Children indoor exposures to (ultra)fine particles in an urban area: comparison between school and home environments

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Abstract

Due to their detrimental effects on human health, the scientific interest in ultrafine particles (UFP) has been increasing but available information is far from comprehensive. Children, who represent one of the most vulnerable groups of society, spend the majority of their time in schools and homes. Thus, the aim of this work is to assess indoor levels of particle number concentrations (PNC) in ultrafine and fine range at school and home environments and to compare the indoor respective dose rates for 3–5 years old children. Indoor particle number concentrations in range of 20–1000 nm were consecutively measured during 56 days at two preschools (S1 and S2) and three homes (H1–H3) situated in Porto, Portugal; at both preschools different indoor microenvironments (classrooms, canteens) were evaluated. The results showed that the total mean indoor PNC (determined for all indoor microenvironments) were significantly higher ($p < 0.05$) at S1 than at S2. At homes the indoor levels of PNC (with means ranging between $1.09 \times 10^4$ and $1.24 \times 10^4$ particles cm$^{-3}$) were 10–70% lower than total indoor means of preschools ($1.32 \times 10^4$ to $1.84 \times 10^4$ particles cm$^{-3}$). Nevertheless, estimated dose rates of particles were at homes 1.3–2.1 times higher than those of preschools, mainly due to longer period spent at home. Furthermore, daily activity patterns of 3–5 years old children significantly influenced overall dose rates of particles.

Keywords: (Ultra)fine particles, children, indoor air, schools, residential environment, exposure.
INTRODUCTION

During the last two decades, there has been considerable interest in the health effects of exposure to airborne particulate matter (Brunekreef et al., 2009; Krewski et al., 2003; Krewski & Rainham 2007; Samet & Krewski 2007). As the knowledge about the size dependency of particle toxicity has grown (Kelly & Fussel, 2012), the ongoing research has focused its attention on ultrafine particles (UFP) (Morawska et al., 2013).

UFP represent a fraction of particulate matter (PM) with particles of aerodynamic diameter smaller than 0.1 µm (Morawska et al., 2013). Unlike coarse particles, UFP contribute little to PM mass but they dominate number concentrations. Due to their small size, high number concentrations, high surface area, and ability to penetrate into the interstitial spaces of the lungs (Bakand et al., 2012; Pereira Gomes et al., 2012), UFP can cause various adverse health effects. Clinical and epidemiological studies have linked exposure to ambient UFP with adverse respiratory outcomes (impaired lung function and pulmonary defense mechanisms, inflammatory responses and worsening of respiratory diseases), and possibly with cardiovascular health effects (Bakand et al., 2012; Heal et al., 2012; Ibald-Mulli et al., 2002) though the evidence is not consistent (Rückerl, et al., 2011). While more epidemiological studies on UFP fraction are needed, exposure assessment issues for UFP (such as spatial variability, indoor sources, infiltration of UPF from various outdoor emission sources, seasonal variability in concentrations and composition) are being further addressed (Azarmi et al., 2014; Bekö et al., 2013; Rivas et al., 2015; Viana et al., 2014, 2015; Wang et al., 2013).

In view of the evidences of negative health impacts of UFP, research has focused on investigation of main sources and processes affecting the levels and size distributions of these particles in ambient air of urban areas (Kumar et al., 2010; Morawska et al., 2008; Solomon, 2012). UFP can be formed by condensation of semi-volatile organic aerosols, photochemically induced nucleation, and/or nucleation through gas-to-particle conversion (Morawska et al., 2008, 2013). Concerning the indoor air, UFP originate
from combustion processes which includes cooking (namely boiling, stewing, frying, baking, grilling), smoking and use of candles (Bekő et al., 2013; Morawska et al., 2013), and as result from occupant–related activities such as use of consumer products, use of painting and cleaning products (Bhangar et al., 2011; Long et al., 2000).

