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Spatial and temporal variation of particle number concentration in Augsburg, Germany

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Abstract

Epidemiological studies on health effects of outdoor air pollution are largely based on single monitoring site for estimating the exposure of people living in urban areas. For such an approach two aspects are important: the temporal correlation and the spatial variation of the absolute levels of concentrations measured at different sites in an urban area. Whereas many studies have shown small spatial variability of fine particles in urban areas, little is known on how well a single monitoring station could represent the temporal and spatial variation of ultrafine particles across urban areas.

In our study we investigated the temporal and spatial variation of particle number concentration (PNC) at four background sites in Augsburg, Germany. Two of them were influenced by traffic, one was placed in the outskirts of the city.

The average PNC levels at two urban background sites with traffic impact were 16,943 cm⁻³ and 20,702 cm⁻³, respectively, compared to 11,656 cm⁻³ at the urban background site without traffic impact (ratio 1.2 to 1.8). The Spearman correlation coefficients between the monitoring sites were high ($r > 0.80$).

The pronounced differences in absolute PNC levels suggest that the use of a single monitoring station in long-term epidemiological studies must be insufficient to attribute accurate exposure levels of PNC to all study subjects. On the other hand, the high temporal correlations of PNC across the city area of Augsburg implicate that in epidemiological time-series studies the use of one single ambient monitoring site is an adequate approach for characterizing exposure to ultrafine particles.

Keywords

particle number concentration (PNC); spatial variation; correlation coefficients; wind direction; epidemiological studies

1. Introduction

More and more epidemiological studies have been showing consistent associations between exposure to particulate air pollution in urban areas and increasing morbidity and mortality rates (Pope, 2000, Pope and Dockery, 2006). Most of these studies have used mass concentration of PM_{2.5} or PM₁₀ (particulate matter with an aerodynamic diameter smaller than 2.5 or 10 µm, respectively) to characterize particle exposure. There is, however, a number of studies suggesting that human health is even more impaired by ultrafine particles (UFPs, particles with diameters smaller than 100 nm) (Ibald-Mulli et al. 2002, Englert 2004, Delfino et al., 2005).

Epidemiological long-term and time-series studies investigating the association between particle exposure and health effects are largely based on a single monitoring site located somewhere in an urban background. Hence, a central exposure assessment issue is to learn how well particle concentrations are represented in a wider urban area if measured at one single centrally located site.

Studies in urban areas have shown that spatial variability for PM_{2.5} and PM₁₀ is generally small and temporal correlation measured at different sites is high (Monn, 2001). Hence, there is a consensus in the scientific community that a background station measuring PM_{2.5} and PM₁₀ mass concentrations could be regarded as representative for larger urban areas.

In contrast, exposure assessment for UFPs is still in its initial stage compared to exposure assessment for fine particles PM_{2.5} and PM₁₀ (Pekkanen and Kulmala, 2004; Sioutas et al., 2005). Compared to fine particles UFPs have shorter atmospheric lifetimes and are transported over shorter distances, so that they are less evenly distributed over a city area. Their atmospheric lifetimes are in the order of hours and can be even shorter in the vicinity of local particle sources with higher UFP concentrations (Pekkanen and Kulmala, 2004). It has been shown that there is a rapid decrease of PNC with increasing distance to a downwind freeway (Hitchins et al., 2000, Morawska et al., 2002, Zhu et al., 2002a, Zhu et al., 2002b, Weijers et al., 2004). With growing distance from the particle source, both atmospheric dilution and coagulation play an important role in the rapid PNC decrease. Kulmala et al. (2004) indicate that after nucleation, typical particle growth rates in mid-latitudes, depending on temperature and availability of condensable vapours, are in the range from 1–20 nm h⁻¹ (increase in physical diameter).

Due to their different physical properties, as described above, UFPs are supposed to have larger spatial and temporal variability than fine particles. Moreover, there are not many studies on temporal and spatial correlation of UFP across an urban area available (Buzorius et al. (1999), Hussein et al. (2005), Aalto et al. (2005), Tuch et al. (2006) and Puustinen et al., (2007)). Compared to exposure assessment of mass concentration of PM_{2.5} or PM₁₀ exposure assessment of UFP based on values measured at one single monitoring site is more error-prone (Monn, 2001, Pekkanen and Kulmala, 2004).

