Ordered by
PTS, Program för Teknisk Standard

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Datum
2024-04-29

Version
Final report

The Impact of Air Cleaners in Hospital Environments

Compilation of measurement results from Kungälv Hospital, March 2024

Introduction

This report condenses descriptions, results, and conclusions based on measurements made in Kungälv's hospital from 13 to 15 March 2024. The effort was made as part of a more extensive assignment[1] for PTS (programme for technical standards), a network for healthcare facilities. In that study, the impact of the airflow in healthcare facilities was analysed in terms of risk of infection, installation costs, energy use, installation space, noise, etc.

Purpose and Background

The study's main purpose was to quantify the impact of a newly developed air cleaner on the risk of airborne infections and the level of bacteria, in a waiting room and a newly built patient room in a hospital. The intention was to inspire continued studies on the subject and to form a knowledge base for property owners in connection with action planning to reduce the spread of airborne infections in hospital premises.

The air cleaner used was in a development stage (prototype) but is based on proven technology with electrostatic filtration. The prototype has an innovative novelty value that lies in its design for quiet operation, high capacity, and washable filters.

By measuring particle and bacteria content in both rooms when the air cleaner was alternately switched OFF or ON, a good indication of its effect on bacteria content and clean airflow rate was obtained concerning the risk of spreading infection.

[1] Filipsson P, Ekberg L (2024). Luftflöde i vårdlokaler - Med ett fastighetstekniskt perspektiv. Chalmers tekniska högskola, Institutionen för arkitektur och samhällsbyggnadsteknik, Avdelningen för installationsteknik. Rapport ACE 2024:2. Link

Approach

The air cleaner prototype was tested in a waiting room and in a new built patient room. See Figure 1 and 2.

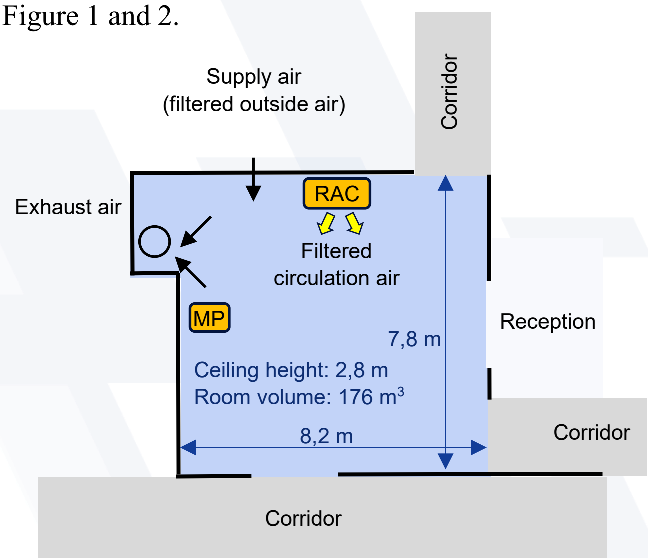

Figure 0 Principal sketch of the waiting room where measurements were carried out. MP = measuring point, RAC = room air cleaner. ATTENTION! The sketch is not to scale, and the corridors are significantly longer than they were drawn.

The supply airflow to the waiting room, illustrated in Figure 1, was measured with an air speed meter[2] to approx. 1,200 m^3/h over an air device. Incoming ventilation flow was filtered with class ISO ePM1 50% filters (class F7 according to the previous standard), which can be considered practice in the context. The exhaust airflow was measured to approx. 880 m^3/h in the same way. Exhaust air was also evacuated from toilets located in the corridor closest to the reception, according to Figure 1. Smoke visualization showed that the waiting room was supplied with air from the corridors. The air volume was thus considerably larger than the room volume of 176 m^3 indicated in Figure 1, which meant that the air cleaner had to clean a vast air volume.

The decay method was used to determine the clean airflow in both rooms, where a pollutant (lime powder) was added to the room air and the dilution of the particle concentration was measured with a particle counter[3]. In addition to the air cleaner's effect on the decay process, it is also affected by air leakage, particles falling to the floor due to their weight, and ventilation. The air cleaner's impact could be quantified by comparing the decay results with and without the air cleaner being active (all else being equal).

