

Pilot Monitoring of Ultrafine Particle Number Concentrations in some Households in Hanoi



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Abstract

Purpose / Context - Epidemiological studies have consistently shown that fine and course airborne particles ($PM_{2.5}$ and PM_{10}), as well as ultrafine (UF) particles measured in terms of particle number (PN) concentrations, are toxic to human health. A number of studies on particle concentrations in households were conducted worldwide; however, no such studies have so far been conducted in Vietnam.

Methodology / Approach - Using two Nano-Tracers, the authors have simultaneously and continuously measured both indoor and outdoor number concentrations of UF particles at one low rise residential house and one apartment at a high rise building in Hanoi in order to quantify the concentrations and develop an understanding of factors driving them.

Results - Daily average indoor and outdoor PN concentrations ranged from 14.5 to 19.8×10^3 p/cm^3 and from 33.4 to 35.5×10^3 p/cm^3 , respectively. However, mean concentrations of indoor and outdoor PN during rush-hours were higher and increased up to the maximum of 23.1 and to 57.8×10^3 p/cm^3 , respectively.



Tran Ngoc, Q. DOI: <http://dx.doi.org/10.4225/50/58107adf661f1>

HealthyHousing2016: Proceedings of the 7th International Conference on Energy and Environment of Residential Buildings, November 2016, edited by Miller, W., Susilawati, C. and Manley, K. Brisbane: Queensland University of Technology, Australia. DOI: <http://dx.doi.org/10.4225/50/58107c8eb9c71>

Key findings / Implications - Inspection of time series of particle concentration and subsequent statistical analysis showed that outdoor PN concentrations were strongly influenced by the outdoor vehicle emissions, while indoor PN concentrations were contributed by both indoor and outdoor sources.

Originality – It is the first time, UF particle number concentrations outside and inside the residential houses in Hanoi were quantified. Outdoor particle concentrations were found strongly influenced by vehicle emissions, while indoor particle levels affected by both indoor and outdoor sources.

Keywords – ultrafine particle, household, traffic, indoor activities.

1. Introduction

Air pollution is considered to be one of the major environmental risks to human health and can cause numerous kinds of diseases, especially respiratory diseases such as asthma, sinusitis, bronchitis, pneumonia, lung cancer and others related to the heart, as well as the nervous, circulatory and digestive system. Epidemiological research has consistently shown an association between fine ($<2.5 \mu\text{m}$; $\text{PM}_{2.5}$) particle concentrations and increases in both respiratory and cardiovascular morbidity and mortality (Pope 2000, Schwartz and Neas 2000, Davidson, Phalen et al. 2005). The health effects of ultrafine ($<0.1 \mu\text{m}$) particles are less well known, however research to date indicates that they may be equally or more detrimental than those of $\text{PM}_{2.5}$ and PM_{10} (Oberdorster 2000, Franck, Odeh et al. 2011).

The amount of fine and ultrafine particles in the urban atmosphere is mainly influenced by vehicle exhaust emissions during the traffic peak hours (Pey, Rodriguez et al. 2008, Perez, Pey et al. 2010, Quang, He et al. 2012). High outdoor particle concentration can reach the interior of buildings via penetration through their envelopes (Thornburg, Ensor et al. 2001). At the same time, indoor activities, such as movement of building occupants, cooking can also affect and increase indoor particle concentrations (Abt, Suh et al. 2000, Long, Suh et al. 2000, He, Morawska et al. 2004, Mazaheri, Clifford et al. 2013, Mazaheri, Reche et al. 2016). The high indoor particle level may impose adverse health effects on the building occupants, especially for households where retired people spend almost all their time inside home. Several studies related to particle mass concentration have been conducted in Hanoi (Hien, Bac et al. 2002, Kim Oanh, Upadhyay et al. 2006, Saksena, Quang et al. 2008, Cohen, Crawford et al. 2010) but so far no study on ultrafine particle number monitoring in Hanoi have been published.

