EXPERIMENTAL STUDY OF THE IMPACT OF AIR PURIFIERS ON THE INDOOR AIR QUALITY INSIDE OF AN APARTMENT

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Abstract. The use of air purifiers to filter polluted or contaminated air, seems an interesting solution nowadays. Using an extensive experimental approach, a commercial air purifier was tested under real conditions in-situ. The IAQ was measured in two rooms: living room and bedroom for different air change rates of the air volume. Measurements of PM2.5, PM10, relative humidity, air temperature and sound pressure level were made. It was found that the PM2.5 levels are quickly reduced from 20.64 μg/m³ and decreased to 5.58 μg/m³. The research was also focused on the noise levels measurements and it was noticed that in Silent to Low mode (60 and 150 m³/h) the sound pressure levels are under 30 dB. Overall, the use of air purifiers in homes is recommended nowadays.

Keywords: Air purifier, Purification technology, Experimental measurements, Relative Humidity, Sound pressure measurements, Fine particulate matter, Indoor air, Dust exposure.

1. Introduction

Several plans are made when it comes to reducing the exposure degree to countless factors of biological origin or non-biological. The evolution of air filters brings effective measures and air filtration starts being an important component of environmental control measures. Based on the studies of World Health Organisation, known as “the promoter of health”, we now know that air pollution is the cause of over six million deaths a year and a very important factor when it comes to allergies. Throughout our lives, we spend most of our time indoors, but this doesn’t mean we’re safe from pollution – a mixture of particulate matter (PM) and volatile organic compounds (VOC), make the air inside our homes to be up to five times more polluted than outside. Our homes contain a mix of airborne particles from mould, cleaning products, dust mites, cosmetics and gases from cooking and heating – and as we know, breathing in these pollutants has been linked to serious health conditions, like asthma, other pulmonary diseases and even more serious problems like lung cancer [1]. One of the things people can do to ameliorate the air condition in their homes, is to keep it well ventilated – especially when cooking and cleaning. Dust is a combination of fine particles from both
indoors and outdoors [2], that can be generated from a variety of different sources and processes. Recent studies aim to highlight the impact of ventilation systems and air purifiers on IAQ. An unplanned controlled test evaluated the efficiency of air filters and classic split units for air conditioning in 126 necessitous houses of children with asthma. IAQ was experimentally measured during four seasons. When indoor air quality was monitored, filters reduced PM levels in the child’s bedroom by an average of 50%, levels that could be reduced only by using filters [3]. Giving the fact that children are exposed frequently to airborne particles and various pollutants, an experimental action was conducted in several sports arenas in Barcelona). The indoor and outdoor measurements of particle amount and PM concentrations, were fulfilled, as well as indoor measurements of CO₂ and NO₂ levels. The study admits that using air purifiers and keeping windows closed (meaning natural ventilation), can lead to an important reduction when it comes to indoor-to-outdoor accumulation ratios. In the space the indoor-to-outdoor concentrations decreased to 93-95% in the matter of particle number and PM₁₁₀, respectively; while in the bigger sport arena, the equivalent reductions were 70% and 84% [4]. Another study of air purifiers, was made to prove the benefits of a HEPA filter in reducing allergic respiratory manifestations. The subjects were 32 patients with never ending rhinitis and asthma symptoms, mostly occurring during winter and fall season, and who were also positive skin tested to house dust or mite extract. The experiment was made with an ENVIRACAIRE air purifier, placed in the bedroom for eight weeks. Randomly, the active filter was used for four weeks, and the following four, a blank one, as a placebo. With the HEPA filter, there was a 70% reduction in the matter of particle number, of 0.3 μm in size. As a conclusion, the study revealed that patients responded positively to the active filter benefits and the overall opinion is that HEPA filters can reduce the symptoms of allergic diseases [5]. In the late years, studies showed that because of fog’s and clouded weather growth, pollution increased, which brings suffering to people and affects their health and also social and business life. According to the government of China’s environmental communication, cities begun monitoring PM2.5 and observed that few reached the standard and almost half of the year, air quality got to 52% of the standard, Beijing being an example. Also, another important noticed fact, was the heavy pollution and the numbers showed 16.2% of days. One more study was made over a six-month period, to record the efficacy of air filters.

