EVALUATION OF THE SOURCES OF ULTRAFINE PARTICLES IN RESIDENTIAL INDOOR

*Extended abstract*

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**Background**

While we often consider the effects of outdoor pollution on our health (Avino et al., 2011), we rarely think about how we are exposed to inside our home. In fact, even though there is a plethora of outdoor UFP sources, including vehicle emissions and outdoor air pollution, studies suggest that indoor sources are greater than outdoor sources for a typical non-smoking suburban consumer (Wallace and Ott, 2011). Nowadays, a person spends his time among his home, transportation and workplace leaving essentially in indoor environments. Basically, a person spends over 90% his time in indoor environments. In this case people are exposed to different gaseous and particle pollutants causing dangerous health effects. In this case, ultrafine particles are airborne particles that can cause personal discomfort and health reactions when inhaled by the occupants of a home. Fine particles show more immediate effects while ultrafine particle show more delayed effects on mortality (Air Quality Sciences, 2011).

During these last years, several studies have investigated the effects of particles in indoor environments, not only industrial as well as residential. In particular, a large number of sources are identified: among the most significant sources it should be considered tobacco smoke, cooking, fuel used for cooking and domestic heating (e.g., kerosene, wood). Other possible sources are anthropogenic, related to human activities in a house, including the resuspension of particulate matter from people and pets, activities such as dusting and vacuuming, the shower, the operation of humidifiers, electric motors.

Internal and external sources contribute and strongly influence the concentration and composition of the particles in the indoor environment. More information on the emission characteristics are usually available in the literature, such as the emission factors of the particle sources both in the ambient air and the indoor environment. However, the quantification of emissions from indoor sources is very important for the evaluation of human exposure to total particles.

Ultrafine particles (UFP) are defined as particles in the air that are less than 100 nanometers in size. Because of their small size, these particles can easily infiltrate the bloodstream and contribute to negative health effects or inhaled and travel deep into the human lung. It is important to study these particles, as people tend to spend most of their time indoors.

Airborne particles can be classified into three modes, according to their diameter and formation mechanisms, each of which may have very different sources and composition (Nazaroff, 2004; Manigrasso et al., 2012):

- **nucleation mode.** Measuring less than 100 nm, these are the UFP. They are formed by nucleation. These particles consist mainly of primary combustion products and reactions between gaseous compounds, and can grow in size either through condensation, when additional vapors condense on the particles, or through coagulation, when two or more particles combine to form larger particles.
- **accumulation-mode.** Particles receive this designation when they grow to a size of between 0.1 μm and 2.5 μm in diameter. They originate from primary emissions, chemical reactions, condensation, and coagulation.
- **coarse-mode particles.** These particles measure greater than 2.5 μm in diameter, and are most frequently generated by mechanical processes.

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In this paper we have focused our attention on the submicrometric fraction, in particular in the fraction 6-560 nm and we have investigated the particle concentration levels and the relative granulometric profiles during routinely operation occurring at home.

**Objectives**

Even if the information on this topic is relevant, the investigation of the release of UFPs from domestic activities is important for different reasons: (i) analyzing the impacts of UFPs on indoor air quality, (ii) assessing the personal exposure to ultrafine particles, and (iii) providing safe guidelines for activities in house. This article investigates the release and physical characteristics of particles during some popular operations occurring in a house. It should be noted that the focus of this study is on the particle numbers for determining the particle dynamic and behavior in relationship to selected sources and processes whereas chemical characterization or exposure quantification is out of the scope of this work.

**Outline of the work**

This work is would like to highlight preliminary information on the task related to the presence of submicron particle in indoor environments and how this pollutant can modify and influence the indoor air quality evaluation.

Factors governing indoor particle concentrations include direct emissions from indoor sources, ventilation supply and infiltration from outdoor air, deposition onto indoor surfaces, and removal from indoor air by ventilation and filtration. In some circumstances, transport and transformation processes within indoor environments may also influence particle concentrations (Nazaroff 2004). Our experiments were performed minimizing these occurrence.

Preliminarily, the effect of outdoor sources was investigated also considering our studies in this field; after the investigation was divided according the typical residential indoor lifestyles. Our concentration was focused in the predominant occurrences such as cooking (breakfast, lunch and dinner), cleaning and no (nighttime) operations. The measurements were performed in regards of the background measures performed at the beginning. These initial measures allowed to determine the steady-state of the area investigated and to correlate to them every determination carried out.

The final objective of this research will be the determination of the effects of each single source on the submicron particle concentration and the granulometric size profile as well (basically, a source apportionment of the different source affecting the residential indoor air quality).

**Methods**

Measurements were performed for studying submicrometric aerosol number-size distributions and their fast-evolution characteristics in different indoor house-environments where people doing different activities are usually exposed. The ultrafine measurement was conducted in a kitchen, living room and bedroom. During every measure the weather and the room condition was monitored for avoiding the influence of external parameters to the indoor air quality. The only anthropogenic sources were the domestic heating whereas the windows were opened after each measurement for 20-30 min allowing a rebalancing of the room atmosphere.

Aerosol number-size distributions were measured by means of a TSI Fast Mobility Particle Sizer (model 3091, FMPS, Shoreview, MN, USA) (Manigrasso and Avino, 2012; Manigrasso et al., 2013). The instrument counts and classifies particles, according to their electrical mobility, in 32 size channels, in the range from 5.6 to 560 nm, with 1 s time resolution. FMPS operates at a high flow rate (10 L min⁻¹) to minimize diffusion losses of UFPs. It operates at ambient pressure to prevent evaporation of volatile and semivolatile particles.