Young children represent one of the most vulnerable group with regard to potentially harmful effects induced by airborne particulate exposure (Schüepp & Sly, 2012). As their physiological and immunological systems are still developing, young children receive a higher dose of airborne particles relative to lung size compared to adults (Burtscher & Schüepp, 2012; Laiman et al., 2014; Mazaheri et al., 2014; Morawska et al., 2013). Children spend a significant percentage of their time at schools and at homes. Specifically in Portugal, young children spend at school approximately 30% of their time (8-9 h/day). Therefore, the knowledge and understanding of indoor air pollution in these specific environments is important in order to child health. As a pollutant of both indoors and ambient air, UFP have the potential to harm children's health (Burtscher & Schüepp, 2012; Moreno et al. 2014; Reche et al., 2014; Rivas et al. 2014; Schüepp & Sly, 2012; Viana et al. 2014), yet the information concerning the children exposure to UFP is limited.

The aim of this work is to assess the indoor exposure to particles in (ultra)fine range (20-1000 nm) of 3–5 years old children, living in urban areas. The specific objectives of this work are: (i) to measure the levels of indoor particle number concentrations (PNC) in two preschools and three homes situated in urban low-moderately trafficked zones of Oporto Metropolitan Area (Portugal); and (ii) to compare the dose rates of the indoor (ultra)fine particles at schools and home environments.

MATERIALS AND METHODS

Characterization of sampling sites
Particle number concentrations in ultrafine (20-100 nm) and fine (> 100-1000 nm) ranges were consecutively measured at two preschools and three homes, all of them situated in urban low-moderately trafficked zones of Oporto Metropolitan Area in Paranhos district (north of Portugal). The sample collection was conducted for 56 days. Both preschools (S1 and S2) and homes (H1–H3) were situated in an urban zone; previously studies that evaluated ambient air pollution demonstrated that emissions from vehicular traffic are the main pollution source in these areas (Slezakova et al., 2011, 2013).

In each preschools, PNC were simultaneously measured at different indoor microenvironments (classrooms, canteens, and, if existent, gymnasium or playroom); all microenvironments were assessed using the identical sampling methodology and during the same amount of time. At homes sampling of (ultra)fine particles was conducted in living rooms that were used also as dining rooms; all meals/snacks were served there.

All indoor places were naturally ventilated through open windows. The characteristic of the studied preschools and homes, the traffic density data, as well as the duration of the sampling at each place are summarized in Table 1.

Sample collection

Particle number concentrations in size range 0.02–1 µm were measured by condensation particle counters – TSI P-Trak™ (UPC 8525; TSI Inc., MN, USA). The instrument operates on the principle of condensing 100% grade isopropyl alcohol (Sigma-Aldrich, Steinheim, Germany) onto ultrafine particles in order to increase their dimensions to a detectable size. At preschools, PNC were measured daily between 8:30 a.m. to 5:30 p.m. which corresponded to the period that children were at preschools, whereas at homes PNC of (ultrafine) particles were measured continuously during 24 h. Intake flow of 0.7 L.min⁻¹ was used and logging interval was 60 s accordingly to
previous studies (Diapouli et al., 2007; Norbäck et al., 2011; Zhang & Zhu, 2012).

Instruments were mounted onto supports so that air was sampled from a height of 0.8 to 1.1 m (in order to simulate children breathing zone). In each indoor environment, particles counters were placed as far as possible from windows or doors, and from other probable sources of particles (heating equipment, blackboards, printers, etc.) in order to minimize direct influence of any source. All requirements to maintain child safety were fulfilled.

At both preschools a researcher was present during sample collection in order to keep a record of room occupancy, ventilation systems (door and window positions), and potential source activities; information concerning child activities and schedules at preschools were also registered by a researcher. At homes all information including child activities were recorded by the parents/child responsible. In addition, teachers, staff and parents were daily inquired regarding the occurrence of additional sources and activities. Furthermore, detailed questionnaires were used daily for better description of the studied indoor environments (both preschools, homes). The first questionnaire was dedicated to registering potential sources of particles where the occupants marked time when these sources/activities were used / conducted in order to cross-reference them with concentration levels. The second questionnaire focused to the occupancy/activities of room where sampling equipment was placed. The last questionnaire focused on schedule of children’s activities and their physical activity during the sampling. All necessary permissions were obtained from administrative boarders of each preschool and directly from parents.