The study contained three parts: active air cleaners, placebo air cleaners mixed with allergen-impermeable mattress covers and active air cleaners mixed with allergen-impermeable mattress covers. Allergen proportions in mattress and floor dust were measured before the intervention, and after the three and six months of the experiment. At the end of the six months, the air cleaners were disassembled and the filters showed that substantial amounts of dust and allergens were caught, more precisely, HEPA filtered 70% of 0.3-μm particles and 95% of 1.0-μm particles and the Rota filter, captured small dust particles, at high speed function [6]. Another experiment was held in three elementary schools located in the same district area in the United States, the
main focus being on the indoor pollutants and the level of their concentrations. The measurements took place between October 2013-June 2014. For the three schools, there were 21 classrooms and active air cleaners with HEPA filters were installed in half of the rooms. For the rest of the classrooms, the author chose cleaners with no HEPA filters and no air flow [7]. Measurements took place in three steps, the first taking place before placing the purifiers. A total of 63 samples were collected, on Teflon filters placed inside specimen boxes. Simultaneously, daily outdoor air pollution concentrations were measured at the on the rooftop of the Countway Library at Harvard Medical School. PM2.5 particles were collected using a specimen box containing a personal exposure monitor. The first period of measurements took place during cold weather months and it was found that the air in the classrooms with active purifiers across all three schools had lower levels of PM2.5 than those classrooms that had no filters. Next period of measurements, which corresponded to warmer months, the air in the classrooms with active purifiers across all three schools had lower levels of PM2.5 than the classrooms with no filters. Another study took place in Iran and the main concern were street cleaners, which are mostly exposed to dust inhalation, conducting to respiratory diseases and airway difficulties. The purpose was to evaluate the multiple pulmonary symptoms of 84 cleaners, with other not exposed of individuals, meaning 80 office workers. For each of the participants, pulmonary symptoms were assessed by using an equipment called spirometer. The results showed that the exposed group presented respiratory symptoms higher than in the reference group. Cough was the main issue reported by the exposed group (81%), compared to the other participants (16.3%). Providing street cleaners respiratory protection instruments and also a periodic spirometry, could be an efficient solution in preventing pulmonary damage [8]. The mineral dust of the Sahara desert, may be a serious health threat. Lately, particular interest has been accorded to mineral dust particles, that could lead to real health issues.

The PM deriving from Saharian dust are responsible to multiple causes of mortality and morbidity. The impact of dust is appearing and sufficiently powerful, therefore it requires further study [9]. As found from these previous papers, the use of air purifier to reduce PM levels, seems an appealing solution. In this paper, a home air purifier is analysed to check its impact on indoor air quality and on the overall indoor environment in an apartment.

4. Experimental campaign

The perfect environment for doing a research study on the impact of an air purifier, was to study in-situ and an occupied apartment was the ideal testing situation. The apartment is located in Bucharest, Romania and it is part of a block of apartments of 10 floors. The building has double exposure, one to Pantelimon Boulevard and the second one to a backyard. During the year 2010 the building was thermally rehabilitated, and the old windows replaced along with the closure of the balconies, with double glazing windows. The Pantelimon Boulevard is a source of pollution among which it is mentioned NOx,
dust particles, noise, etc. In figure 1 it is illustrated a schematic drawing of the apartment and the position of the air purifier, during the two experimental campaigns.

![Schematic drawing of the campaign used during the experimental tests and the position of measurements](image)

The research was conducted with a home air purifier from Daikin, model URURU, that is designed to remove gaseous air pollutants or convert them to harmless by-products. The air purifier has multiple modes: humidification and air purification. The streamer technology, which decomposes odours and allergens, creates an extensive plasma emission inside the equipment, that allows substantial number of electrons to be generated, thus producing a large oxidative effect. Bacteria and viruses are completely eliminated by the titanium apatite and then eliminated by the photocatlyst. The specifications of the analysed air purifier are listed in Table 1.

The highest air flow rate of the URURU system is 450 m³/h being capable of an air change rate of up to 9 ach for a 20 sqm room, while the minimum is 1.1 ach. The manufacturer specifies also the maximum sound equivalent pressure level, that for the silent mode (60 m³/h) is 17 dB(A) while for the Turbo mode (450 m³/h) can reach up to 50 dB(A). URURU is also capable of humidification of the indoor air with an input of maximum 600 ml/h. The experimental measurements were realized with TESTO 480 for air and relative humidity, with DYLOS 1100 PRO for dust particle measurements and with SVAN 979 class 1 precision sound meter, for sound pressure measurements.
### Table 1

**Air purifier specifications**

| Type                                      | Specification                          |
|-------------------------------------------|----------------------------------------|
| **Weight**                                | **11**                                  |
| Air flow rate Turbo/H/M/L/Silent          | 450/330/240/150/60 m³/h                |
| Humidifying operation Turbo/H/M/L/Silent  | 450/330/240/150/120 m³/h               |
| Sound pressure level – Air purifier mode  | 50/43/36/26/17 dBA                     |
| Turbo/H/M/L/Silent                        |                                        |
| Sound pressure level – Humidifier mode    | 50/43/36/26/23 dBA                     |
| Turbo/H/M/L/Silent                        |                                        |
| Power input Air purifier Turbo/H/M/L/Silent| 0.081/0.035/0.018/0.011/0.008 kW      |
| Power input Humidifier mode Turbo/H/M/L/Silent| 0.084/0.037/0.02/0.013/0.012 kW      |
| Humidifier mode Turbo/H/M/L/Silent        | 600/470/370/290/240 ml/h               |
| Water tank capacity                       | 4.0 litres                             |
| Air filter                                | Polypropylene net with catechin        |
| Dust collecting method                    | Plasma ionizer/Electrostatic dust      |
| collection filter                         |                                        |
| Dimensions (Height x Width x Depth)       | 590/395/268 mm                         |