**Results and discussion**

First, we evaluated the contribution of the background of the investigated area before performing particle measurements in a house off home heating and cooking is not working. Fig. 1 shows profiles of submicron particles in the range 6-560 nm: it is interesting to note the presence of three mode, the first around 11 nm, the second (less pronounced) around 34 nm and the third around 70 nm.

In Table 1 the concentration of submicron particles in different intervals (total concentration, i.e., 6-560 nm; 6-16 nm; 16-560 nm) and for the situations studied, are reported. In the case of the background measurements, the total particles in the granulometric range of 6-560 nm are constant (coefficient of variation 7.2 %) with a high particle level (229,000±17,200 particle cm⁻³). This high level is due mainly to the fraction 19-560 nm which represents about 87% of the total concentration while the fraction of particles 6-19 nm presents a much higher variability (coefficient of variation 25 %) due to itself nature (fraction with particles with a high capacity of aggregation and condensation). The ratio between the two fractions is approximately 7.
Evaluation of the sources of ultrafine particles in residential indoor environments.

Fig. 1. Particle profile during background and nighttime measurements.

Table 1. Particle concentration during the different measurements performed (BG background; NT nighttime; BF breakfast; CL cleaning; LC lunch; DN dinner).

<table>
<thead>
<tr>
<th>Particle</th>
<th>BG</th>
<th>NT</th>
<th>BF</th>
<th>CL</th>
<th>LC</th>
<th>DN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (6-560 nm) (# cm⁻³)</td>
<td>229+17</td>
<td>254+17</td>
<td>980+92</td>
<td>374+150</td>
<td>1273+694</td>
<td>196+14</td>
</tr>
<tr>
<td>Fraction 6-16 nm (# cm⁻³)</td>
<td>30+8</td>
<td>37+12</td>
<td>652+778</td>
<td>141+87</td>
<td>934+635</td>
<td>37+13</td>
</tr>
<tr>
<td>Fraction 16-560 nm (# cm⁻³)</td>
<td>199+13</td>
<td>216+9</td>
<td>328+174</td>
<td>233+69</td>
<td>338+110</td>
<td>159+7</td>
</tr>
<tr>
<td>Ratio 16-560 to Total (%)</td>
<td>86.8</td>
<td>85.3</td>
<td>33.5</td>
<td>62.2</td>
<td>26.6</td>
<td>81.1</td>
</tr>
</tbody>
</table>

The presence of these modes characterizes the measures in residential indoor without emission of anthropogenic and/or natural sources affecting the profiles. In fact, the background profile representation will be very similar to that obtained from measurements performed during nighttime, when, once again, there are no external interference or domestic heating or other heating sources in function. It can be noted two well-marked modes, at 9 nm and 70 nm, while it could be extrapolated a very intriguing mode with a maximum at a granulometric size below 6 nm (Fig. 1). The ratio between the two fractions decreases slightly (5.3) while the 16-560 nm fraction is still predominant (82 %).

The situation changes dramatically in the presence of sources and/or anthropogenic activities. Fig. 2 shows the profiles of submicron particles during the main activities characterizing a residential life, i.e., breakfast, cleaning, lunch and dinner. Each activity is accompanied by the use of the relative equipment (e.g., vacuum cleaners) or ignition stoves. In particular for the latter case the three main meals are separated because each of them is different in the load in terms of time and temperature that are reached.

Fig. 2. Particle profile during breakfast, cleaning lunch and dinner measurements.

Particle levels are totally different from those determined during background and nighttime measurements (Table 1), but also the profiles are completely different, even between them (Fig. 2; please, note that the profile “dinner” is on the secondary y-scale).

The first three profiles (breakfast, cleaning, lunch time) are quite similar in terms of levels and trends even if during the cleaning procedure high concentration levels of particles between 10 and 30 nm are reached (ratio...
between the two fraction is 2 whereas total concentration particles are formed by 62 % of particles in the range 16-
560 nm). Both the profiles are characterized to have a peak around 10 nm. This peak is totally absent in the profile
“dinner” where the cooking is more strong as well as the cooking time is longer than the other two situation
(breakfast and lunch time). This profile, almost Gaussian, is characterized by a single mode (around 50 nm) and very
high levels of particles in the range 20-140 nm. Further, the ratio between the two fractions is around 20 and the
main portion of the total concentration particles is due to the 16-560 nm fraction (average 82 % with maximum 95 %
of the total during the maximum peak). In this case, the effect of the fuel used for cooking is relevant for the particle
concentration levels.

Concluding remarks

The indoor air quality is an important task because it regards almost all the population. There are many
factors affecting the air quality but the domestic heating, especially using gas (i.e., methane) as fuel, is one of the
most important source of particle formation and aggregation. There are many factors that people cannot control,
including the weather and traffic, but there are ways to reduce indoor air particles (for instance, keeping windows
closed during heavy traffic time and using air conditioning, an alternative to opening a window). Finally, another
important way to reduce exposure to particles is to avoid smoke and secondhand smoke (study in progress).

Keywords: domestic heating, FMPS, indoor, residential, ultrafine particle

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