Dose rate analysis

Particle dose rates for children were calculated using Equation 1 (Castro et al., 2011; Slezakova et al., 2014):

\[
\text{Dose rate (D)} = \frac{\text{BR}_{WA}}{\text{BW}} \times C_{WA} \times \text{OF} \times N
\]  

(1)
where $D$ is the age-specific dose rate (particle number kg$^{-1}$ day$^{-1}$); $\text{BR}_{\text{WA}}$ is the age-specific weighted average breathing rate (L min$^{-1}$); $\text{BW}$ is age-specific body weight (kg); $\text{C}_{\text{WA}}$ is the age-specific weighted average concentration of particles (number of particles L$^{-1}$); $\text{OF}$ is the occupancy factor (i.e. percentage of residents likely to be in the microenvironment at a given interval; it was considered 1, as children kept their schedules and associated locations tightly); and $N$ is the total time per day spent by age-specific children in the respective indoor environment (min day$^{-1}$). Particle dose rates were estimated for 3–4 and 5 years old children. The daily activity patterns of children were analyzed throughout each day. Locations in which the different activities happened during the day were identified. Total daily residence time of children spent in each micro-environment (home, preschool) and the types of performed activities were registered. Each activity was characterized in terms of intensity level in order to assess the corresponding $\text{BR}$. An example of children timetable and activity patterns is shown in Table 2. As the information concerning the Portuguese population is not available, the age–specific factors ($\text{BW}$, $\text{BR}$) were retrieved from USEPA data (USEPA, 2011) considering the mixed population (both male and females). $\text{BW}$ of 18.6 kg for 3–5 years old children was used. The values of $\text{BR}$ were selected as the followings: 4.3 L min$^{-1}$ for rest or sleep; 4.5 L min$^{-1}$ for sedentary or passive activities; 11.0 L min$^{-1}$ for light intense activity, and 37.0 L min$^{-1}$ for highly intense activities (running, etc.). $\text{BR}_{\text{WA}}$ was estimated then as weighted average, i.e. considering the intensity of each performed activities and the amount of time. The dose rates were then estimated using the average indoor concentrations of each microenvironment (and considering the real amount of time that children spent in each place).

Statistical analysis
For the data treatment, the Student’s t-test was applied to determine the statistical significance ($p<0.05$, two tailed) of the differences between the determined means. All statistical analyses were performed using IBM® SPSS® Statistics software.

RESULTS

Particle number concentrations

Total means of particle number concentrations and the statistical parameters (minimum and maximum values, 25th, and 75th percentile) at the two preschools and three homes are shown in Figure 1. These parameters of (ultra)fine particles were determined using all measured data of all existent indoor environments. Concerning two preschools, mean of indoor PNC was significantly (1.4 times) higher ($p < 0.05$) at S1 ($1.84 \times 10^4$ particles cm$^{-3}$) than at S2 (mean of $1.32 \times 10^4$ particles cm$^{-3}$).

At all three homes, obtained means of indoor (ultra)fine particles (Table 1) were rather similar; the results showed that the total indoor means of PNC at three homes were not statistically different ($p < 0.05$). Overall, the highest mean and the ranges of PNC were observed at H1 with mean concentration 1.1 times higher than at H2 and H3.

Dose rates

The activities that children conducted during their school time were alike at both preschools. However, the dose rates of indoor particles were estimated for 2 age categories, namely 3–4 years old and 5 years old children because their daily schedules slightly differed. Children spent the majority of their preschool time in classrooms (approximately 70–75% for 3–4 years old, and 57%–70% for 5 years old). The younger children rested (i.e. slept which was an activity associated with the lowest breathing rates) after lunch for 2–2.5 hours whereas older children performed indoors more frequently physical activities (such as running, playing, exercising, use of climbers, swings and slides). In addition, the 5 years old children spent less time (0.75–1.75 h)
indoors. Overall, the daily activity patterns of children at three homes were remarkably similar. On average, children spent 13 h at home, out of which 3 h took place in a living room (sedentary or light activities; studying, games playing, drawing, or eating). Morning and evening routines (breakfast, bath, and etc.) took approximately for 1 h whereas child sleep accounted for about 9 h.

