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PARTICLE IN AN EXPERIMENTAL OPERATING ROOM

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Abstract. *This work aims to evaluate the influence of filtration systems on the concentration and size of particles in an experimental operating room. Filters with a wide efficiency range (from 65% to 99.97%) have been examined. The tests were carried out in a specific experimental operating room of approximately 19 m2. The results of the analysis indicate that indoor particle concentration is dominated by the smaller particles. This has a strong influence on indoor particle concentration and the use of high efficiency filtration is the best alternative, because it dramatically reduces the indoor/outdoor ratio for small particles. As particle size increased, the benefits of high efficiency filtration decreased, presumably because the efficiency of normal filters for particle removal increases with particle size. It was also noted that outdoor particle concentration varied depending on the day and time. This fact is very important, especially in large cities, whose hospitals are commonly placed in urban areas, with a very polluted atmosphere. The results also showed that, for small particles, the reduction of particle concentration in ducts and components represented a low percentage of particle flow rate. This reduction increased with particle size.*

Keywords*: Air quality, experimental operating room, transplantation, air filtration efficiency, particles.*

1 Introduction

Nowadays animal preclinical research is of fundamental importance as it allows the aquired knowledge to be applied in domain of human medical practices and procedures. The environments for this type of research should be strictly controlled to guarantee the excellence of the procedure results, which are becoming more and more specific. As such, adequate environmental conditions should be provided for the validation of the results. These conditions include not only the evaluation of physical aspects but also the dynamic factors that assure the environment control of dispersed particles in the air that may contain microorganisms and toxic substances (Galvão, et al., 2003; Frasier, et al., 2005; Hendriks et al., 1998; Riskowsk et al., 1998).

Due to their reduced size, the microorganisms tend to attach to the particles, such as skin and hair fragments, dust etc. These particles are easily dispersed by drafts. The particles containing microorganisms capable to produce colonies in a culture medium are called viable particles. Such particles have, basically, three origins: 1) those generated inside the surgery room; 2) those coming from adjacent areas; and 3) those coming from the ventilation system. Those particles, when dispersed in the air, tend to deposit, with varying speed, on surfaces, due to the effect of gravity. The smallest can stay in suspension for several hours. Any movement of the air close to the deposition surfaces (floor, equipments, walls) can cause resuspension. The microorganisms adhered to the particles dispersed by the air can contaminate the surgical wound directly, by falling onto it, or indirectly, after they precipitate on instruments, other surgical materials (gloves, gauze, fields etc.) and on the clothes of the medical team.

Inappropriate air conditioning systems used in surgical rooms represent an important potential source for the dispersion of particles that may contain microorganisms.

On the other hand, air conditioning systems can also play a crucial role in a surgical room, to protect the surgical wound and the sterile equipment against the microorganisms carried by the particles. This protection is provided by the simultaneous control of the filtration, distribution and movement of air, which are factors that affect the amount of particles present in a surgical room.

Thus, an efficient ventilation system comprising specific filters is of fundamental importance to establish an efficient control of airborne pollutants and to maintain a controlled environment in the conditioned space.

Operating rooms should have filtration devices to perform two functions: protection of the air treatment system and ductwork against the harmful effects of the airborne particles; and the protection of the environment and occupants against the airborne particles in suspension (ASHRAE, 2001 Galvão, et al., 2003; Pereira and Tribess, 2004; Pereira et al., 2005).

In large cities, hospitals are commonly placed in urban areas, with a very polluted atmosphere. Thus, filtering systems constitute a very important defense against the outside air pollution, especially in environments which demand a large amount of external air, such as operating rooms.

We have two concerns here, regarding airborne particles: first, the possibility of wound infection by particles containing microorganisms; and second, the protection of the surgical team against the urban outdoor air pollution, brought to the inside of the room by the ventilation system. This second effect may be especially important, due to the extended periods of time spent by the surgical team inside the operating room.

As such, the objective of this work is to evaluate the influence of filtration systems on the concentration and size of particles in an experimental operating room.