To help addressing the gap in knowledge about ultrafine particle concentrations in developing countries and Hanoi, Vietnam in particular, this pilot study was set up with the aim to: (1) quantify the indoor and outdoor UF particle number concentration in one low rise residential house and one apartment at a high rise building in Hanoi; and (2) initially evaluate factors influenced UF particle concentrations at these residential houses.

2. Methods

2.1. Study area and measured locations

Hanoi is located in Red River Delta in North Vietnam (21.02°N , 105.85°E), about 100 km west of the East Sea of Vietnam. Hanoi has 30 urban and sub-urban districts with the area of 3345 km^2 and the population of 7.2 million (Vietnamese statistic book, 2015). Central of Hanoi is boundary by the ring-road No3, where various new urban areas are being constructed.

The climate in Hanoi is representative for northern climate in Vietnam. The characteristics of the tropical monsoon climate are warm, hot and rainy summers (May to August), cold and dry winters (November to January). Located in the tropical site, Hanoi receives an abundant solar radiation and high temperature. The average amount of radiation in Hanoi is 122.8 kcal/cm^2 and average temperature is 23.6°C . Due to the influence of the sea, Hanoi humidity and rainfall is quite large. The annual humidity is 79%. Average annual rainfall is 1.800mm and every year, there are approximately 114 days of rain. It is obvious to see the change between seasons in Hanoi.

In Hanoi, motorbikes are the main transport mode that people use for travelling. In the beginning of 2016, the total number of registered motorbikes and cars reached 5 million and 1 million units, respectively. The number of motorbikes and cars in Hanoi has increased rapidly in recent years, surpassing the growth rates of population, GDP, and the growth of automobiles will continue to grow for years ahead.

We selected one low rise residential house and one apartment at a high rise building to measure, and named them as site S1 and S2, respectively. Two selected sites have retired grandparents living in, especially, they were at home during the measurement.

Sites S1 is a four storey residential houses, locate in the new urban area in the southern of Hanoi. They are about 20 m from the city ring-road and 50 m from the elevation free way No3 with a total daily traffic volume of about 83 000, consisting of 52 000 motorcycles.

Site S2 is an apartment at high rise buildings. It locates in the eight floor and its main elevation faces to a national express way with only four wheel vehicle volume per day of about 74 000. The distances from site S2 to the main road are about 50 m wide and 30 m high.

2.2. Instrumentation and quality assurance

Two Philips Aerasense NanoTracers (NTs) were used to measure UF particles continuously and simultaneously indoor and outdoor of each households for at least 48 h. In brief, NT measures particle number (PN) concentrations up to $1 \times 10^6 \text{ p/cm}^3$ in the size range of 10 to 300 nm and it also provides an indication of mean particle diameter. If operated in Advanced mode, it measures both UF particle number concentration and average particle diameter at a fixed sampling interval of 16 s. Details of design and operational procedures for the NT are available elsewhere (Marra, Voetz et al. 2010)

The NT's time stamp was synchronised to the local time using the Nano Reporter software prior to each measurement. The NTs were tested at the International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, Australia prior to their shipment to Hanoi, Vietnam. The two NTs ($n = 1,2$) used in this study were run side by side with a TSI model 3787 condensation particle counter (CPC) in order to calibrate the instruments the same way, and ensure the readings from each NT were directly comparable. The correction factors were derived using the following equation: where, C_{CPC} and C_{NTn} refer to the concurrent total particle number concentrations in the ambient air, as measured by the CPC and the NTs.

2.3. Sample sites and measurement procedures

Two NTs were used to measured UF particle number concentrations. One measured continuously at the outside of each household. The second measured simultaneously inside the rooms of this house. At the same time, a data logging sheet was supplied to a house member; and requested him/her to fill the sheet when any inside activity occurred. The logging sheet then was collected for data interpretation.

