PILOT MONITORING OF ULTRAFINE PARTICLE NUMBER CONCENTRATIONS IN SOME HIGH RISE APARTMENTS IN HANOI

Tran Ngoc Quang[1], Nguyen Thi Hue[2]*

***Summary**: 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. Using two Nano-Tracers, the authors have simultaneously and continuously measured both indoor and outdoor number concentrations of UF particles at two high rise apartments in Hanoi in order to quantify the concentrations and initially develop an understanding of factors driving them. Daily average indoor and outdoor PN concentrations ranged from 12.9 to 19.8 x 10^3 p/cm^3 and from 21.3 to 35.5 x 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 24.0 and to 57.8 x 10^3 p/cm^3, respectively. Inspection of time series of particle concentration and subsequent statistic 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. It is the first time, UF particle number concentrations outside and inside the high rise apartments in Hanoi were quantified.*

***Keywords**: Ultrafine particle; high rise apartment; traffic; indoor activities.*

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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 μm; $PM_{2.5}$) particle concentrations and increases in both respiratory and cardiovascular morbidity and mortality [1-3]. The health effects of ultrafine (<0.1 μm) particles are less well known, however research to date indicates that they may be equally or more detrimental than those of $PM_{2.5}$ and PM_{10} [4-5].

The amount of fine and ultrafine particles in the urban atmosphere is mainly influenced by vehicle exhaust emissions during the traffic peak hours [6-8]. High outdoor particle concentration can reach the interior of buildings via penetration through their envelopes [9]. At the same time, indoor activities, such as movement of building occupants, cooking can also affect and increase indoor particle concentrations [10-14]. The high indoor particle level may impose adverse health effects on the building occupants, especially for households where retired people and children spend almost of their time inside home. Several studies related to particle mass concentration have been conducted in Hanoi [15-18] 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 Hanoi, Vietnam, this pilot study was set up with the aim to: (1) quantify the indoor and outdoor ultrafine particle number concentration in two different high rise apartments in Hanoi; and (2) initially evaluate factors influenced UF particle concentrations at these apartments.

[1] *Dr, Faculty of Environmental Engineering. National University of Civil Engineering (NUCE).*
[2] *ME, Faculty of Environmental Engineering. National University of Civil Engineering (NUCE).*
** Corresponding author. E-mail: quangtn@nuce.edu.vn.*

2. Methods

2.1 Study area

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 3324,5 km^2 and the population of 7.26 million [19]. Central of Hanoi is boundary by the ring-road No3, where various new urban areas are being constructed.

In Hanoi, motorbikes are the main transport mode that people use for travelling. In the first eight months of 2015 the capital saw 183,000 newly-registered vehicles (over 39,000 motor cars and 143,000 motorcycles), bringing the total number to 5.5 million (nearly 535,000 motor cars and over 4.9 motorcycles) [20]. 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. In which, many old and even expired vehicles are still circulating on the road. At the same time, the control of motorcycle emission is not regulation in Vietnam now.

Recently, the number of high rise apartments have been increasing rapidly to satisfy the living demand of high population increasing in Hanoi. Of which, many buildings locate closed to busy traffic roads.

We selected two different high rise apartments to measure, one in the Phap Van urban area, other in Duong Noi urban area and named them as site S1 and S2, respectively. Site S1 locates in the eight floor of the high rise apartment No 22, Phap Van urban area. The building is closed to the National Express way No1B with only four wheel vehicle volume per day of about 34 000 [21]. Around S1, farmer grow crops, they usually burn leaves to produce fertilizer. Sites S2 locates in the twelve floor of the high rise apartment CT7B, Duong Noi urban area. The building locates behind CT7A building, which close and parallel with To Huu street with a total daily traffic volume of about 25 000, of which 8 000 vehicles [21].

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 x 10^6 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 [22].

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:

$$CF_n = \frac{C_{CPC}}{C_{NTn}}$$

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. The instrument operates in advanced mode, with 16s sampling intervals allowing for measurement of both PN and mean particle diameter. One measured continuously at the outside of each household. The other 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 a balcony of level 8, about 26 m height and 125 m from the National Express Way No1B, 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. Locations of samples at Site 1 are shown in Figure 1.