Based on the research platform KORA (Cooperative Health Research in the Augsburg Region) several epidemiological studies have successfully been carried out in the last years in Augsburg, Germany (Peters et al., 2005, von Klot et al., 2005). The exposure to fine and ultrafine particles was characterized by measurements taken at a central background monitoring site in a monastery garden. In 2004 the measurement station was reconstructed and moved to a place 2 km to the south of the center of Augsburg.

The current paper is evaluating the spatial and temporal variability of ultrafine particles at the “old” and “new” monitoring site, and two further urban background monitoring sites in Augsburg, Germany. It examines whether the selected background sites are representative for similar areas not only in the direct vicinity of the sampling point and discusses the use of one

monitoring site as an approximation for particle number concentrations over a wider urban area from the epidemiological point of view.

2. Methods

2.1. Study area and regional characteristics

The study was conducted in the city of Augsburg situated in Southern Germany. In 2005 Augsburg had approximately 261,000 inhabitants living in an area of 146.9 km². Between 1971 and 2000 the average temperature was −0.7°C in January, 17.8°C in June and annually 8.4°C. Southwesterly and northeasterly winds are prevailing. In the northeastern part of Augsburg small and middle-sized industrial entities are located. The terrain is moderately flat, being on average 490 m above sea level.

2.2. Measurement period and measurement sites

The measurements were conducted during two periods, from December 2 to 12, 2003 (winter period, 11 days) and from April 5 to May 12, 2004 (spring period, 38 days).

Lenschow et al. (2001) suggests following classification of the monitoring sites: regional background, urban background and urban traffic sites. For this study we selected four locations in an urban background environment three of them near the city center, one in the suburb (Figure 1). The first monitoring site was located in a monastery garden (MON), one kilometer to the north of the downtown area with the next minor road with low traffic intensity at a distance of 50 m, and the next major road at about 150 m. We placed the second monitoring site on the premises of the Fachhochschule Augsburg (FH, University of Applied Sciences Augsburg), approximately 1 km south to the city center with the nearest major road in the north-east at a distance of 100 m. The third monitor was placed at a square (Bourgesplatz, BOU), 2 kilometers to the north of the city center, the nearest road with low traffic intensity being 20 m away, and the nearest major road with a busy intersection about 100 m away in the northeast. For the fourth monitoring site (operated only during the winter measurement period) we chose a site in the outskirts of the city, on the premises of the University Augsburg (UNI). The nearest minor road with low traffic intensity is 100 m to the east, on the opposite side is a highway 600 m to the west. At each monitoring site samples were taken in a height of approximately 2 m, apart from UNI, where the sampling height was about 4 m.

All monitoring sites fulfilled the criteria for an urban background site as defined in the TRAPCA study on the impact of **Traffic-Related Air Pollution on Childhood Asthma**. In TRAPCA study urban background sites were those in which no more than 3000 vehicles per day typically pass through a circle of 50 meter radius around the measurement site. Within this circle no other significant source of particulate matter should be present (as e.g., construction works, small industries, district heating plant, parking lot/garage). Urban background sites should be located in mere residential areas, not within or near industrial regions (Hoek et al., 2002).

Not only the distance from the nearest local particle sources, but also the prevailing wind direction was considered by the classification of the monitoring site. The prevailing wind in Augsburg is southwesterly (57% in 2004) and none of the sampling sites has a major road lying in this direction in its vicinity. With 27% in 2004 the northeasterly winds rank second. Two of the monitoring sites (FH and BOU) might be partly influenced by a major road lying in this direction. That is the reason why we defined those two locations as “traffic influenced background sites”.

The meteorological station was located in an open area at the outskirts of Augsburg (Augsburg Haunstetten) about 1 km to the east from the UNI site. The measurement height there was 25

m above the ground. Hence, this site can be considered as representative for the whole examined area.

2.3. Measurement methods

To measure the particle number concentration (PNC) we used condensation particle counters (CPC, TSI Inc., USA) model 3022A and model 3025A. Model 3022A measures PNC in the size range from 7 nm to 3 μm (concentration range 0-10⁶ particles cm⁻³, concentration accuracy $\pm 10\%$ up to 5 $\times 10^4$ cm⁻³). Model 3025A measures PNC in the size range from 3 nm to 3 μm (concentration range 0-10⁴ particles cm⁻³, concentration accuracy $\pm 10\%$). The lower size range corresponds to the 50% detection limit of the respective device. Normally, ultrafine particles account for > 90% of number-based particle concentrations (Sioutas et al., 2005). For further details regarding the instruments please refer to Harrison et al. (1999) and Aalto et al., (2005).