The presence of airborne bacteria was measured with an active microbial sampler[4]. The sampler sucks in a specific airflow that is swept over a rotating plate with nutrient jelly for bacterial culture. After measurement, the plates are placed in an incubator. The bacterial colonies (CFU) appear as dots and can be counted manually.

The air cleaner capacity (clean airflow) was manually set to 1 780 m3/h (495 l/s) in the waiting room and 1 410 m3/h (390 l/s) in the patient room, based on subjective experiences of acceptable sound level.

[2] Swema 3000 md + SWA31
[3] TSI – AeroTrak 9303
[4] Klotz – Impaktor FH6 (active sampling, i.e. sucks in air with a selected air flow)

The patient room in Figure 2 was considerably smaller than the waiting room and closed to adjacent rooms and corridors.

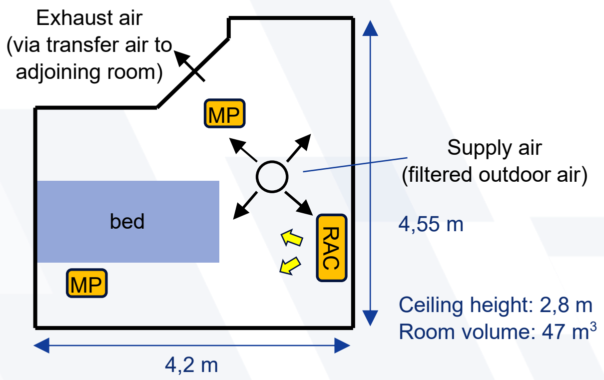

Figure 2 Principle sketch of the patient room where measurements were carried out. MP = measuring point, RAC = room air cleaner. ATTENTION! The sketch is not to scale. Windows and doors to the corridor and toilet were kept closed.

The operational personnel centrally adjusted the supply airflow in Figure 2. The flows were 15, 30, and 45 l/s during the measurements, respectively (see Tables 2 and 3). The supply air filter was class ISO ePM1 50% (F7). Smoke visualization showed that the air direction was out of the room, partly via some leakage to an adjacent corridor but primarily via transfer air from an adjoining toilet.

Measurement results

This section summarises the results from the decay measurements regarding particles (0.3 µm and 1.0 µm) and bacterial content. The latter is expressed as the number of bacterial colonies (CFU) per m^3 of room air. As the patient room had two measurement locations, mean values for these are presented in Table 3.

This section summarises the results from the decay measurements regarding particles (0.3 µm and 1.0 µm) and bacterial content. The latter is expressed as the number of bacterial colonies (CFU) per m^3 room air. As the patient room had two measurement locations, mean values for these are used.

The terms "measured decay" and "change factor" are used in the tables. Here is a brief description:

<u>Measured decay</u> The total dilution is expressed as clean airflow (m^3/h). This includes the influence of ordinary ventilation, air leakage, and particle sedimentation. When the air cleaner is ON, its impact is also included in the term.

Change ratio — A ratio that describes the proportional impact of the air cleaner. It's a quota for results when the air cleaner is ON and OFF, respectively. Consequently, if the original measured value (air cleaner OFF) is multiplied with the change ratio, the results equal when air cleaner is ON.

Note that the design of the tables differs slightly since the general ventilation flow in the waiting room was the same during the measurement period, while the patient room was given three different ventilation flows.

Table 1 Results from measurements of particles and bacteria in the hospital's central waiting room, second only to the one in the entrance.

Waiting room	Air cleaner OFF	Air cleaner ON	Air cleaner impact	Change ratio	Persons
Measured decay	4 570 [m³/h]	6 310 [m³/h]	1 740 [m³/h]	1,4 [-]	3 – 5 [pc]
Bacteria content	240 [CFU/m³]	170 [CFU/m³]	- 70 [CFU/m³]	0,7 [-]	

Table 2 Results from measurements of airborne particles in a newly built single-patient room