Dose rates associated with inhalation exposure to (ultra)fine particles (20–1000 nm) number concentrations at two preschools and three homes were estimated for two different age categories of children. The results are shown in Table 3. Concerning preschools, the results clearly show that: (i) for both age categories the highest dose rates of PNC were found at S1; and ii) for both schools the highest values of PNC total dose rates were observed for 5 years old children. Furthermore, the results in Table 3 clearly show that for 3–4 years and 5 years old children dose rates at homes were 1.3–2.1 times higher than at schools.

**DISCUSSION**

As children represent one of the most vulnerable groups in society, more information concerning the air pollutants to which they are adversely exposed in schools and home environments is needed. Overall, levels of (ultra)fine particles at the two Portuguese preschools were in similar ranges to those reported for indoor air of schools in Greece ($2.4 \times 10^4$ particles cm$^{-3}$; Diapouli et al., 2008), Italy ($1.95–2.04 \times 10^4$ particles cm$^{-3}$; Buonanno et al., 2012, 2013a), Spain ($1.56 \times 10^4$ particles cm$^{-3}$; Reche et al., 2014; Rivas et al.; 2014), South Korea ($1.82 \times 10^4$ particles cm$^{-3}$; Kim et al., 2011;) or Australia ($1.21–1.69 \times 10^4$ particles cm$^{-3}$; Rumchev et al., 2007). In addition, large ongoing epidemiological study of UFP in schools has been conducted in Melbourne (Australia). The authors reported emission rates of UFP as well as deposition of UFP in lungs so direct comparison with levels in air was not possible. Other studies from Europe, namely from Denmark, Germany, and Sweden, (Clausen et
al., 2012; Fromme et al., 2007; Norbäck et al., 2011) reported much lower levels of ultrafine particles ($0.7 \times 10^3$–$6.5 \times 10^3$ particles cm$^{-3}$) than in present work. Different levels of urbanization and development of area surrounding schools, meteorological conditions or seasonal influences could account for some of these differences (Morawska et al., 2009). It is also necessary to point that the majority of the existent studies on UFP in educational settings focused on assessments in classrooms (Clausen et al., 2012; Fromme et al., 2007; Guo et al., 2010; Mullen et al., 2011; Norbäck et al., 2011; Weichenthal et al., 2008). Only one study (Zhang & Zhu, 2012) reported the information on ultrafine particles also in other school microenvironments (gymnasium, canteen, libraries), being otherwise inexistent. In this work, classrooms were the microenvironment associated with lower particle number concentrations at both preschools (mean of $9.31 \times 10^3$ and $1.13 \times 10^4$ particle cm$^{-3}$ at S1 and S2, respectively), which is reassuring, considering that they are the places where children spend the majority of their school time. The major identified sources of (ultra)fine particles, based on the daily registered information, were: classroom cleaning, children activities during classes (such as sculpturing, and etc.) and combustion sources; levels of (ultra)fine particles in ambient air ranged from $2.4 \times 10^3$ to $4.3 \times 10^4$ (Slezakova et al., 2014). On the contrary, at both preschools PNC in canteens (mean of $5.17 \times 10^4$ and $3.28 \times 10^4$ particle cm$^{-3}$ at S1 and S2, respectively) were the highest ones. Although, children spend in canteens rather short periods of time (18 and 19% of their school time at S1 and S2, respectively) the exposures in this type of indoor microenvironment might be relevant for overall child school exposure. Furthermore, exposure to high levels of ultrafine particles numbers, even if during a limited period of time, may pose some risks to child health (Burtscher & Schüepp, 2012). In agreement with these findings, Mullen et al. (2011) previously reported that cooking events were the most significant indoor sources (during normal occupancy) at six schools in California (USA). The importance of cooking and eating activities have been also demonstrated in more recent studies
evaluating particle deposition in the alveolar and tracheobronchial region (Buonanno et al., 2011, 2012; 2013b; Mazaheri et al., 2013). At three homes the mean concentrations of particles number ranged between 1.09×10^4 and 1.24×10^4 particles cm^{-3}. These levels of PNC were similar to mean concentrations reported in literature for homes in Germany (0.9×10^4 particles cm^{-3}; Fittschen et al., 2013), Greece (1.3–1.4×10^4 particles cm^{-3}; Diapouli et al., 2011), Canada (0.8–1.03×10^4 particles cm^{-3}; Kearney et al., 2011; Wheeler et al., 2011), and Australia (1.24×10^4 particles cm^{-3}; Morawska et al., 2003). However, recently Bekö et al. (2013) conducted a large study that assessed UFP in 56 residences in Denmark. These authors reported UFP approximately three times higher than in Portuguese homes (mean of 2.91×10^4 particle cm^{-3}; Bekö et al., 2013). Different study design (sampling period, duration, number of homes) and/or different particle size ranges of measured ultrafine fraction could also contribute to these differences (Morawska et al., 2013).