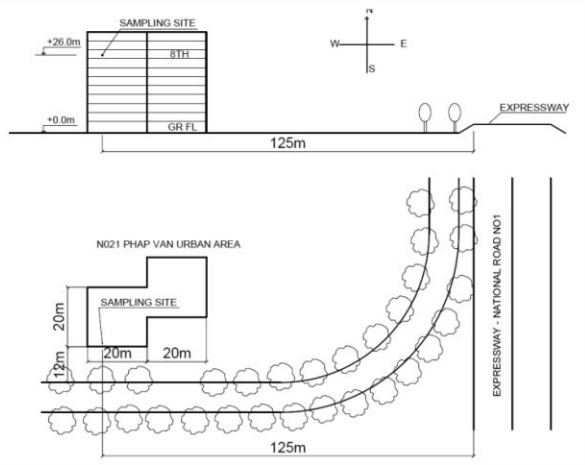

Figure 1. *Location of samples at site S1*

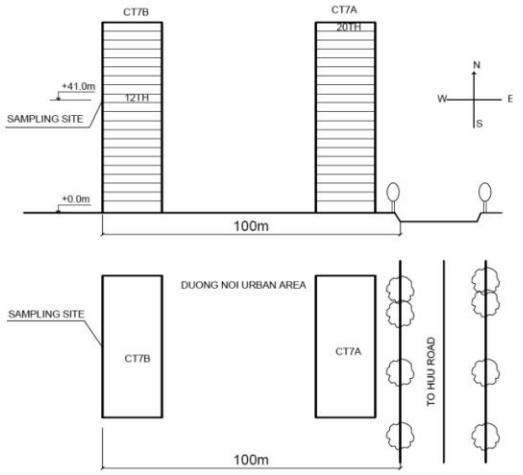

Figure 2. *Location of samples at site S2*

Site 2

One NT continuously measured at a balcony of level 12, about 41 m height and 100 m from To Huu street, catching up outdoor UF particle number concentration. The other measured simultaneously at the same level and inside a combined dining and kitchen room from 21:30, 13 Jan to 13:30, 16 Jan 2016. Locations of samples at Site 2 are shown in Figure 2.

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

3. Results and discussion

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 in Table 1. Time series variations of outdoor and indoor UF particle number concentrations at each site are showed in Figures 3 and 4.

In general, average outdoor UF particle number concentrations measured at two sites in Hanoi were from (21.3 – 35.5) x 10^3 p/cm^{-3}, which were significantly higher than those measured at the outside of three office buildings closed to busy streets in Brisbane, Australia [23-24]. 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 ($p < 0.01$).

Both indoor and outdoor PN concentrations at site S1 were significantly higher than those at site 2. In addition, the fluctuation of outdoor PN concentrations was larger at site S1 compared to site S2. It could be explained that the outdoor sample at site S1 is directly faced to South-East wind from the National Express way with high vehicle density. While the outdoor sample at site S2 was located higher than S1, and at the rear of the building. On the other hand, the traffic density at To Huu was likely lower compared to National Express way No1. These implied the outdoor PN concentrations were stronger influenced by the traffic emissions.

Based on the time series data, the indoor PN concentrations were some time higher than those outside at both sites, but mainly at early morning or late afternoon (from 6:00 to 7:00 am or 4:00 to 5:00 pm, respectively). It could be understood that some cooking activities during these times contributed to indoor PN levels. Both of them use gas to cook.

One special events related to indoor particle emissions was reported by a house owner at site 1, during midnight at 1:30 am on 13rd Jan, indoor particle concentration in the dining room suddenly increased, measured PN levels rose exponentially. 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.