2 Filter system problems in operating rooms

Most of the studies that analyse the effects of filtration systems on the indoor concentration of particles are related the commercial buildings (Burroughs et al., 1998; Fisk et al., 2002; Howard-Reeda et al., 2003; Jamriska et al., 2003; Jamriska et al., 2000; Thatcher et al., 2001). As such, available information on filter use is relatively abundant and representative for office buildings and residence, but mostly unavailable for other buildings, such as hospitals and specifically, operating rooms. The available literature on air contamination in operating rooms provides rich information on models for the prediction of particle concentration (Salvigni et al, 1996; Jamriska et al., 1998). However, very little is said about the impact of different filtering efficiencies on the reduction of particle concentration in operating rooms. This way the importance of the filters on the control of the atmosphere in these environments is not yet well understood.

As mentioned above, the filter system in an operating room plays a fundamental role in maintaining a controlled atmosphere. The external air normally contains pollutants such as bacteria, pollens, insects, dust etc, especially in larger urban building facilities, as is the case of the operating room examined in this study, which is located in São Paulo downtown area. This way, the filter system becomes a decisive control mechanism for the biological quality of the air. The filter system is also important for the combat of the microorganisms that can grow in the components of the facilities and that cannot be entirely avoided (Pereira and Tribess, 2004).

Insufficient maintenance and lack of substitution of the filters is a serious problem in many Brazilian hospitals. The accumulation of dust and the condensation of moisture at the entrance surface of air filters may turn them into a potential source for IAQ problems in the operating room. Moisture and dust provide a medium for the growth of fungi and bacteria, and the growing colonies can reach to the clean side of the filter.

Another problem that occurs frequently is when the filters are badly fit into their frames, which allows the leakage of pollutants to the inner space. Air leakage through openings or joints is highly important in an atmosphere that demands highly clean air. However, this phenomenon is difficult to control in places where the maintenance is insufficient or inexistent.

3 Experimental method

The tests were carried out in a specific experimental operating room used for preclinical research of liver, kidney, intestine and multivisceral transplantation in large animals. The room has an area of approximately 19 m^2 Fig. 1 shows the layout of the room.

The experimental operating room has a self-contained air conditioning system. The equipment capacity is 10 TR, and it provides clean air for the entire laboratory (animal resection facilities).

The air conditioning system works continually and is located in a room adjacent to the laboratory. The external air enters this room and is immediately aspirated by the equipment. The first filtration stage (65%) is located at the outside entrance of the air conditioning unit. The second filtration stage is as the air leaves the unit, prior to entering the air distribution system.

The air enters the surgical room through ducts and is distributed by supply grills located on the ceiling, at the extremities of the surgical table. The two supplying grills horizontal jets, which cause mixture of the air through high helical induction. The air in the room returns through four return grills, also located on the ceiling. The system operates with absolute filtration and produces a rate of air renewal of 100%. Fig. 2 shows an outline of the air distribution system of the room.

