 10.3 | 2.69E+04 |
| | CV% | 57.5 | 48.2 | 19.9 | 46.3 | 49.1 | 74.4 | 22.2 | 58.0 | 43.7 |
| | **N** | **143** | **89** | **81** | **183** | **178** | **178** | **178** | **183** | **158** |
| *4/02-9/02* | mean | 20.9 | 37.5 | 0.57 | 0.92 | 52.8 | 16.7 | 36.2 | 44.9 | 3.04E+04 |
| spring-summer | S.D. | 6.8 | 12.0 | 0.09 | 0.26 | 18.1 | 9.0 | 11.0 | 13.0 | 1.38E+04 |
| | CV% | 32.4 | 32.1 | 16.0 | 28.4 | 34.3 | 53.9 | 30.4 | 29.0 | 45.6 |
| | **N** | **106** | **115** | **101** | **147** | **174** | **174** | **174** | **182** | **138** |
| *10/02-3/03* | mean | 29.1 | 46.1 | 0.63 | 1.56 | 108.0 | 55.1 | 52.9 | 19.7 | 5.40E+04 |
| autumn - winter | S.D. | 13.1 | 22.7 | 0.14 | 0.66 | 57.9 | 48.2 | 15.4 | 11.7 | 2.60E+04 |
| | CV% | 45.1 | 49.2 | 22.3 | 42.3 | 53.6 | 87.5 | 29.1 | 59.5 | 48.1 |
| | **N** | **138** | **185** | **132** | **329** | **309** | **309** | **309** | **323** | **334** |
| *4/01-3/02* | mean | 23.4 | 41.5 | 0.55 | 1.53 | 94.4 | 49.0 | 45.4 | 33.3 | 4.93E+04 |
| first year | S.D. | 14.6 | 18.2 | 0.14 | 0.91 | 57.9 | 49.6 | 12.9 | 18.7 | 2.51E+04 |
| | CV% | 62.3 | 43.8 | 25.6 | 59.3 | 61.4 | 101.2 | 28.4 | 56.1 | 50.9 |
| | **N** | **249** | **204** | **182** | **330** | **352** | **352** | **352** | **365** | **296** |
| *4/02 - 3/03* | mean | 24.4 | 42.4 | 0.60 | 1.20 | 80.1 | 35.7 | 44.4 | 32.4 | 4.14E+04 |
| second year | S.D. | 10.7 | 19.3 | 0.13 | 0.58 | 50.8 | 39.4 | 15.8 | 17.7 | 2.35E+04 |
| | CV% | 44.1 | 45.5 | 20.8 | 47.8 | 63.4 | 110.6 | 35.4 | 54.6 | 56.9 |

S.D: standard deviation; N: number of valid data; mean: mean of the 24-h daily averages over the period.

Each filter was weighed twice both before and after the sampling session (once after conditioning, and then again after 24 – 48 h).

The limit of detection, (LOD) was calculated on the basis of the estimate of the collected mass imprecision following the ISO standard (ISO 15767, 2003). The LOD was 25 μg (1.0 $\mu g/m^3$ for the $PM_{2.5}$ sampler operating at 1 $m^3/h$ and 0,5 $\mu g/m^3$ for the $PM_{10}$ sampler operating at 2.3 $m^3/h$).

As a quality control check, three field blank filters were weighed during each weighing session. If the mean calculated mass difference between pre- and post-sampling exceeded 50 μg, then the sample was discharged.

Particles number concentration (PNC) was measured by two TSI model 3022A condensation particle counters (CPC). This type of counter can monitor particles larger than 0.02 μm in diameter, but still have a 50 % counting efficiency at 0.007 μm (Agarwald and Sem, 1980; Sem, 2002). Sampling lines were stainless steel tubing 2.5 m long and with an inner diameter of 4 mm. Inlet reached one meter out from the outside wall of the container in which the instruments were placed.

The HEAPSS standard operating procedures (SOP), containing the measurement protocol of total particle number concentration in ambient air, was strictly followed (Aalto et al., 2004).

One CPC was factory calibrated and serviced after six months of continuous work. Factory service and calibration assured proper operating conditions and the correct readings of the instruments. During the campaign both instruments were compared against a reference instrument once a year and a new calibration for the instrument operating at the INIH site was made by the University of Helsinki, according to the quality assurance procedure of the HEAPPS project.