Table 1. *Summary of UF particle number concentrations (p/cm^3) 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	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
Site S2									
Mean	12906	21272	0.60	13918	23970	0.63	12587	20992	0.60
SD	6320	7753	0.09	4536	6141	0.07	6758	8008	0.09
Max	103165	99544	2.02	27733	42797	1.17	103165	99544	2.02
Min	4514	7672	0.45	4630	12542	0.52	4514	7805	0.45

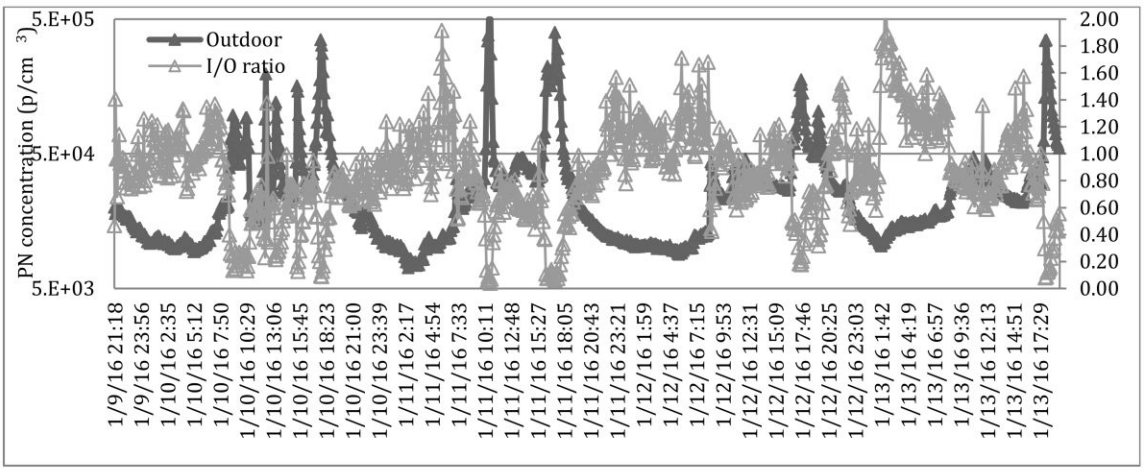

Figure 3. *Time-series of indoor and outdoor UF particle number concentrations at site S1*

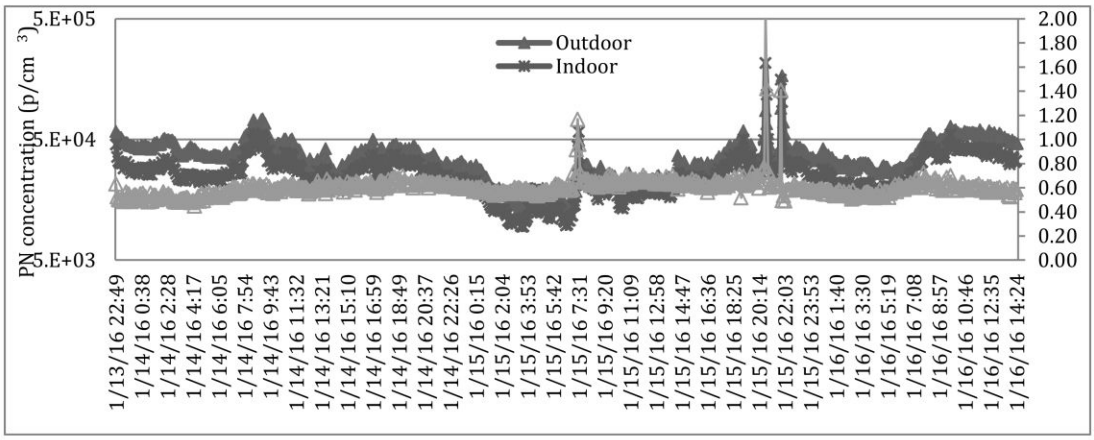

Figure 4. *Time-series of indoor and outdoor UF particle number concentrations at site S2*

4. Conclusions

The first time, UF particle number concentrations were measured at the high rise apartments 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.

Based on the primary results, the research should keep doing for different types of public and private buildings to catch up a general picture of ultrafine PN levels, as well as to determine clearer factors driving ultrafine particle concentrations in Hanoi.

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