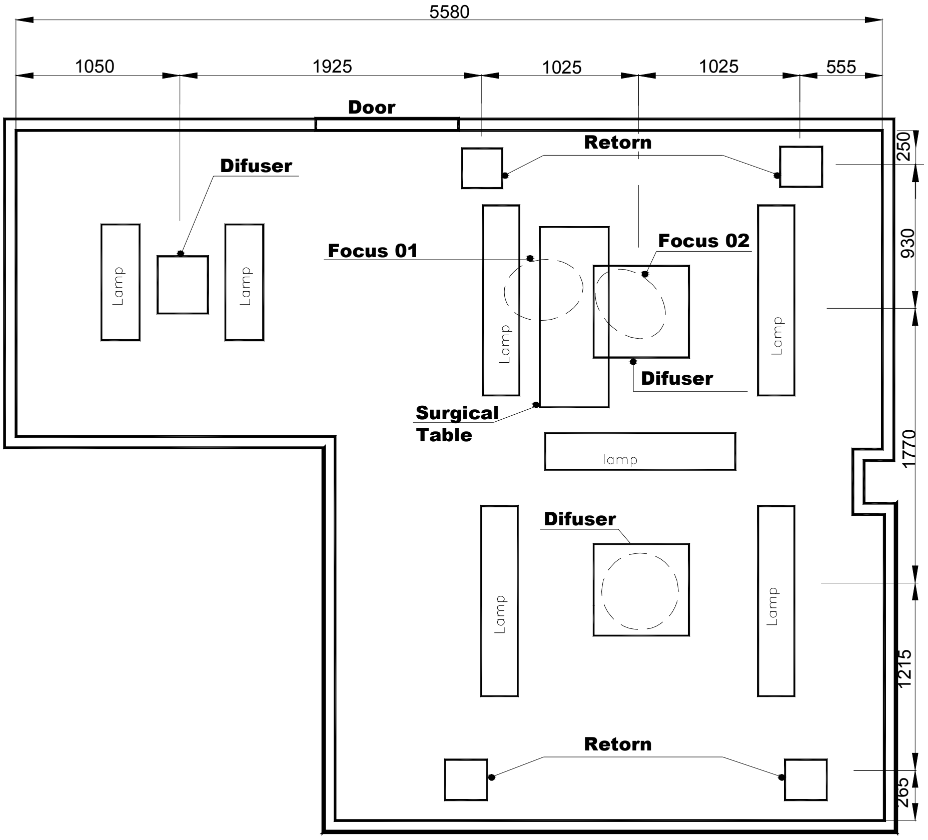

Figure 1 – Layout of the operating room.

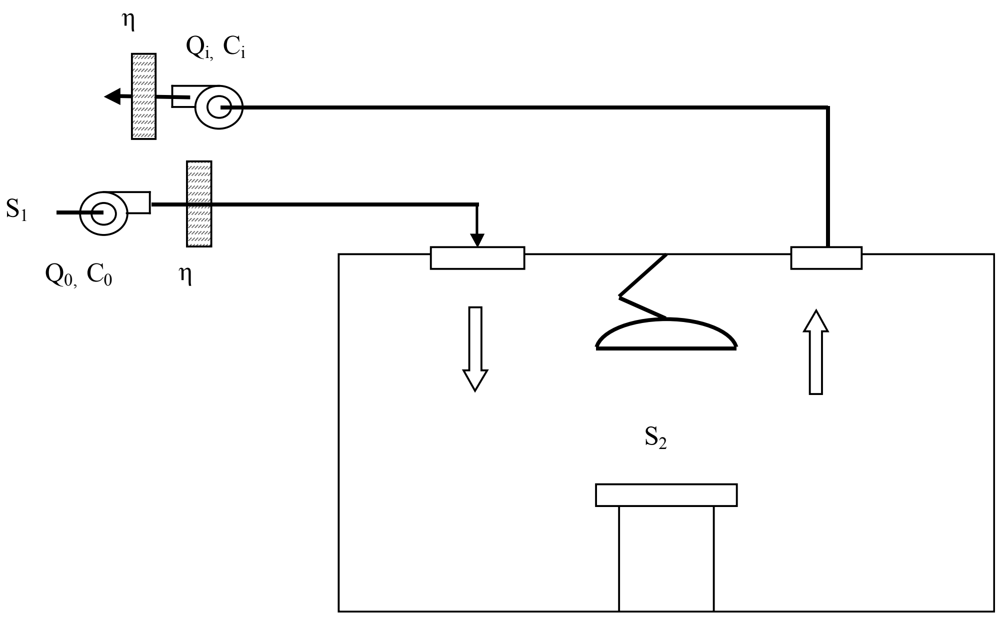

Figure 2 – Ventilation system and measurement sites

3.1 Airborne particle concentrations

Airborne particle concentrations were measured with a light scattering automatic particle counter, calibrated by the manufacturer (MET ONE). It yields counts of particles in six size ranges, 0.3 µm to 0.5 µm, 0.5 µm to 1.0 µm, 1.0 µm to 3.0 µm, 3.0 µm to 5.0 µm, 5.0 µm to 10.0 µm, and >10 µm, with a flow of 0.1 cfm (2,83 L/min).