The significant number of particles in the size fraction between 3 to 7 nm causes a difference between the PNC measured by CPC model 3022A and 3025A. For estimating of the difference we operated both CPC models (3022A and 3025A) in parallel: at MON site from June to November 2004 (124 days), and at FH site from September to November 2004 (70 days). The correlation between the two instruments was very strong at both sites: the Spearman correlation coefficient was 0.95 and 0.90 at MON and FH site, respectively. At MON site the mean ratio between CPC 3025A and CPC 3022A was 1.14 on a daily basis. A similar mean ratio (1.16) was estimated at the FH site. The similar values estimated at two different sites during two different measurement periods suggest that the PNC measured by model 3022A could be adjusted for the particle fraction 3-7 nm by a multiplying factor of 1.15.

PNC was measured every second by both CPCs and a half minute means were recorded. The half minute means were then validated visually using time series to delete outliers, afterwards the half minute means were converted into hourly averages which were considered valid if at least 66 % of the data were available. Meteorological parameters were recorded by the Bavarian Environmental Protection Agency in Augsburg-Haunstetten.

2.4. Statistical Methods

The temporal variation of PNC was determined by the Spearman correlation coefficients (r). The spatial variation was characterised by means of coefficients of divergence (COD) (Wongphatarakul et al., 1998) which are defined as

$$COD_{fh} = \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{x_{if} - x_{ih}}{x_{if} + x_{ih}} \right)^2} \quad (1)$$

where x_{if} is the i th concentration measured at the f th site, f and h represent two monitoring sites, n is the number of observations. The COD provides information on the degree of uniformity between monitoring sites. For the spatial distribution, the COD approaches zero if the measured values at two monitoring sites are similar. In contrast, the COD approaches unity if the measured values are quite different. All computations were made with the statistical software package SAS 9.1 for Windows.

3. Results

Table 1 provides the descriptive statistics of 1-hour average particle number concentrations for each measurement site (only hours with valid measurements for all sites were taken for the calculation) and each measurement period.

3.1. Winter period

During the winter period the lowest PNCs were measured at the UNI site ($15,272 \text{ cm}^{-3}$) and the highest at the FH site ($24,022 \text{ cm}^{-3}$). The PNCs measured at the two remaining sites (BOU and MON) were comparable and ranged between the levels observed at FH and UNI. The coefficients of divergence are shown in Table 2. The lowest CODs were observed between BOU site and MON site, the largest between UNI (remote site) and the other sites. It indicates that the difference between the PNCs measured at BOU and MON sites was negligible compared to that between the remote site (UNI) and the other urban background sites.

Figure 2a presents the time series of hourly PNC averages for the winter period. There is a pronounced daily variation of PNCs on each of the measurement sites. Especially between the 9th and 12th December high concentrations of PNCs were observed, associated with a rather low wind speed and wind blowing from the north-east during this sub-period. At all sites the PNCs followed the same pattern and strong correlations were observed at a The Spearman correlation coefficients on hourly and daily basis for the winter period are shown in Table 2. Almost all correlation coefficients exceeded 0.8. In general, correlations on daily basis were stronger than on hourly basis.

3.2. Spring period

Figure 2b shows the time series of hourly PNC averages for the spring period when the highest PNC levels were again observed at the FH site, followed by BOU and MON (Table 1). PNCs at FH site were almost twice as high as at MON site ($20,702$ vs. $11,656 \text{ cm}^{-3}$). The COD for particle number concentration between FH and MON sites was 0.32 on an hourly and 0.30 on a daily basis (Table 3). In spite of the differences in PNC levels, the inter-site correlations were strong ($r > 0.80$), both on daily as well as on hourly basis (Table 3).

3.3. Meteorological conditions and the temporal variation of NC

To investigate the influence of the wind direction on the spatial variation of PNC, we calculated the Spearman correlation coefficients for specific wind direction sectors separately. The wind direction sector width was set to 30° (12 sectors in total), hours with calm wind ($< 1 \text{ m s}^{-1}$) were excluded (6.4 % of the total number).