Overall, the highest mean of PNC as well maximal levels (i.e. 2.1×10^5 particle cm^{-3}) were observed at H1. Based on the analysis of information available from the questionnaires, the indoor sources of UFP at H1 included: cooking (boiling and frying), use of toaster and oven, use of cleaning products, vacuuming and ironing. Certainly the frequency and durations of these indoor activities might have influenced the respective levels. However, it is also necessary to remark that contrary to the other two homes, at H1 the room where the sampling was conducted was directly connected with a kitchen. In addition, occupants of this home maintained doors between kitchen and living room almost constantly opened. Thus, PNC from cooking emissions easily penetrated to the sampling area (Bordado et al., 2012; Buonanno et al., 2013b), and accounted for the high concentrations at this home. The variation of time and location (room type) can account for the obtained differences of (ultra)fine particles (Bekö, et al., 2013).

Overall, the levels of PNC at three homes were 10–70% lower than at preschools. However, activities (and the levels of their physical intensity) that are
typically performed in an educational institution vary greatly from those of home. Therefore, the dose rates resulting from a stay in these two environments might differ considerably.

The highest doses of PNC at preschools were found for children of S1 (Table 3). Although levels of PNC in classrooms were the highest at S2, doses of UFP resulting from school exposure were higher (up to 50%) for children at S1, probably due to the higher levels of PNC in the canteen of the respective preschool. These findings thus demonstrate that all potential microenvironments should be considered when assessing children exposure to PNC in preschools and schools.

The estimated dose rates of indoor PNC at both schools were compared between both age groups of children. The results in Table 3 show that at S2 the dose rates were higher for 5 years old children. As mentioned previously, older children performed more frequently physical activities which were associated with the highest breathing rates and consequently led to higher inhalation doses of particles. On the contrary 3–4 years old children spent more time in classrooms where levels of PNC were the lowest. Furthermore, after the lunch 3–4 years old children slept in the classrooms which was an activity associated with the lowest breathing rates. At S1, the estimated dose rates were not statistically different ($p < 0.05$) between 3–4 years old and 5 years old children, which was probably due to the different activity patterns; older children spent indoors less 1.75 h and contributions resulting from the outdoor exposure was not considered in this work. Therefore, in future work when assessing children a period spent during school daytime outdoors should be considered as it might be relevant to child overall school exposure.

When evaluating the three homes (Table 3), the highest dose rates of particles were observed for children at H1 due to the highest levels of UFP at this home. When in use, particles samplers make minor noise. Therefore, in order to maintain soundless rest of children it was not possible to conduct measurements directly in children
bedrooms. The obtained dose rates of PNC at H1–H3 thus represent an approximation of child home exposure and need to be interpreted carefully.

Finally, dose rates of particles in (ultra)fine range at homes were higher than those of preschools. Although number concentrations (ultra)fine particles at the three homes were lower than total levels at both preschools (Figure 1), children spent at homes approximately 13 h (opposed to 9 h at preschools). The longer exposure time could account for the obtained values. These results thus show that daily activity patterns significantly influenced overall doses to PNC in 3–5 years old children.