3.2 Method

Data collection was carried out on two subsequent days, a holiday and a working day, respectively. On the first day, measurements of particle concentration in the outdoor air were taken, in the morning and in the afternoon. On this same day, in the afternoon, particle concentration was measured inside the room, without filtering and with a 65% efficiency filter. On the following day, all measurements were carried out in the afternoon. Outdoor air particle concentration was obtained and indoor particle concentration was measured with 65%, 85%, 95% filters and with a HEPA filter. The measurements were performed according to the following table:

Table 1 – Filter configurations

Measurements	Configuration
F1	65%
F2	65% + 85%
F3	65% + 95%
F4	65% +95% + HEPA

All of the measurement stages were accomplished with the room empty. The particle samples were taken in two locations: at the upstream of the air conditioning system and on the operating table. The measurements were used to directly calculate particle reduction efficiencies using the following equation:

$$\eta = 1 - \frac{C_{\text{upstream HVAC}}}{C_{\text{operating table}}} \qquad (1)$$

Where:

η = particle reduction efficiency;
$C_{\text{upstream HVAC}}$ = particle concentration at the entrance of the HVAC system;
$C_{\text{operating table}}$ = particle concentration on the operating table

The particle concentrations used in equation 1 were measured during a one hour period, for a duration of 60 seconds, every 6 minutes. Equation 1 obtains the total removal, that is, particle removal in filters, ducts and HVAC components.

4 Results

For each filter combination, particle reduction efficiency, particle concentration and indoor/outdoor ratio were analysed as a function of particle size and particle concentration, as a function of time.

4.1 Particle reduction

As mentioned above and shown in Fig. 2, particle samples were taken at two locations: at the upstream of the air conditioning system (S_1) and on the operating table (S_2). As expected, the configuration F4 showed a good performance for all the particle sizes. This configuration had the best performance for particle sizes from 0.3 to 1 µm. For the sizes from 0.3 to 0.5µm, the reduction efficiency was about of 99.87%, and for the sizes 0.5 to 1 µm, it was 99.06%. The worst performance was for particle sizes above 10 µm, with an efficiency of 89.76%. The other filters showed a poor performance for particles from 0.3 to 1µm.

For configuration F3 the best performance was achieved for particle sizes from 3 to 5 µm (96.10%) and the worst performance (48.61%) was for particle sizes of 0.3 to 0.5 µm. Configuration F2 also had the best performance (88.85%) for 3-5µm particles.
And the configuration F1 showed a very poor efficiency (25.59%) for 0.3-0.5µm particles. Its best efficiency (79.94%) was for particles from 5 to 10 µm.

Fig. 4 shows the effects of HVAC system (ducts and components) on the reduction of particle concentration. The measurements were carried out with the HVAC system operating without filters. This figure confirms the results published in others studies (Thatcher at al., 2001; Fisk et al., 2002). The results show that, for smaller particles, the effect of ducts and components on particle removal are only a small percentage of the total particle flow rate. However, particle reduction on duct surfaces and in HVAC components increased with particle size.