In general, two wind directions prevail in Augsburg, namely northeasterly and southwesterly. In 2004 2353 hours (i.e. 27 %) with northeasterly wind (30° - 120°) were recorded and 4870 hours (56 %) with southwesterly wind (180° - 300°).

No associations between the inter-site correlations and the wind direction have been seen in the winter period. It should be noted that for this period the distribution pattern of the wind direction differed significantly from the annual pattern; the north-east direction was overrepresented with the wind coming from there during 142 hours, i.e., 64 % of the whole winter period.

In the spring period, we observed wind coming from north-east during 297 hours (33 % of the total number) and from south-west during 456 hours (50 % of the total number). Figure 3 shows the Spearman correlation coefficients between the PNC levels calculated for each wind direction sector. The two prevalent wind directions in Augsburg are highlighted in gray. The inter-site correlations with regard to PNC levels were stronger for southwesterly than for northeasterly winds.

To investigate further effects of meteorological parameters on the inter-site correlation between PNC levels, all hourly observations were classified into three categories (high, medium and low) for wind speed and temperature, separately. To ensure equal distribution of the values

between the three categories, tertiles were used as cut-off values. For each category correlation coefficients were calculated separately. It was found that neither wind speed nor temperature affected the inter-site correlation between the PNC levels.

4. Discussion

In our study we estimated the spatial and temporal variability of PNC at four urban background monitoring sites in an urban area and evaluate the usefulness of one single monitoring site as an approximation for particle number concentrations in epidemiological studies.

According to the EU criteria on the location of the sampling points directed at the protection of human health, the sampling sites located at urban background should be representative of air quality in a surrounding area of several square kilometres (EU 1999). From the epidemiological point of view two aspects are important to meet the need of representativeness. For long-term studies the spatial variability (the differences in absolute levels of particles concentrations measured across the city area) should be considered. By contrast, the spatial variation do not bias the results of short term health effect studies (time-series studies), assumed that the temporal correlation of particles levels measured at different sites in the city is strong.

4.1. Spatial variability

We observed a pronounced gradient of PNC across the study area both during the winter and the spring measurement period. The CODs are in the same range for both periods. The largest differences in the PNC levels have been seen between the remote site (UNI) and the two other urban background sites. In the spring period, the levels of PNC were almost twice as high at the FH site compared to the MON site. Note that during 25 % of the spring measurement period the FH site was downwind a major road, this was not the case for the MON site. Apparently, higher traffic impact at FH is reflected in increased levels of PNC.

The pronounced differences in the absolute concentrations measured across the city area are in line with the results reported by other studies. Hussein et al. (2005) measured higher PNCs in the center of Helsinki ($23,908 \text{ cm}^{-3}$) compared to PNC levels observed at less urban traffic and suburban traffic sites ($20,627 - 12,828 \text{ cm}^{-3}$). The lowest PNC was measured at a suburban background site ($5,691 \text{ cm}^{-3}$). Recently Puustinen et al. (2007) reported on spatial and temporal variability of particle mass ($\text{PM}_{2.5}$ and PM_{10}) and PNC for four European cities: Amsterdam, Athens, Birmingham, and Helsinki. A central site was selected in every city and additional measurements were made at about 35 sites spread over the whole city area. The spatial variability within cities of the absolute concentrations between the sites was considerable higher for PNC than for $\text{PM}_{2.5}$ and PM_{10} . In Helsinki and Athens, the central monitoring site overestimated PNC at all satellite sites (urban background and traffic). A modest impact of major road nearby the central site couldn't be excluded. In Amsterdam and Birmingham, the central site resulted in modest over- and underestimation of the background satellite sites, whereas the PNC measured at traffic satellite sites were almost twice as much as at the central site. Puustinen et al. concluded that it is virtually impossible to characterize the city-average concentration of PNC with one site.

This indicates that the spatial resolution of exposure estimates with regard to PNC in cross-sectional studies should be improved in order to be able to attribute more accurate exposure levels to the study subjects. Future studies might consider different approaches of exposure assessment, e.g. modeling to better characterize population exposure or increasing of the number of monitors in order to cover the spatial variability in cities.

4.2. Temporal variability

The correlation coefficients between the different sites were similar for both measurement periods. The inter-site correlations for PNC were very strong, both in the short time scale (hourly basis) as well as in the daily time scale.

