On the indoor air quality problem in residential areas: the Athens case

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ABSTRACT

The buildings’ environment plays a very important role in health matters and the quality of life. A series of experimental measurements were carried out in the residential sector of the greater region of Athens. Parameters influencing the indoor air quality such as particles, CO, CO2 and total organic compounds (TOCs) concentrations were monitored. Thermal and acoustic comfort as well as characteristics linked to the type, size and existing thermal insulation materials of the buildings were investigated.

INTRODUCTION

It is well understood that since 70 per cent of a humans’ time is spent indoors, indoor air pollution may pose a serious threat to human health. Indoor air pollution can be caused by outdoor and/or indoor sources as well as anthropogenic activities. There are many studies on this topic which refer primarily to the air pollution aspect and secondarily on its impact on health. The evidence of indoor air pollution and its impact on public health is consistent in showing adverse health effects at exposures that are currently experienced by urban populations in both developed and developing countries. The range of health effects is broad, but is predominantly to the respiratory and cardiovascular systems. All population is affected but susceptibility to the pollution may vary depending on the age and health condition of the subjects. The risk has been shown to increase with exposure and there is little evidence to suggest a threshold below which no adverse health effects would be anticipated. Recently the research interest is focused on the indoor concentration of pollutants such as particulate matter, carbon monoxide, carbon dioxide and total volatile organic compounds. Naturally the evaluation of the indoor environment is also affected by the outdoor regime. The sources of indoor pollution and its impact has been a research topic in a great number of studies. In particular detailed research on the impact tobacco smoking on human health was discussed by Rushton (2004). Indoor air quality measurements performed in the work environment in Greece (Lagoudi et al, 1996, 1996a, Bernhard et al, 1995), followed by similar studies in schools (Synnefa et al, 2004, Chaloulakou and MAVRODIS, 2002), hospitals (Santamouris et al, 1994) and residences (Bayal et al, 2004, Alexopoulos et al, 2006, Lai et al 2006) report a number of pollutants including black smoke, nitrogen dioxide, volatile organic compounds, PM10 and PM2.5.

The present work takes into account both outdoor and indoor measurements as well as the type and characteristics of the buildings under investigation. The measurements presented here extend to over seventeen private residences in a number of different locations in Athens.

EXPERIMENTAL CAMPAIGN

The experimental campaign incorporates automated instrumentation placed for short periods in and around seventeen private buildings. The details of these buildings are shown in table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Cite</th>
<th>Location</th>
<th>Area (m²)</th>
<th>Building type</th>
<th>Inhabitants number</th>
<th>Specific remarks</th>
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<td>Apartment</td>
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<td>- Non smokers</td>
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<td>2 (+1 child)</td>
<td>- Non smokers</td>
</tr>
<tr>
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<td>1 (+1 child)</td>
<td>- Non smokers</td>
</tr>
<tr>
<td>6</td>
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<tr>
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<tr>
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<td>House</td>
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<tr>
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<td>Urban</td>
<td>110</td>
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</table>

The instrumentation included monitors of the determination of particulate matter with dynamic diameter 10, 2.5 and 1 µm (PM10, PM2.5, PM1), total volatile organic compounds (TVOCs), carbon monoxide (CO) and carbon dioxide (CO2).
The instrument used to collect the particulates is a lightweight personal sampling device consisting of a single-stage impactor and a final filter. Aerosol particles are sampled through the single-stage impactor to remove particles above the cut-point, which is either 2.5 or 10 µm aerodynamic equivalent diameter, depending on which a sampling head is chosen. Particles smaller than the cut-point are collected on a 37mm diameter filter. The impactor uses the principle of inertial separation of airborne particles. Measurements of carbon monoxide, carbon dioxide and TVOCs have been performed using a multigas analyser. The gas analyser is a highly accurate, reliable and stable quantitative gas monitoring system. By installing up to five filters in the analyser, it can measure the concentration of up to five component gases and water vapour in any air sample. Although the detection limit is gas-dependent, it is typically in the 10⁻² ppb region. The analyser has a built-in pump system that allows samples to be drawn from up to fifty metres away.

RESULTS

The results are conveniently divided into two categories: homes without smokers and homes with smokers.

Non smoking residences

A guideline for the carbon dioxide concentration limit has been set by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). This allowance is 1000 ppm for schools, offices, and areas where people spend extended periods of time indoors. The Federal Standard for exposure limits of carbon monoxide in the home is 50 ppm. The Environmental Protection Agency (EPA) standard for ambient air is 9 ppm averaged over an eight-hour period and 35 ppm for one hour. The mean measured concentrations of the carbon dioxide, carbon monoxide and total volatile organic compounds are shown in Figure 1. The average indoor concentration varied between 350 and 610 ppm for all residences without smokers, however measurements of the maximum indoor CO2 concentration showed that 85% of the buildings were below the 1000 ppm limit.

The mean carbon monoxide concentration did not exceed the 9 ppm limit in any of the residences tested. The maximum carbon monoxide concentration showed that approximately 16% of the buildings were above the limit. The mean concentration of the total volatile organic compounds (TVOC’s) in the non smoking homes was between 5 and 9 mg/m³, while the absolute maximum measured concentration reached 15 mg/m³. According to Molhave (1990) the maximum permitted concentration for TVOC’s depends on the health consequences. It is considered that indoor concentrations below 0.2 mg/m³ do not pose any threat for the human health, while concentrations between 0.2 to 3 mg/m³ may cause discomfort when in combination with other environmental problems. Concentrations higher than 3 mg/m³ have been shown to cause respiratory problems. The existing air quality standards for PM₁₀ entered into force on 1 January 2005 (Directive 1999/30/EC). The daily limit is 50 microgrammes per cubic metre (averaged over 24 hours) and the annual limit 40 microgrammes per cubic metre. This limit can be exceeded for up to 35 days a year taking account unusual and adverse weather. The limit on PM₁₀ concentrations introduced by WHO Air Quality Guidelines is 25 micrograms per cubic metre, 24-hour mean. On the contrary, limits on PM1 concentrations do not exist. The measured concentrations of PM10, PM2.5 and PM1 in the non-smoking residences are shown in figures 2-4. On average the concentration of PM10 was approximately 42.5 µg/m³ and the mean concentration of PM2.5 and PM1 was 31.8 µg/m³ and 25.2 µg/m³ respectively.