Patient room	Unit	Ventilation airflow in room		
		15 [l/s]	30 [l/s]	45 [l/s]
Measured decay – air cleaner OFF	[m³/h]	90	110	205
Measured decay – air cleaner ON	[m³/h]	1 620	1 785	1 740
Air cleaner impact	[m³/h]	+ 1 530	+ 1 675	+ 1 535
Air cleaner impact	[l/s]	425	465	425
Change ratio	[-]	17,8	16,5	8,6
Persons in room	[pc]	2	2	2

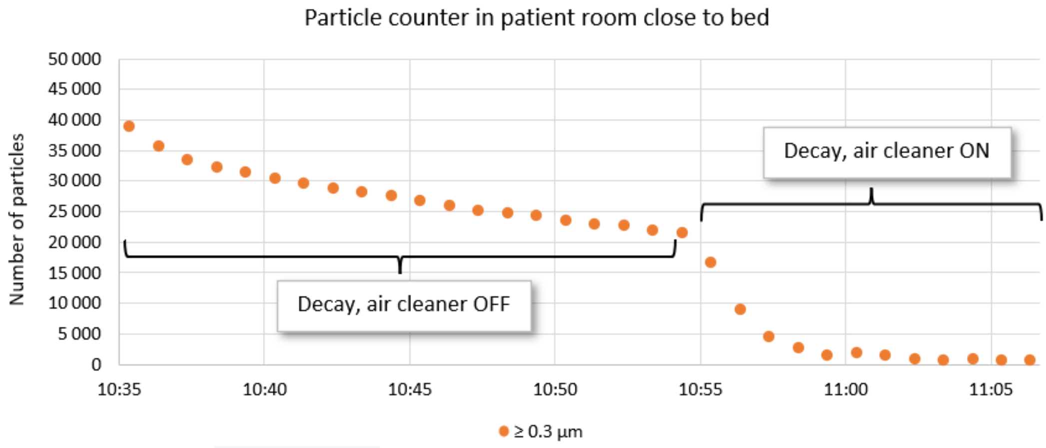

Figure 3 Decay progress, with and without air cleaner, for particles with a diameter of 0.3 µm.

The graph in Figure 3 refers to a measurement near the bed in the same patient room as in Table 2. However, results from the centre of the room show similar results. Lime particles were sprayed shortly before 10:35, and the room ventilation was 30 l/s throughout the period.

Table 3 Results from measurements of airborne bacterial colonies in the same newly built patient rooms as in Table 2.

Vårdrum	Sort	Ventilation airflow in room		
		15 [l/s]	30 [l/s]	45 [l/s]
Bacteria content – air cleaner OFF	CFU/m^3	310	345	195
Bacteria content – air cleaner ON	CFU/m^3	25	35	15
Air cleaner impact	CFU/m^3	- 285	- 310	- 180
Change ratio	[-]	0,1	0,1	0,1
Persons in room	[pc]	2	2	2

Analysis and Discussion

The air cleaner considerably impacted the quantity of airborne particles and bacteria, especially in the closed patient room, where the bacteria content was reduced to one-tenth compared to before. This was a result of increased clean airflow rates by approximately 9 – 18 times, depending on the room ventilation flow.

The decay method contains certain moments that can influence the results somewhat, which probably explains why the measured clean airflows do not relate linearly to the room ventilation flows. The results would have been better ensured with some more measurements for the same conditions and longer decay periods. However, the conclusion that the air cleaner had a large impact in the patient room remains.

The risk of being infected in a patient room by an airborne infection depends on severa factors such as exposure time, number of people, room volume and the clean airflow rate. Air cleaners affect the latter factor, and its impact on airborne infections can be quantified by applying an infection-risk model by Aganovic et al[5]. It is a developed version of the better-known Wells-Riley model, which was developed already in the 1950s for measles and tuberculosis. If the results from Kungälv's hospital are put into Aganovic's model, it shows that the risk of getting infected is reduced to approximately one-sixteenth compared to if the patient room had its original ventilation flow rate (15 l/s, which can be considered practice in this context). The reduction aligns with the measured air cleaner impact on the bacteria content; see Table 3, where the bacteria content was reduced to one-tenth.

[5] Aganovic, A., Cao, G., Kurnitski, J., & Wargocki, P. (2023). New dose-response model and SARS-CoV-2 quanta emission rates for calculating the long-range airborne infection risk. Building and Environment, 228, 109924

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