That there is a strong correlation on hourly basis (short time correlation) is largely due to a common diurnal PNC pattern that could be seen at all monitoring sites (data not shown). The similarity of the diurnal PNC pattern could be explained by the relatively homogeneously distribution of the main UFP sources (traffic and domestic heating) across the city area and dynamics of atmospheric motion also being the same for all sites. The strong influence of meteorological conditions on the UFP levels is supported by the high inter-site correlation on daily basis. The pronounced day-to-day variability in PNC could not be caused by traffic intensity being uniform for all working days. The PNC fluctuation on daily basis is mainly caused by meteorological conditions such as solar radiation, formation of the convectively mixed boundary layer (CBL) and wind conditions. Meteorological conditions influence nucleation processes which may produce a substantial portion of PNC, especially in background areas. The high correlation between the background sites shows that these processes are common for a whole urban area.

The median of the individual Pearson correlation coefficients between PNCs measured at the central monitor and at the satellite sites as reported by Puustinen et al. (2007) were 0.67 in Athens and Birmingham, and 0.76 in Amsterdam and Helsinki, thus being slightly lower than the correlations found in our study ($r > 0.80$). At least 25% of the selected satellite sites, however, show a similar strong correlation with $r > 0.8$ as found in our study.

The comparison with other related studies published previously (Buzorius et al., 1999, Hussein et al., 2005, Aalto et al., 2005) is possible under reservation, only. Whereas we selected mere urban background sites, measurement sites in the previous studies were referred to as traffic sites or were not classified at all in this respect. Hussein et al. (2005), for example, showed a strong correlation ($r > 0.80$) between two traffic sites, other correlations observed in this study, however, were much weaker (0.45 – 0.65). Though Buzorius et al. (1999) provide information about the distance to a major road; they do not classify the measurement locations with regard to traffic or urban background. As some of the sites are located at opposite sides of the same road, it is not possible to clearly classify the sampling sites without better knowing the prevailing wind direction. As shown by numerous studies (Hitchins et al., 2000, Zhu et al., 2002a, Zhu et al., 2002b, Weijers et al., 2004), there is a large differences in UFP concentrations between the upwind and downwind side of a major road.

The importance of accurately classifying the type of site is supported by the study published by Tuch et al. (2006). In this study, PNCs were measured at an urban background site and at a traffic site located in a street canyon with a distance of only 1.5 km between them. Correlation coefficients ranged from 0.35 to 0.46 depending on the particle size range which demonstrated that one can expect only low temporal correlation for measurement sites located in such different micro-environments. It shows clearly, that the choice of the sampling point location (background or traffic related) is one major issue when employing ambient air quality data for assessing health effects. For this reason EU guidelines (EU 1999) require measurement sites to be placed: (i) to provide data on the areas where the highest concentrations occur to which the population is likely to be exposed (traffic sites, hot spots) and (ii) to provide data on levels in other areas which are representative of the exposure of the general population (background sites).

4.3. Meteorological conditions and the temporal variation of PNC

The short time correlations between PNC levels at different monitoring sites were influenced by the direction of the wind, but not by its speed or by temperature. The highest inter-site correlations in the spring period were associated with southwesterly winds. Although this wind is pushing the air masses over the city center (especially at MON and BOU sites), PNCs were nevertheless relatively low. Higher PNCs were correlated with northeasterly winds, which push air masses over some industrial areas in the north of the city. Traffic impact on the BOU and FH measurement site should be also stronger for this wind direction. The correlation coefficients associated with this wind direction (north-east), however, were somewhat lower compared with wind blowing from south-west. It suggests that the influence of some strong local sources could weaken the influence of local traffic, which is more homogenously distributed in a whole urban area.

One of the major limitations of this study is that the measurement periods were relatively short (11 days in the winter and 38 days in the spring period) what leads to the question how representative are these periods for the whole year. The comparison of the meteorological parameters during the two measurement periods with annual averages for the whole year 2004 shows, however, that the spring period could be considered as nearly representative for the whole year, while the winter period was more specific (data not shown).

It should be noted that the results of our study depend on several local factors, such as geographical and topographical conditions, the urban planning and building structure of the city, the prevailing wind direction, location of the local particle sources, and the long range transport of particles. For this reason we hesitate to generalize the results for cities or areas with different topographical and meteorological conditions.