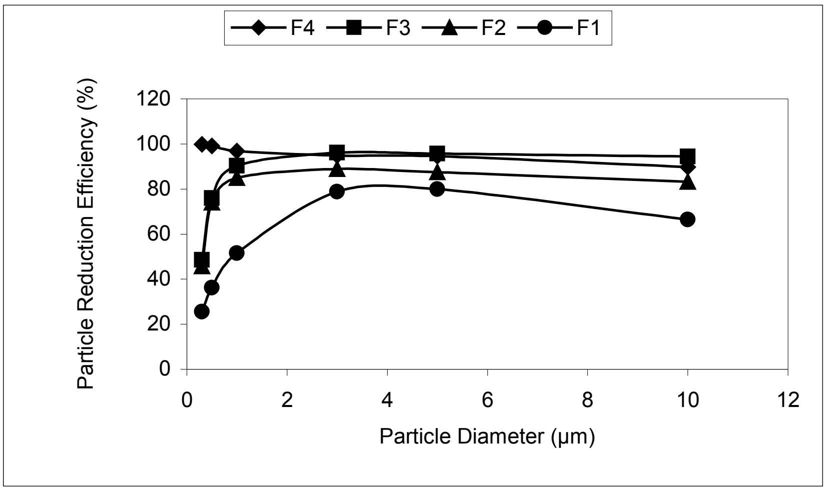

Figure 3 – Particle reduction efficiency in filters, ducts, and HVAC components

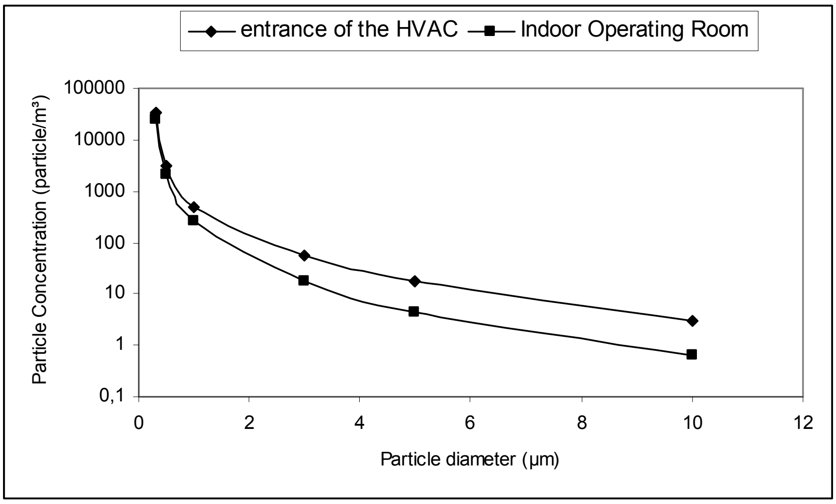

Figure 4 – Particle reduction in ducts and HVAC components

4.2 Particle concentration

Fig. 5 shows the results of the tests applied for each filter system. The figure shows particle concentration as a function of size for all cases. As expected, for all filter systems, particles of different diameters present various concentrations in the operating room. For all configurations, particle concentrations decreased with increasing particle size, especially for smaller sizes. For particle sizes from 0.3 to 0.5µm, the configuration F4 produced a low particle concentration (19.82 particle/cm^3), and for particle sizes above 10µm, particle concentration fell to less than 1 particle/cm^3. For this size, the other filter configurations also achieved concentrations around 1 particle/cm^3. Configuration F3 had the second best filtration for particle sizes from 0.3 to 0.5 µm. This configuration had the best performance for 3-10µm particles. This particle size is very important, because most viable particles are of this size (Pereira and Tribess, 2004; Pereira et al., 2005).

Fig. 6 illustrates the average concentration for 0.3-0.5µm particles, as a function of time. F4 and F3 differ by a factor of approximately 1.000.

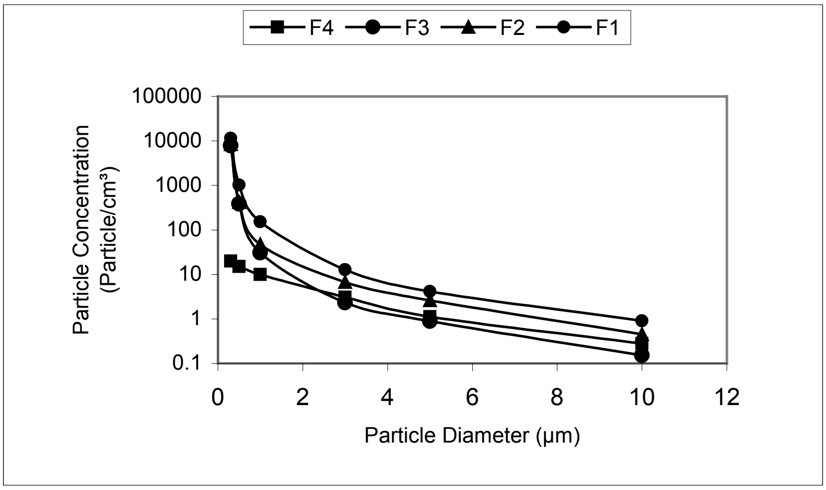

Figure 5 – Results of the tests applied for each type of filter system.

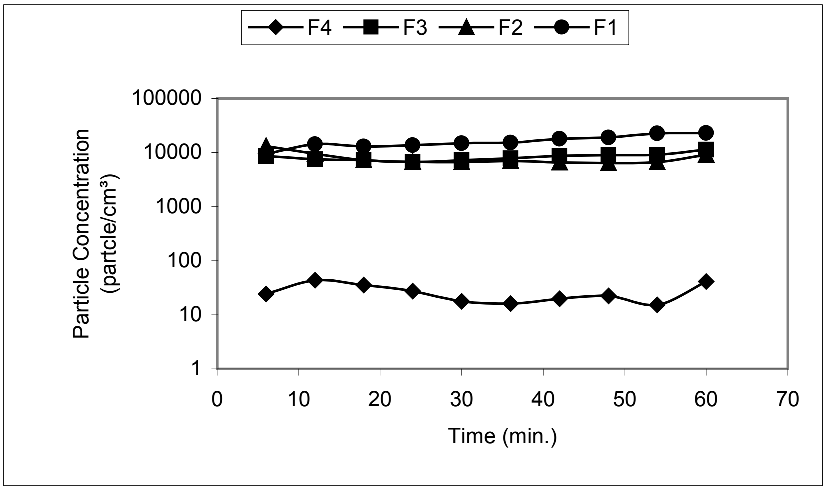

Figure 6 – Average particle concentration as a function of time for 0.3-0.5μm particles