The CPC measurement program recorded the data at least once a minute. Concentrations of traditional air pollutants (hourly averages of CO, $O_3$, NO, $NO_x$, $NO_2$) from fixed monitors, installed in a monitoring station in operation for many years at the same site (INIH), were measured according to standard procedures already employed in several European studies of air pollution.

At the secondary site only PNC were measured starting from February 2002. The instrument went out of service in July 2002. After factory maintenance and re-calibration and several comparison trials of the two CPCs performed at the primary site, it was operating again in January 2003.

In the correlation analysis of the data obtained at the INIH site, the conventional Pearson correlation coefficient was used.

**RESULTS**

Descriptive statistics calculated from the whole set of 24-h average concentrations of PNC, $PM_{2.5}$, $PM_{10}$, CO, NO, $NO_x$, $NO_2$ and $O_3$, measured at the INIH site, are presented in Table 1. Averages, standard deviations and the Coefficient of Variation for all pollutants over different periods of the two years of monitoring - 2001-2003 - (spring-summer period: April through September; autumn-winter period: October through March) are presented in Table 2.

Mean values through the year were lower than the target value recommended by the EU Directive (1999/30/EC) for all the pollutants except for $PM_{10}$. No target limits values are still proposed by EU for $PM_{2.5}$ and PNC.

A slight pattern toward decreasing concentrations was found by comparing the data of the first year (4/01 - 3/02) and the second year (4/02 - 3/03) for all the pollutants except for $PM_{10}$ and $PM_{2.5}$. This pattern was similar for CO and particle number concentration (-21.3 % and -16.1% respectively).

Higher daily mean values for all the pollutants, except ozone, were recorded during winter period. Focusing on PNC, the peak events were found during winter. The cleanest month was August, during which the main urban activities are substantially reduced (in Italy many people are on holiday during this period and most of the commercial/industrial activities are closed or strongly reduced). January was the most polluted month: the mean values throughout this month were 3 – 4 times higher than the average values during August.

Variation in the parameters measured can be examined mathematically by comparing the coefficients of variation (CV; standard deviation divided by the mean). In general, the variability was higher during winter. Even if $PM_{2.5}$, $PM_{10}$ and PNC showed a significant variability (Table 2), the highest variability was associated

with the gaseous compounds (like NO), which reflects the uneven local emissions from the primary traffic sources at the site.

The $PM_{2.5}/PM_{10}$ ratios were higher during the winter season (0.61 and 0.63 for the first and the second year respectively), than during summer (0.51 and 0.57).

As shown in Table 3, CO (r = 0.77) NO (r = 0.82) and $NO_X$ (r = 0.83) were all highly correlated with the particle number concentrations (simultaneous obs. n. 576). Daily $PM_{2.5}$ and $PM_{10}$ levels were found to be poorly correlated with the daily PNC.

Table 3. INIH site – traffic-oriented: relationship (number of observations) between the different variables, expressed by the Pearson correlation coefficient.

| Variable | $PM_{2.5}$ | $PM_{10}$ | CO | $NO_X$ | NO | $NO_2$ | $O_3$ | Particles |
|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ | - | | | | | | | |
| $PM_{10}$ | 0.8511 (314) | - | | | | | | |
| CO | 0.6452 (343) | 0.5729 (337) | - | | | | | |
| $NO_X$ | 0.7052 (361) | 0.6269 (349) | 0.8954 (612) | - | | | | |
| NO | 0.6710 (361) | 0.6037 (349) | 0.8970 (612) | 0.9767 (661) | - | | | |
| $NO_2$ | 0.5550 (361) | 0.4598 (349) | 0.5852 (612) | 0.7456 (661) | 0.5851 (661) | - | | |
| $O_3$ | -0.4044 (382) | -0.3080 (380) | -0.7039 (626) | -0.7082 (629) | -0.6756 (629) | -0.5851 (629) | - | |
| Particles | 0.5534 (327) | 0.4976 (332) | 0.7688 (577) | 0.8336 (576) | 0.8168 (576) | 0.6234 (576) | -0.6341 (597) | - |

Figure 2 shows a time series plot of the daily average of PNC. These data exhibit large temporal variability with occasional spikes that exceeds the mean by a factor 2 or more. The comparison between the two sites (traffic oriented, INIH, and Urban Background, Botanical Garden) is only possible for the PNC. The comparison of the results (Table 4) is limited to the 172 simultaneous 24-averages values available. Urban background values were about 50% lower with respect to the traffic-oriented site. Comparison between the PNC measured at the two sites showed a good correlation (r = 0.74 – Figure 3). These findings do not seem particularly affected by the different period of the year.