5. Conclusions

The PNCs measured at different background locations in Augsburg, Germany were not homogenously distributed over the study area. This indicates that one fixed measurement site is not a good approximation for absolute values of PNC over a whole urban area with geographical and topographical characteristics similar to those of Augsburg. Consequently, for future long-term epidemiological studies one should consider to approach estimates of the overall community UFP exposure in a different way. For example, one might include spatial variability modeling of PNC and/or increase the number of monitoring sites. The last conclusion is consistent with previous suggestions made by Harrison and Deacon (1998) and Puustinen (2007); meaning that in epidemiological studies assessing health effects in relation to long-term average exposure one should set up a large number of monitors to cover the spatial variability in cities.

On the other hand, high correlation of PNCs has been observed at urban backgrounds as well as at suburban sites within Augsburg. This implies that temporal variation of PNCs is being caused by varying emissions and meteorological conditions which are similar for the whole city area and it could be reflected by one central monitoring site. It suggests that using one carefully chosen monitoring site might be a proper approach to characterize adequately exposure to UFP in epidemiological time-series studies (short-term effect studies).

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Figure 1.

Map of air pollution measurement sites in Augsburg, Germany. BOU is Bourgesplatz; MON is Monastery garden; FH is Fachhochschule; UNI is University of Augsburg.

Figure 2.

Figure 2a: Particle number concentrations at different monitoring sites during the winter measurement period (December 2 - 12, 2003) in Augsburg, Germany.

Figure 2b: Particle number concentrations at different monitoring sites during the spring measurement period (April 5 - May 12, 2004) in Augsburg, Germany.

Figure 3. The Spearman correlation coefficients between the particle number concentrations measured at different monitoring sites separated by wind direction sectors. The two prevalent wind directions in Augsburg are highlighted in gray.

Table 1

Descriptive statistics of the hourly NC (cm^{-3}) levels measured in the winter period (December 2 - 12, 2003) and in the spring period (April 5 - May 12, 2004).

Abbreviation	Item	N	Mean	Median	10th percentile	90th percentile	N	Mean	Median	10th percentile	90th percentile
MON	NC	227	2021 ^a	1654 ^a	560 ^a	3843 ^a	844	11629 ^a	9394 ^a	5625 ^a	19653 ^d
FH	NC	227	24022	19375	5820	45140	844	20662	18414	9930	35320
BOU	NC	227	20299 ^a	16719 ^a	5401 ^a	39541 ^a	844	16905	15052	6932	29991
UNI	NC	227	15272	10816	2951	33472	-	-	-	-	-

^a measured values were corrected by a factor of 1.15 (see section 2.2.)

Table 2

Coefficients of divergence (COD) and Spearman correlation coefficients (r) of NC in the winter period (December 2-12, 2003). Hourly means are in bold type and daily means in regular style.

COD (spatial)	MON	FH	BOU	UNI
MON	0	0.16^a n=227	0.16 n=239	0.25^a n=228
FH	0.13 ^a n=9	0	0.20^a n=236	0.31 n=236
BOU	0.09 n=10	0.11 ^a n=9	0	0.31^a n=252
UNI	0.22 ^a n=9	0.31 n=9	0.28 ^a n=10	0
r (temporal)	MON	FH	BOU	UNI
MON	1	0.92 n=227	0.89 n=239	0.91 n=228
FH	0.95 n=9	1	0.84 n=236	0.88 n=236
BOU	0.89 n=10	0.87 n=9	1	0.77 n=252
UNI	1.00 n=9	0.95 n=9	0.89 n=10	1

^a COD was calculated for the NC values corrected by a factor of 1.15 (see section 2.2.)

Table 3

Coefficients of divergence (COD) and Spearman correlation coefficients (r) of NC in the spring period (April 5 - May 12, 2004). Hourly means are in bold type and daily means in regular style.

COD (spatial)	MON_NC	FH_NC	BOU_NC
MON_NC	0	0.32^a n=866	0.24^a n=848
FH_NC	0.30 ^a n=36	0	0.18 n=886
BOU_NC	0.20 ^a n=35	0.15 n=37	0
r (temporal)	MON_NC	FH_NC	BOU_NC
MON_NC	1	0.81 n=866	0.81 n=848
FH_NC	0.85 n=36	1	0.83 n=886
BOU_NC	0.86 n=35	0.86 n=37	1

^aCOD was calculated for the values corrected by a factor of 1.15