The dose rates of in (ultra)fine particles estimated in this work were due to indoor exposure at preschools and homes only. However, children spend on a daily basis some of their time in other microenvironments (transportation modes, extracurricular activities, and etc.) where they are exposed to UFP from additional sources. Therefore, characterization of the respective exposures to UFP for children in these microenvironments is of upmost importance. Furthermore, future studies focusing on the health effects of airborne pollutants should always account for children exposures in different microenvironments (homes, schools, transportation modes, and etc.) in order to obtain a correct representation of child’s overall exposure.

Acknowledgments

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contribution of UFP and BC, OC, secondary inorganic ions and metals in PM2.5 in

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**Figure Captions**

**FIGURE 1.** Levels of (ultra)fine particles at two schools (S1, S2) and three homes (H1–H3): minimum and maximum values, average, 25th, and 75th percentile. Particle number concentrations were determined considering the measured levels in all indoor microenvironments existent in each school and home.
### TABLE 1. Characterization of the studied environments (preschools and homes) and obtained concentrations of (ultra)fine particles.

<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th>Location</th>
<th>Traffic density data(^{a})</th>
<th>Studied indoor microenvironments</th>
<th>Sampled period</th>
<th>Particle number concentration (particles cm(^{-3}))</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Two–floors building</td>
<td>Situated on moderately trafficked street</td>
<td>Mean: 16 vehicles/min</td>
<td>Classrooms (3)</td>
<td>13 days</td>
<td>Classrooms 9.31×10(^3) 8.23×10(^3)</td>
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<tr>
<td></td>
<td>173 students 3–5 years old</td>
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<td></td>
<td>Canteen (1)</td>
<td></td>
<td>Canteen 5.17×10(^4) 3.41×10(^4)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Playroom (1)</td>
<td></td>
<td>Playroom 1.70×10(^4) 1.25×10(^4)</td>
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<td>Total</td>
<td></td>
<td>Total 1.82×10(^4) 2.16×10(^4)</td>
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<tr>
<td>S2</td>
<td>Three–floors building</td>
<td>Situated on intersection of moderate and low trafficked street</td>
<td>Mean: 13 vehicles/min</td>
<td>Classrooms (3)</td>
<td>13 days</td>
<td>Classrooms 1.13×10(^4) 5.24×10(^4)</td>
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<tr>
<td></td>
<td>30 students 3–5 years old</td>
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<td></td>
<td>Canteen (1)</td>
<td></td>
<td>Canteen 3.28×10(^4) 3.21×10(^4)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Gymnasium (1)</td>
<td></td>
<td>Gymnasium 9.72×10(^3) 2.36×10(^3)</td>
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<td>Total</td>
<td></td>
<td>Total 1.32×10(^4) 1.25×10(^4)</td>
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<tr>
<td></td>
<td>Building Type</td>
<td>Location Description</td>
<td>Traffic Conditions</td>
<td>Room Type</td>
<td>Days</td>
<td>Emission 1</td>
<td>Emission 2</td>
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<tr>
<td>H1</td>
<td>Multi–unit apartment building</td>
<td>Situated on intersection of two low trafficked streets</td>
<td>Mean: 3 vehicles/min</td>
<td>Living room</td>
<td>10 days</td>
<td>$1.24 \times 10^4$</td>
<td>$1.28 \times 10^4$</td>
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<tr>
<td></td>
<td></td>
<td>Situated on 4th floor</td>
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<tr>
<td></td>
<td></td>
<td>4 occupants (2 children of 3 and 5 years old)</td>
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<tr>
<td>H2</td>
<td>Multi–unit apartment building</td>
<td>Situated nearby highly trafficked road</td>
<td>Not available</td>
<td>Living room</td>
<td>9 days</td>
<td>$1.11 \times 10^4$</td>
<td>$1.15 \times 10^4$</td>
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<tr>
<td></td>
<td></td>
<td>Situated on 4th floor</td>
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<tr>
<td></td>
<td></td>
<td>4 occupants (1 child of 5 years old)</td>
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<tr>
<td>H3</td>
<td>Two–floors house</td>
<td>Situated in suburban zone with moderate traffic</td>
<td>Mean: 4 vehicles/min</td>
<td>Living room</td>
<td>11 days</td>
<td>$1.09 \times 10^4$</td>
<td>$1.11 \times 10^4$</td>
<td></td>
</tr>
</tbody>
</table>
4 occupants (1 child of 5 years old)