4.3 Indoor/Outdoor ratio

Fig. 7 shows the ratio between indoor particle concentration at the operating table zone and outdoor particle concentration (at the upstream of the air conditioning system), for each particle size range. For configuration F4, at the 0.3-0.5 μm size range, indoor particle concentration is substantially lower than outdoor particle concentration (the indoor/outdoor ratio is close to 0). Within this range, configurations F2 and F3 caused a great decrease in the indoor/outdoor ratio (from around 0.5 to around 0.2). Configuration F1 removes few particles at this size range. For 0.5-1.0μm particles, configurations F2 and F3 showed a good improvement, such that is the indoor/outdoor ratio fell to about 0.1. For this size range, the configuration F4 showed a little increase in the indoor/outdoor ratio. From 1 to 3μm, configuration F1 showed a remarkable reduction in the indoor/outdoor ratio (from 0.5 to 0.2). For the 3-5μm range, the configuration F3 achieved the best performance. And for the 1-10μm, the situation remained basically the same for all filter configurations.

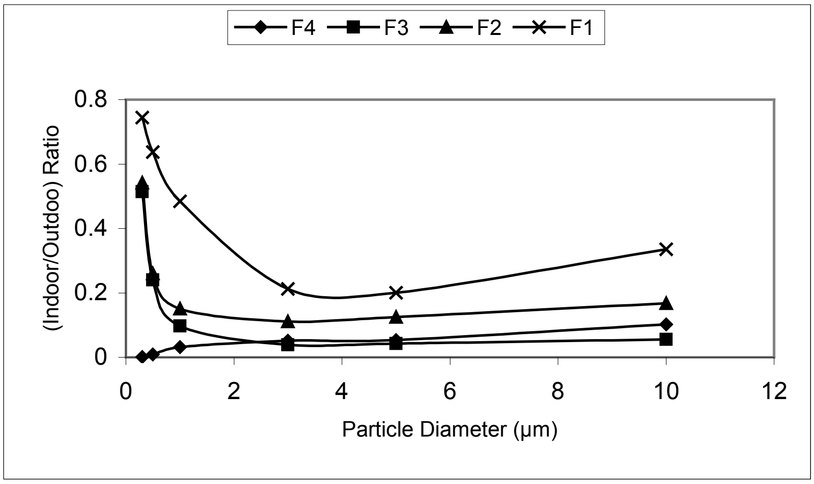

Figure 7 – Indoor/outdoor ratio as a function of particle diameter.

4.4 Outdoor particles

The present study was carried out in an experimental operating room located in an urban area of São Paulo, a large city with heavy automobile traffic that contributes to high levels of environmental pollution. As such, the efficiency of the filter system is fundamental for the control of the indoor atmosphere in the operating room, especially because the ventilation system of this room operates with 100% of external air.

This is a room where organ transplants are performed, which implies lengthy surgery, with many operations lasting longer than 12 hours. As the surgical team remain inside the room for extended periods, an efficient filtering system is also important for the protection of these professionals against outdoor air pollution.

In order to examine the performance of the filtration and ventilation system for the control of external air pollution, measurements were made at the air inlet of the air conditioning system on a holiday and on a working day. The results (Fig. 8) show a great variation in particle concentration in the outdoor air, especially for particles ranging from 0.3 to 0.5µm. For this particle size, concentration in a working day afternoon of was $3.4x10^4$ particle/cm^3. On a holiday, concentration was $1.2x10^4$ particle/cm^3 in the morning and $1.5x10^4$ particle/cm^3 in the afternoon. Thus, particle concentration in the outdoor air was about 30% higher in the afternoon than in the morning and more than double on a working day than on a holiday.