Figure 1. Mean concentration of carbon dioxide, carbon monoxide and total volatile organic compounds for houses without smokers

Figure 2. PM10 concentrations in the non-smoking residences (in mg/m³)
In the majority of the non-smoking residences (approximately 72%) the concentrations of PM10 measured were below the 50 μg/m3 limit, while 28% presented PM10 concentrations ranging from 50 to 90 μg/m3. Measurements performed in dwellings in Beijing found that the mean indoor PM10 concentration was 109.9 μg/m3, (Houyin, Z. et al, 2005).

Measurements of the PM2.5 concentrations, however, showed that only 18% of the residences were below the limit of 25 μg/m3, 63% of the buildings ranged from 25 to 50 μg/m3 and 19% of the buildings reached 70 μg/m3. Measurements performed in 20 residences in California found that the median PM2.5 concentrations were 32.2 μg/m3, (Sawant et al, 2004).

It is important to mention here that the PM1 concentrations showed that 71% of the residences were below 30 μg/m3, while 29% were between 30 and 70 μg/m3.

Smoking residences

Tobacco smoking is a major source of indoor carbon dioxide and contributes highly to indoor TVOC’s concentration (Santamouris et al., 2006).

The mean measured concentrations of the carbon dioxide, carbon monoxide and total volatile organic compounds are shown in Figure 5. The average indoor concentration varied between 450 and 810 ppm for all residences with smokers however, measurements of the maximum indoor CO2 concentration showed that approximately 33% of the buildings were above the 1000 ppm limit.

The mean carbon monoxide concentration did not exceed the 9 ppm limit in any of the residences tested. On the contrary, the maximum carbon monoxide concentration showed that approximately 50% of the buildings were above the limit. The mean concentration of the total volatile organic compounds (TVOC’s) in the smokers’ homes was between 5 and 15 mg/m3, while the absolute maximum measured concentration reached 37 mg/m3.

The measured concentrations of PM10, PM2.5 and PM1 in the smokers’ residences are shown in Figures 6-8. On average the concentration of PM10 was approximately 105 μg/m3 and the mean concentration of PM2.5 and PM1 was 224 μg/m3 and 131 μg/m3 respectively.

In the case of residences with smokers the majority of the buildings present very high PM10 and PM2.5 concentrations. In approximately 67% of the buildings the PM10 and PM2.5 concentrations exceeded 100 μg/m3, while in 33% of the buildings were 50 μg/m3.
CO2 concentration measurements showed that in 3/9/2007, on average, buildings without smokers were found to have lower CO2 concentrations than the 600 ppm limit.

- Concerning the average CO levels, the 9 ppm limit is not exceeded in any case. Maximum carbon monoxide concentrations increase highly as a function of smoking levels inside the dwellings.
- The mean total volatile organic compounds (TVOC’s) measured in all homes was above 5 mg/m³. The absolute maximum measured concentration for residences without smokers did not exceed the limit of toxicity of 25 mg/m³ while this was not the case for the houses with smokers.
- In the majority of the non smoking residences the concentrations of PM10 measured were below the acceptable limit however the PM2.5 concentrations showed that only 18% of the residences were below the acceptable limit. The highest measured PM2.5 concentration did not exceed 70 µg/m³. PM1 concentrations showed that 71% of the residences without smokers were below 30 µg/m³, while 29% were between 30 and 70 µg/m³.
- All the smokers’ residences had concentrations of PM10 and PM2.5 exceeding the acceptable limits while in most cases the measurements approached the 100 µg/m³ mark. PM1 concentrations in only 17% of the residences with smokers were below 50 µg/m³ and in 83% of the buildings the concentrations measured were higher than 100 µg/m³.

In conclusion it is obvious that indoor pollution in homes has a major significance in the health and well being of their inhabitants. There is an unmistakable effect of tobacco smoking in the indoor air quality of dwellings and measurement clearly show non-smokers homes to have a cleaner environment with fewer adverse effects due to indoor air pollution.

CONCLUSIONS

Measurements of the indoor concentration of CO2, CO, TVOC’s and PM10, PM2.5and PM1 quality in seventeen buildings have been performed in the greater area of Athens, Greece. The main conclusions are:

- CO2 concentration measurements showed that in houses with smokers the 1000 ppm limit was exceeded in more cases than in houses without smokers. On average, buildings without smokers were found to have

Measurements of the PM1 concentrations however showed that only 17% of the residences were below 50 µg/m³ and in 83% of the buildings the concentrations measured were higher than 100 µg/m³. The above levels are very high and may pose a serious threat for the health of the residents.

For the PM2.5 almost 24 % of the dwellings present a concentration below 50 µg/m³, while the 64 % are below 100 µg/m³. The ratio between PM2.5/PM10 varies between 0.2 to 0.8. Measurements performed in 20 residences in California found that the median PM2.5 concentrations were 32.2 µg/m³, (Sawant et al, 2004).

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