aData was obtained by manual counts during 10 min of each hour (between 5 a.m. to 12 p.m.) on two consecutive days (avoiding Mondays and Fridays). The location distance between the counting point and main entrance/building outside wall was 5 and 8 m at S1 and S2, respectively and 3–4 m at H1 and H3.
<table>
<thead>
<tr>
<th>Time</th>
<th>Environment</th>
<th>Observed activities</th>
<th>Activity intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:30–9:00</td>
<td>Arrival to school</td>
<td>Indoor Playing (calm, seated, TV)</td>
<td>Sedentary</td>
</tr>
<tr>
<td>9:03–10:29</td>
<td>Classes/education</td>
<td>Indoor Seated only (talking)</td>
<td>Sedentary</td>
</tr>
<tr>
<td>10:30–11:15</td>
<td>Recess</td>
<td>Playground Running, jumping, swings</td>
<td>High intensity</td>
</tr>
<tr>
<td>11:17–11:40</td>
<td>Classes/education</td>
<td>Indoor Sedentary and other (painting, walking)</td>
<td>Sedentary</td>
</tr>
<tr>
<td>11:45–13:00</td>
<td>Lunch</td>
<td>Indoor Seated (eating, drinking, talking)</td>
<td>Light</td>
</tr>
<tr>
<td>13:05–15:00</td>
<td>Rest</td>
<td>Indoor Sleeping</td>
<td>Sleep</td>
</tr>
<tr>
<td>15:04–16:00</td>
<td>Classes/education</td>
<td>Indoor Seated, and other</td>
<td>Sedentary</td>
</tr>
<tr>
<td>16:00–17:30</td>
<td>Leaving school</td>
<td>Indoor Organized activities (singing dancing), running</td>
<td>High intensity</td>
</tr>
<tr>
<td><strong>Home</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18:00–19:20</td>
<td>Living room</td>
<td>Home works, school preparation, studying</td>
<td>Sedentary</td>
</tr>
<tr>
<td>19:25–20:00</td>
<td>Living room</td>
<td>Seated (eating, drinking, talking)</td>
<td>Sedentary</td>
</tr>
<tr>
<td>Time</td>
<td>Location</td>
<td>Activity</td>
<td>Sleep Stage</td>
</tr>
<tr>
<td>-----------</td>
<td>---------------</td>
<td>---------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>20:05–22:00</td>
<td>Living room</td>
<td>Playing games, painting, walking</td>
<td>Light</td>
</tr>
<tr>
<td>22:00–6:50</td>
<td>Bedroom</td>
<td>Sleeping</td>
<td>Sleep</td>
</tr>
<tr>
<td>7:00–8:00</td>
<td>Various</td>
<td>Morning routine, breakfast</td>
<td>Light</td>
</tr>
</tbody>
</table>
TABLE 3. Age–specific dose rates (particles kg\(^{-1}\) day\(^{-1}\)) to UFP for 3–4 years and 5 years old children at two preschools (S1 and S2) and three homes (H1–H3).

<table>
<thead>
<tr>
<th>Dose rate (particles kg(^{-1}) day(^{-1}))</th>
<th>S1</th>
<th>S2</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>3–4 years</td>
<td>1.99×10(^9)</td>
<td>1.49×10(^9)</td>
<td>3–5 years</td>
<td>3.06×10(^9)</td>
<td>2.69×10(^9)</td>
</tr>
<tr>
<td>5 years old</td>
<td>2.02×10(^9)</td>
<td>1.92×10(^9)</td>
<td>3–5 years</td>
<td>2.74×10(^9)</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 1

(Ultra)fine particles
(particles cm$^{-3}$)