### 3. Results

As we can see from the measurements made with the air purifier in the living room, the results show the evolution of ambient air quality. At the beginning of measurements, the PM2.5 concentration in the living room, showed 20.64 μg/m³ units and a decrease to 5.58 μg/m³ units within 1 hour of system operating at High level and Humidification function ON (330 m³/h or 7.33 ach). The next step was to set the system to stage 2 (Low level – 150 m³/h or 3.33 ach) with humidification mode ON, which maintained the PM2.5 under 11 μg/m³, being considered a good ambient air quality. The results were even better during stage 3 and Humidification function OFF, PM2.5 reaching the lowest value of 4.2 μg/m³. At the end of the experimental measurements the system was turned on Silent mode (max. 60 m³/h) and the PM2.5 average values were found in the range 8 to 13.3 μg/m³. The larger particles PM10 followed the same pattern presented previously, with a maximum value at the beginning of 2.01 μg/m³ and a lower value of 0.1 μg/m³. The air purifier’s discharge temperature varied from 24.4 °C during the humidification function, to 25.9 °C. Measurements were taken also for the relative humidity at the exhaust air and interesting information was found. After 1 hour of functioning in Turbo mode and Humidification, the relative humidity increased from 60% to a maximum value of 67.5%, while during the Silent Mode (Stage 1) and no humidification, the humidity stabilized at 57.5%.
Fig. 2 – PM2.5, PM10, Purifier temperature and relative humidity variations during different stages in the living room
On the other hand, in the bedroom (V=27.5 m$^3$) the efficiency of the system was even higher, as the PM2.5 decreased in less than 40 minutes from 20.76 μg/m$^3$ to 1.47 μg/m$^3$ for 150 m$^3$/h (5.7 ach) and even more, during stage 4 (High – 330 m$^3$/h or 12.6 ach). However, during normal occupants activities in the room, the PM2.5 slightly increased to 4.24 μg/m$^3$ still being situated in the “green,” zone of good air quality. It is a clear evidence that the system performs better in lower volumes enclosed rooms.

As we spend more than 8 hours/day in the bedroom it is also mandatory to have as well, a good acoustic comfort. The measurements took place in the bedroom during night time, in order to have lowest background noise. It can be observed from Table 2 that for 1000 Hz the sound pressure level is only 9.8 dB, a very low value, confirming that the measurements were correctly executed. Using the sound meter SVAN 979, the air purifier noise level was measured for different stages (1 to 5 / Silent to Turbo). During the Silent mode, the air purifier only slightly increased the noise level in the bedroom and even in Low mode (150 m$^3$/h), the sound levels are still under 30 dB considered an acceptable value for sleeping areas. However, the system is not recommended to be used during night-time in Medium to Turbo mode, as the acoustic comfort is no longer fulfilled.
Table 2

| Type       | Frequency (Hz) |
|------------|----------------|
|            | 31.5 | 63     | 125   | 250   | 500   | 1K    | 2K    | 4K    |
| Background noise | 0.76  | 5.70  | 8.37  | 13.30 | 10.75 | **9.88** | 12.58 | 14.43 |
| Silent     | 1.49  | 4.53  | 9.87  | 14.88 | 12.57 | **10.93** | 12.86 | 14.32 |
| Low        | 2.13  | 5.89  | 17.17 | 24.30 | 27.04 | **26.32** | 20.73 | 17.50 |
| Medium     | 3.68  | 8.03  | 24.64 | 31.20 | 37.09 | **38.91** | 33.22 | 28.35 |
| High       | 6.06  | 12.77 | 31.63 | 44.76 | 45.47 | **45.47** | 43.89 | 37.44 |
| Turbo      | 11.71 | 19.26 | 39.39 | 44.35 | 51.49 | **53.53** | 50.70 | 48.49 |

Figure 4 illustrates the global sound equivalent pressure level, expressed in a single value, measured in dB(A) that corresponds the best to human hearing system. As expected, the air purifier greatly increases the noise level during the Turbo mode with values reaching up to 58 dB(A), but remaining acoustical comfortable in Silent and Low modes.

It can be noticed that for the range of frequencies 31.5 Hz to 250 Hz even in Medium mode (240 m³/h) the sound pressure levels are under 30 dB while for the Turbo mode (450 m³/h) from 125 Hz the maximum sound pressure admissible level are no longer respected. However, the results demonstrates that even with 60 m³/h to 150 m³/h the indoor air is cleaned sufficiently and the noise levels are low.

Fig. 4 – Sound pressure levels measured.
4. Conclusions

Taking into consideration that tests were made in-situ, with a commercial air purifier, measurements showed that in the living room, the air purifier reduced considerably the amount of present dust particles PM2.5 within 1 hour of system functioning. PM10 was also reduced, proving its capacity to filter small or large particles. For the humidification process it was found that the system can rapidly increase humidity of up to 10% in maximum 1 hour, therefore it is safe to state that has a good capability of moisturizing the air. One remarkable conclusion of the measurements conducted in the bedroom, is that for smaller volume spaces, the air purifier performs best, as the PM2.5 and PM10 reached lowest possible values (<0.1 μg/m³). As acoustic comfort is an important parameter when dealing with HVAC (Heating Ventilation Air Conditioning) systems, a series of sound pressure measurements were conducted for different air flows.

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