Site 1

One NT continuously measured at level 4 for catching up outdoor concentration. The other measured simultaneously inside a tightly closed and un-occupancy bedroom at level 3 from 16:30, 7 Jan to 16:30, 8 Jan 2016; then in dining combined with kitchen room at ground floor from 17:00, 8 Jan to 17:30, 9 Jan 2016.

Site 2

One NT continuously measured at a balcony of level 8, about 30m high catching up outdoor UF particle number concentration. The other measured simultaneously at the same level inside a combined living and dining room from 21:30, 9 Jan to 18:30, 13 Jan 2016.

2.4. Ambient PM_{2.5} concentrations

Hanoi has seven automatic air quality monitoring (AAQM) stations. However, only one in Gia Lam District is still working, but its data during our site campaign was unable to access. Therefore, we obtained average hourly PM_{2.5} concentrations, which monitored at and by US embassy in the centre of Hanoi, and about 5 - 7 km from the survey sites for reference ambient PM_{2.5} concentration.

2.5. Data preparation and analysis

Data from the NTs were downloaded after each measurement and multiplied by the corresponding NT correction factors. The corrected data were grouped according to their location and time period.

2.6. Statistical techniques

All statistical analyses were performed with SPSS version 20 (SPSS Inc.), with a 5% level of significance ($p < 0.05$).

3. Results and discussion**3.1. Referenced ambient PM_{2.5} concentrations in Hanoi**

A summary of the descriptive statistics for relevant Hanoi ambient PM_{2.5} concentrations during the each site survey and whole period from 7 Jan 2016 to 13 Jan 2016 is presented in Table 1. Average concentration is $59.2 \pm 12.1 \mu\text{g}/\text{m}^3$, which is higher than annual mean concentration of $(36.1 \pm 1.3) \mu\text{g}/\text{m}^3$ reported by Hien et al. (2002). Actually, our measure period is during dry season, when Hanoi recorded high PM levels due to climate and atmospheric conditions both do not support the vertical dispersion there (Hien, Bac et al. 2002). However, the ambient PM_{2.5} concentration was significant lower than those measured at residential site, $200 \mu\text{g}/\text{m}^3$ (Kim Oanh, Upadhyay et al. 2006).

Table 1: Statistic description of PM_{2.5} ambient concentrations ($\mu\text{g}/\text{m}^3$)

Measured site	S1	S2	Average
Time period	7-9 Jan	9-13 Jan	7-13 Jan
Mean	64.8	57.2	59.5
SD	7.3	13.2	12.1
Max	77.5	82.1	117.2
Min	52.7	42.1	28.1

3.2. Quantification and assessment of factors influenced UF particle number concentrations in Hanoi

A summary of the descriptive statistics for outdoor and indoor UF particle number concentrations and their I/O ratio at each site for whole period as well as during rush-hour and non-rush-hour are presented Table 2. Time series variations of outdoor and indoor UF particle number concentrations at each site are showed in Figures 1 and 2.

In general, average outdoor UF particle number concentrations measured in two sites Hanoi were from $(33.4 - 35.5) \times 10^3 \text{ p/cm}^{-3}$, which were significantly higher than those measured at the outside of three office buildings closed to busy streets in Brisbane, Australia (Quang, He et al. 2013). Outdoor PN levels during rush-hour periods were significantly higher than other periods at both sites ($p < 0.05$). The higher PN concentrations at both sites in Hanoi compared to those in Brisbane could be explained by the close distance of the measured site to the busy ring-road and national express way. On the other hand, farming crop burnings occurred around the high rise building, where site 2 located contributed to outdoor PN concentration there.

Comparing indoor and outdoor PN concentrations, overall 24-h average outdoor particle concentrations were significantly higher than indoor concentrations for both sites ($p < 0.01$). I/O ratios of PN concentrations at all sites were significantly lower than 1 ($p < 0.01$).