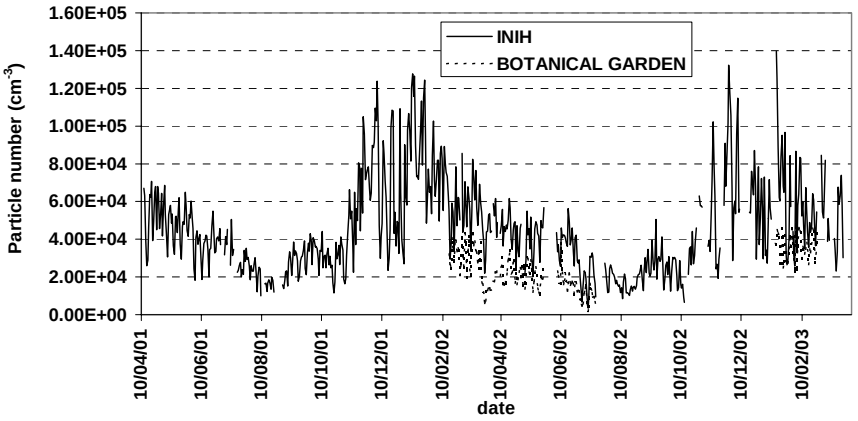


Figure 2. Time series of daily average total number concentration of particles measured at two sites (INIH – traffic-oriented and botanical garden - urban background).

Table 4. Mean of the 24-h average concentrations and descriptive statistics of particle number concentrations ($cm^{-3}$): comparison between the two sites. INIH (traffic-oriented) and Botanical garden (urban background) number of contemporary observations: 172.

| | overall data | | autumn - winter | | spring - summer | |
|---|---|---|---|---|---|---|
| | **INIH** | **botanical garden** | **INIH** | **botanical garden** | **INIH** | **botanical garden** |
| Valid n | 172 | 172 | 73 | 73 | 99 | 99 |
| mean | 4.69E+04 | 2.46E+04 | 5.89E+04 | 3.43E+04 | 3.80E+04 | 1.75E+04 |
| ds | 1.99E+04 | 1.10E+04 | 2.12E+04 | 7.17E+03 | 1.31E+04 | 7.14E+03 |
| min | 3.50E+03 | 1.73E+03 | 2.58E+04 | 1.93E+04 | 3.50E+03 | 1.73E+03 |
| $25^{th}$ perc | 3.38E+04 | 1.64E+04 | 4.62E+04 | 2.77E+04 | 2.90E+04 | 1.29E+04 |
| median | 4.59E+04 | 2.36E+04 | 5.73E+04 | 3.49E+04 | 4.11E+04 | 1.68E+04 |
| $75^{th}$ perc | 5.63E+04 | 3.39E+04 | 6.77E+04 | 3.92E+04 | 4.73E+04 | 2.23E+04 |
| max | 1.40E+05 | 4.83E+04 | 1.40E+05 | 4.83E+04 | 6.17E+04 | 3.83E+04 |

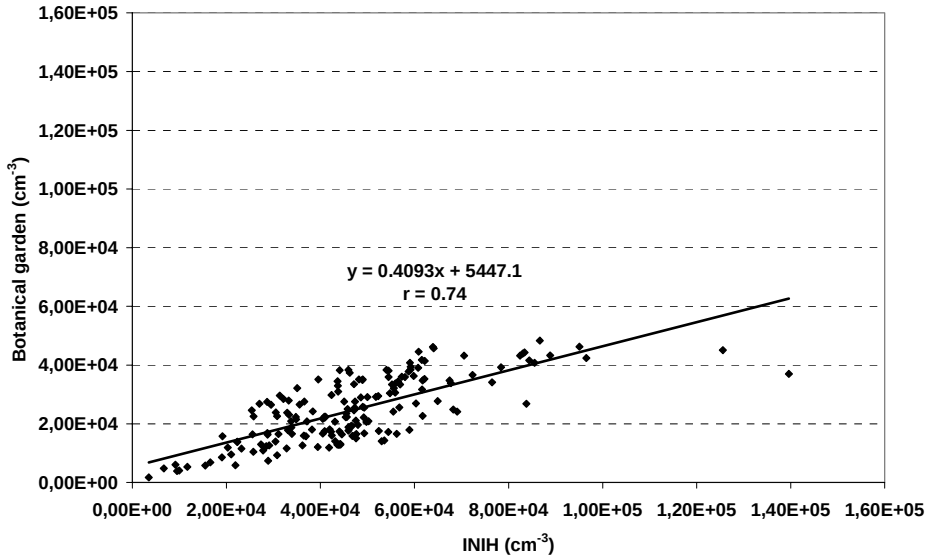


Figure 3. Correlation between daily average total concentration of particles measured at two sites (INIH – traffic- oriented and botanical garden - urban background). Number of pairs: 172. February 2002 through March 2003.