Fig. 9 shows particle concentration as a function of particle diameter for all particle sizes inside the operating room, when a 65% filter is used (configuration F1). Particle concentration on a workday is about 40% larger than on a holiday for all particle sizes.

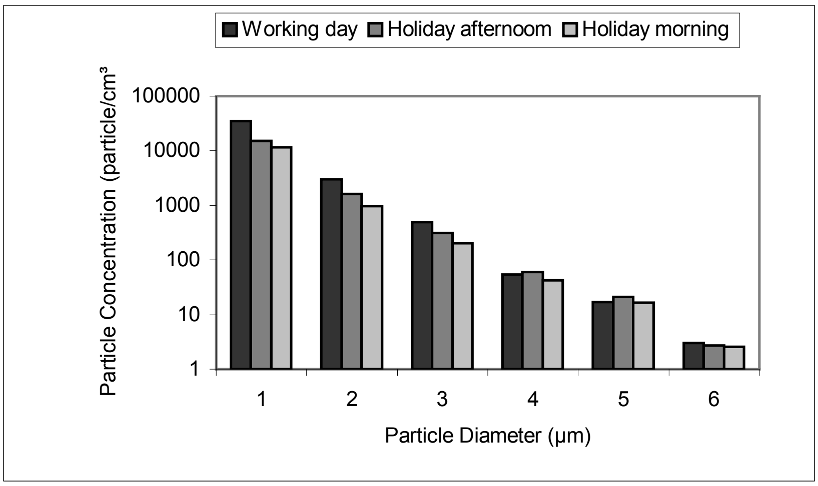

Figure 8 Outdoor particle concentration as a function of diameter.

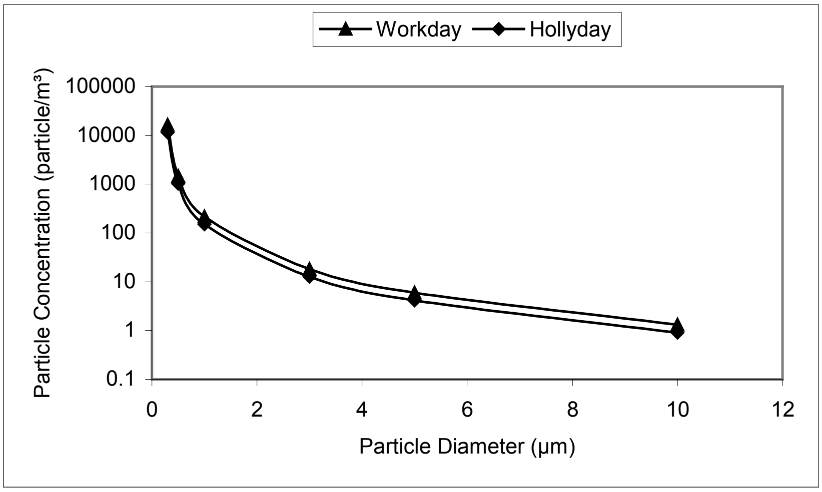

Figure 9 Indoor particle concentration as a function of diameter (for configuration F1).

5 Conclusion

As already pointed out in other studies, indoor particle concentration is dominated by the smaller particles. For small particle sizes the use of high efficiency filtration is the best alternative, because it dramatically reduces the indoor/outdoor ratio for small particles. As particle size increases, the benefits of high efficiency filtration decrease, because the particle removal efficiency of normal filters increases with particle size.

Small particles of outdoor origin have a strong influence on indoor particle concentration. The relationship between indoor and outdoor particle concentration is a matter of concern because epidemiological studies have associated indoor health effects with outdoor particle concentration.

Outdoor particle concentration varies, depending on the day and time. This fact is very important, principally in large cities, where hospitals are commonly placed in urban areas, with a very polluted atmosphere. When the filtering system is not efficient, this outdoor variation may produce great changes in indoor air quality.

This work confirmed the results of other studies about particle removal from the indoor air by means of the HVAC system. The measurements showed that, for small particles, the effects on reduction are a small percentage of the particle flow rate. However, particle removal on duct surfaces and in HVAC components increased with particle size.

It is important to develop further studies on particle concentration in operating room, due to the importance of the theme and the small amount of studies published in this area.

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