Two special events related to indoor particle emissions were reported by house owners. Firstly, measured PN levels rose exponentially. at site 1 and during cooking activities, including roasting peanuts using micro-oven, when the indoor NT was moved from the bedroom to the kitchen. Secondly, at site 2, during midnight at 1:30 am on 13rd Jan, indoor particle concentration in the dining room suddenly increased. The house owner was inquired about that, and he did remember that he got up early to watch a European Champion League football match. Feeling hungry, he operated the micro-oven to cook instant noodle.

At site S1, indoor NT was used to monitored UF particle level in a tight, un-occupancy bedroom from 16:30, Jan 7th 2016 to 16:30, Jan 8th 2016. Results showed that I/O ratios of PN concentrations at this room was 0.31 ± 0.08 and significant lower than other room. It implied that tighter room or low infiltration ventilation concentration can significant reduced the influence of outdoor particles indoor.

Table 2: Summary of UF particle number concentrations at measured sites S1 and S2

	Whole period			Rush-hour			Non Rush-hour		
	Indoor	Outdoor	I/O ratio	Indoor	Outdoor	I/O ratio	Indoor	Outdoor	I/O ratio
Site S1									
Mean	14479	33338	0.45	19946	35617	0.51	13074	31134	0.43
SD	7567	9570	0.20	12359	9665	0.35	4832	8957	0.13
Max	68384	91167	1.79	68384	91167	1.79	30489	59738	0.92
Min	7744	17100	0.11	8756	23064	0.11	7744	17100	0.19
Site S2									
Mean	19863	35514	0.87	23061	57808	0.79	18972	29301	0.89
SD	8727	57471	0.35	8126	73913	0.41	8684	50295	0.33
Max	93441	1016967	2.35	48736	397551	1.74	93441	1016967	2.35
Min	6399	7128	0.04	10597	9940	0.06	6399	7128	0.04