Figure 4 shows the diurnal variation of PNCs, from both sites. In both sites PNCs were very well correlated with the daily traffic flow, with highest mean values during rush hours between eight and nine a.m. and at around seven or eight p.m. Peak concentrations at the two sites followed the same pattern, but resulted higher at the traffic oriented site.

## DISCUSSION

From the results reported in Tables 1 and 2 it can be argued that the general seasonal pattern observed could be due to the weaker atmospheric convective processes in winter. This pattern for PNC, as well as for other traffic-related air pollutants, was found more pronounced during the cool season than in summer also in other studies (Wiedensohler et al. 2002; Jeong et al., 2004; Gomiscek et al., 2004). During winter the morning and evening PNC peaks at rush hours can be considered the result of the motor vehicle emissions combined with a lower mixing layer height and lower ambient temperature, which favours nucleation mechanisms, at least for particles with dimensions up to some tenths of nanometers (McMurry et al., 2002). The morning peak still present in summer months, but with lower absolute values of PNC than in winter, might be related predominantly to

particles directly emitted by traffic and to the more favourable conditions of atmospheric dispersion. The high correlation found between gaseous compound as CO, NO and $NO_x$ and PNC agrees essentially with other studies carried out in three European cities (Ruuskanen et al., 2001) and in Göteborg (Sweden) (Janhäll et al., 2004), in which it was shown that nitric oxide can be considered a better tracer of traffic related ultrafine particles, than traffic intensity itself. Moreover, in a recent study, significant correlation at street level was observed between CO, $NO_x$, and ultrafine particles in a street canyon, close to the central Copenhagen, indicating that the traffic is the major source of ultrafine particles in the air (Wahlin et al., 2001).

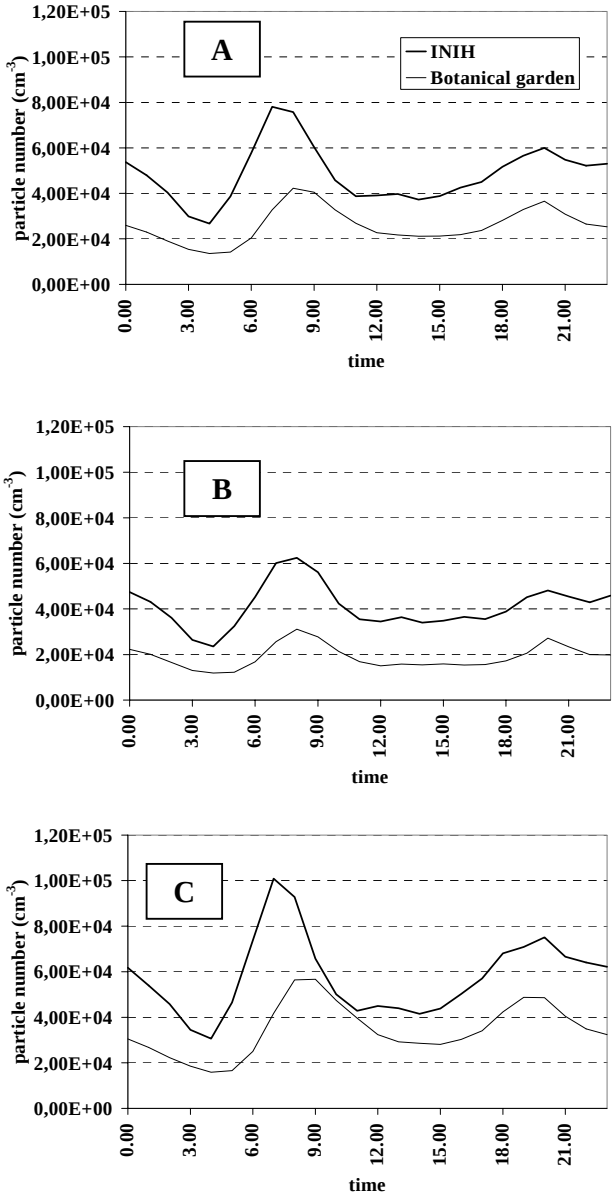


Figure 4. Diurnal variation of total number concentration of particles measured at two sites (INIH – traffic-oriented and botanical garden - urban background); A: all data available; B: spring-summer period; C: autumn-winter period.