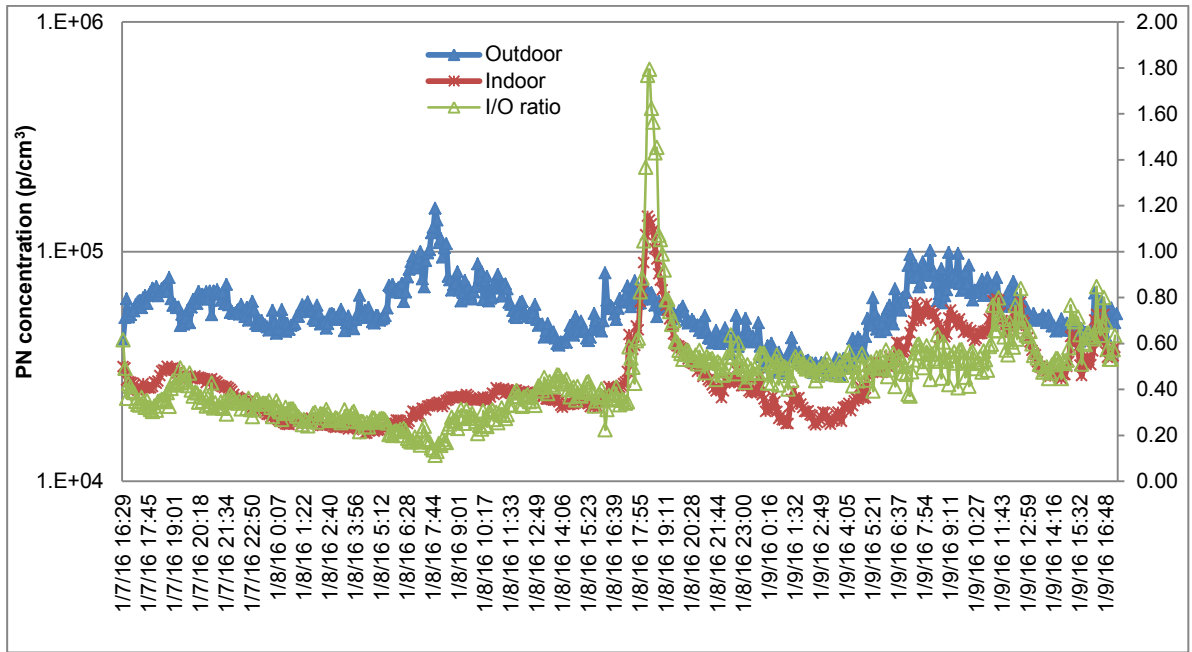


Figure 1: Time-series of indoor and outdoor UF particle number concentrations at the site S1.

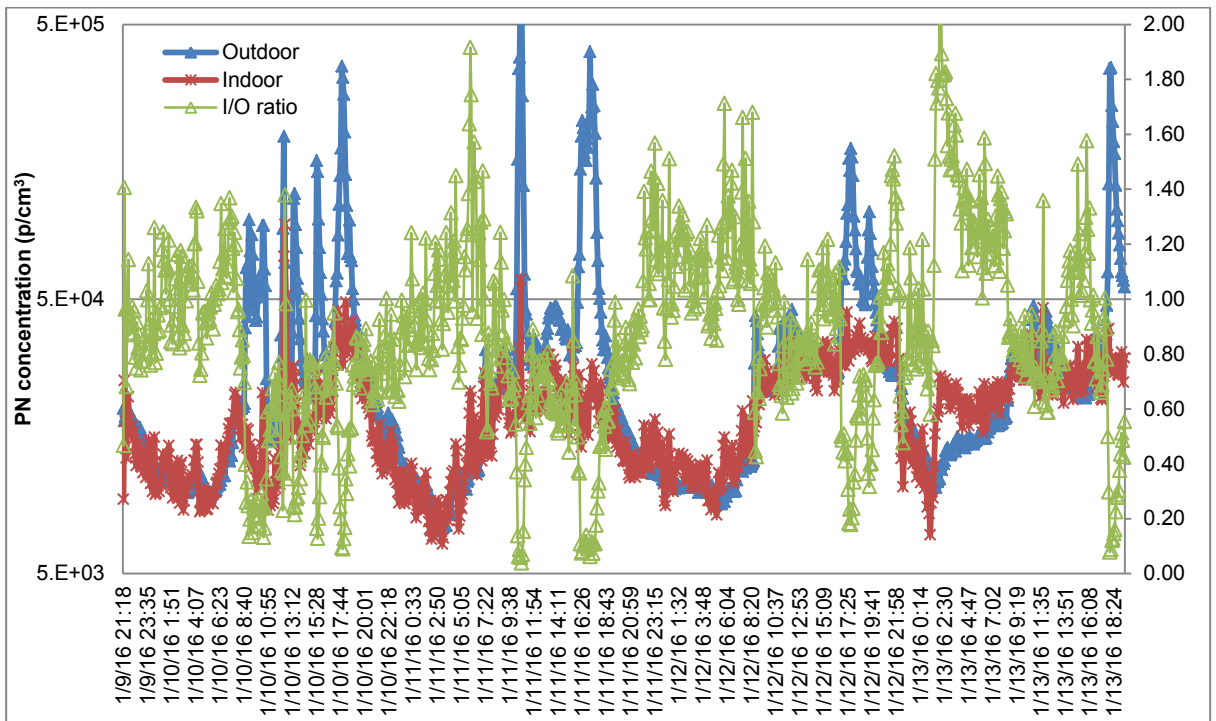


Figure 2: Time-series of indoor and outdoor UF particle number concentrations at the site S2.

4. Conclusions

The first time, UF particle number concentrations were measured at the residential houses in Hanoi. Both indoor and outdoor particle concentrations were quantified and compared with other published results. This preliminary research indicated that vehicle emissions strongly influenced outdoor particle concentrations. At the same time, both outdoor and indoor sources contribute to the concentrations of indoor particles.

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