These results underline the importance of the primary particles originating from road traffic. These particles are directly emitted during combustion processes and constitute a significant contribution to the total number of

particles in city centers (Ruuskanen et al., 2001; Jeong et al., 2004). This fact is highlighted by the strong correlation between PNC and the traffic flow during the day and the higher PNC at the traffic site. The significant correlation between PNC and CO and $NO_x$ concentrations may suggest that nucleation occurs as the exhaust mixes with the cool ambient air (Shi and Harrison, 1999). In these circumstances the formation of ultrafine particles could be attributed more to the direct emission than to the photochemical gas-to-particle conversion (Jeong et al., 2004).

The diurnal behaviour of the PNC with the two peaks at rush hours appeared to be caused mainly by the traffic variability during the day and by the height of the vertical mixing. The lower evening peak might be related to the increase of the height of the boundary layer later in the day or to the diurnal pattern of the relative amounts of petrol and diesel vehicles (Aalto et al., 2004).

The behaviour of the PNC at the urban background site follows a similar pattern, with the only difference of the lower absolute values of the concentrations.

The PNC difference between the two sites is probably due to the distance from emission sources, but the influence of the traffic is still significant, even at distances of some hundreds of meters from streets. The reason for the average decrease of about 50% at the urban background site, could be explained by the findings of the measurements carried out in Los Angeles (Zhu et al., 2002) and Copenhagen (Ketzel and Berkowitcz, 2004). In the first study the relative concentrations of CO, black carbon BC, and particle number tracked each other well as distance from the freeway increased. PNC (6-220 nm) decreased exponentially with downwind distance from the freeway. It was suggested that both atmospheric dispersion and coagulation contribute to the rapid decrease in particle number concentration and change in particle size distribution as the distance from the freeway increased. In the second study more emphasis is given to the dilution process with little alteration of the size distribution.

The values of the $PM_{2.5}/PM_{10}$ ratios obtained in this study confirm the results shown in several previous studies (Harrison et al., 1997; D'Innocenzio et al., 1998; Janssen et al., 1999; Marconi et al., 2000; Gomiscek et al., 2004). The higher value of this ratio in winter might reflect the increasing occurrence of particles from both nucleation and accumulation mechanisms combined with poor atmospheric mixing conditions. The decrease of the $PM_{2.5}/PM_{10}$ ratio during summer could be due to the contribution of the events of long range transport from the Sahara desert (more frequent in spring-summer), and to the resuspension of particles belonging to the coarse fraction, which is more pronounced during dry weather and better mixing conditions, normally occurring during summer months.

The poor correlation between PNC (where the particles in the ultrafine range, less than 0,1 μm, are predominant) and mass concentration of the respirable fraction of particulate matter, $PM_{2.5}$ (where a dominant contribution to the mass is due to the larger particle fractions) is consistent with the findings of a number of recent studies (Laakso et al., 2003; Stanier et al., 2004; Jeong et al., 2004).

## CONCLUSION

PNC, $PM_{2.5}$, $PM_{10}$, CO, $NO_x$, $NO_2$ and $O_3$ were continuously monitored in a traffic-related site and, simultaneously, PNC were measured at an urban background site in Rome. A clear seasonal and daily pattern was found, with higher 24-mean values during winter and peak concentrations during rush hours. The occurrence of the morning events tended to follow the typical pattern of mixing depths in winter, the season with the lowest mixing depth. These results underline the importance of the primary particles originating from road traffic. Although the absolute values found in the urban background site were lower (about 50%) than the values found in the traffic related site, they show a good correlation, suggesting dispersion of these particles also at relatively long distances from the primary sources (hundreds of meters). The magnitude of these findings needs more attention, because the selection of the sampling site could influence the classification of the pollution level (Aalto et al., 2004) and its use in epidemiological studies. On the other hand, a statistically significant association between PNC concentration and hospital admissions for myocardial infarction has been observed in Rome (Lanki et al, 2004). The modest correlation between PNC and currently measured mass-based aerosol indicators $PM_{2.5}$ and $PM_{10}$ suggests that ultrafine number concentration information from these indicators could not be inferred, so independent measurement systems are required if the relationships between health outcomes and ultrafine number concentrations are to be assessed.

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