Experimental study of the effect of operation lamps on downward airflow distribution in an operating theatre in St. Olavs Hospital in Norway





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The objective of this study was to exam the effect of surgical lamps on the downward airflow distribution from the laminar ceiling diffuser in the operating microenvironment in one operating theatre at St. Olav Hospital in Norway. Measurement results show that both the height of the operating lamps and the angle of the lamps may influence the particle concentration in the operating microenvironment. The measured value of Colony Forming Unit (CFU) was higher when the operating lamps were located at a height of 1.92 m from the floor than at a height of 1.75 m from the floor. The particle concentration (0.3–3.0 micron) increased when the angle of the operating lamps was changed from 45° to horizontal. However, the increase of measured particle concentration did not result in the increase of measured CFU, which may indicate that the CFU may be affected by other factors.

Keywords: Airflow distribution, operating room, operating lamp, particulate matter, Colony Forming Unit, operating microenvironment.

Introduction

The indoor air quality of operating theatres is important for patients and surgical staff in terms of surgical-site infections. Earlier studies shown that among surgical patient's surgical-site infections (SSIs) are the most common hospital-acquired infections accounting for

36% of nosocomial infections [1]. Currently, SSI occurs for approximately 7% of all operations and is the third most frequently reported healthcare-associated infection in Sweden [2]. In Norway, the national average SSI rate was 2.0% which is higher than lower respiratory infection (1.4%), urinary tract infection (1.2%) and septicaemia (0.9%) in 2015 (Helsenorge, 2015).

In fact, the design of the microclimate in operating theatres (OT) is a complex task mainly due to the stability of air temperature, relative humidity, scheme of pressures, mean velocity and air quality [3]. The ultra-clean ventilation systems and laminar air flow ceilings are used in OTs to improve the indoor air quality. (One early study found that the measured bacterial and particle concentrations close to the operating field and at the level of instrument table were 20-fold lower in operating theatres with laminar airflow ceilings than in hospital rooms used for diagnostic or therapeutic procedures without ultra-clean ventilation systems [4].) However, another individual study showed significantly higher severe SSI rates following knee prosthesis and significantly higher SSI rates following hip prosthesis under laminar airflow conditions [5-6].

The objective of this study was to exam the effect of surgical lamps on the downward airflow distribution from laminar airflow ceilings in the operating microenvironment in an operating theatre at St. Olav Hospital in Norway.

Materials/Methods

The operating theatre (OT)

The measurements were conducted in a real OT which is located in St. Olav Hospital in Norway. In the middle of the OT, a laminar airflow ceiling was mounted to provide laminar downward airflow to the operating table (see **Figure 1**). In this study, five people were employed during the measurements to mimic two surgeons, one patient, one assistant and one anaesthetist in simulated operations. Two people simulating surgeons stood beside the operating table with one assistant standing close to the operating table. The simulated anaesthetist sat close to the head of the simulated patient laying on the operating table. Two type of measurement instruments were installed closely to the operating table to measure the number concentration of particulate matter pollutants and colony forming unit (CFU) (see **Figure 2**). The small zone close to the operating site may be defined as operating microenvironment (OMiE) and the rest of the operating zone may be defined as operating macro environment (OMaE). The OMiE is exterior and immediately adjacent to the surface of the operating site, where heat and moisture may be exchanged between body tissues and the indoor airflow [7]. The air quality of OMiE plays an important role of postoperative infection.

Measurement instrument

Two TSI AeroTrak® Handheld Particle Counters Model 9306-v2 were used to measure the particle concentration. The particle counters may measure particles in the range of 0.3 to 10 µm with a flow rate of 0.1 CFM (2.83 L/min). The counting efficiency of this instrument is 50% at 0.3 µm; 100% for particles >0.45 µm (per ISO 21501-4 and JIS). The two AeroTrak counters have been calibrated by the manufacturer before the measurements.

Measurement conditions

The measurements were performed in the OT and all the normal procedures for a real operation were followed, including cleaning, room preparation, sterilization of operating field and equipment and arrangement of surgical staff. **Table 1** shows more detailed information of the 6 cases.

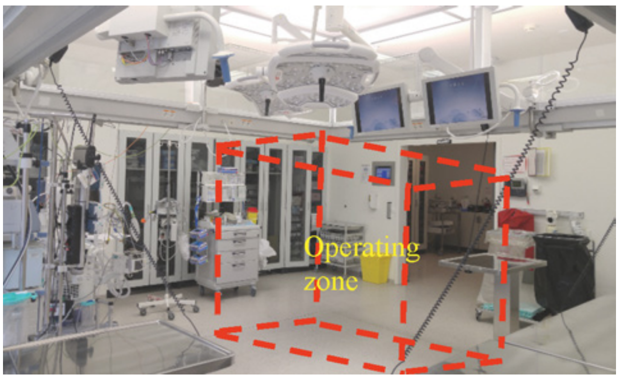

Figure 1. A photo of the operating theatre with all the medical equipment used in real operations.

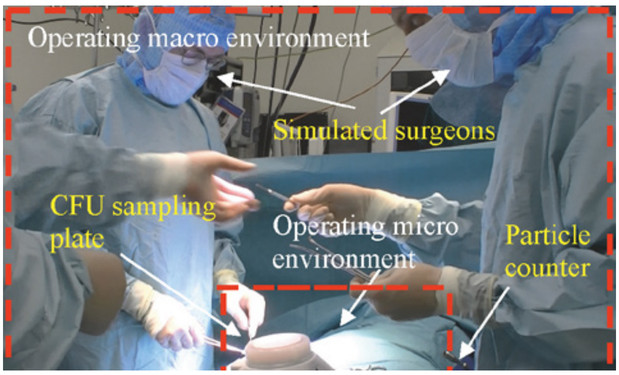

Figure 2. The locations of the measurement instruments for CFU measurement and particle measurement.

Table 1. Measurement conditions.

	Persons inside the operating room		Door opening	Measured parameters	Light position	
	nonsterile	sterile			Angle	Height from the floor
Case 1	4	3	2	PM, bacteria	45°	1.93±0.01 m
Case 2	4	3	3	PM, bacteria	45°	1.75±0.01 m
Case 3	3	3	2	PM, fungus	45°	1.75±0.01 m
Case 4	3	3	0	PM, bacteria	horizontal	1.75±0.01 m
Case 5	3	3	0	PM, fungus	horizontal	1.75±0.01 m
Case 6	3	3	2	PM, bacteria	45°	1.75±0.01 m

a) b)

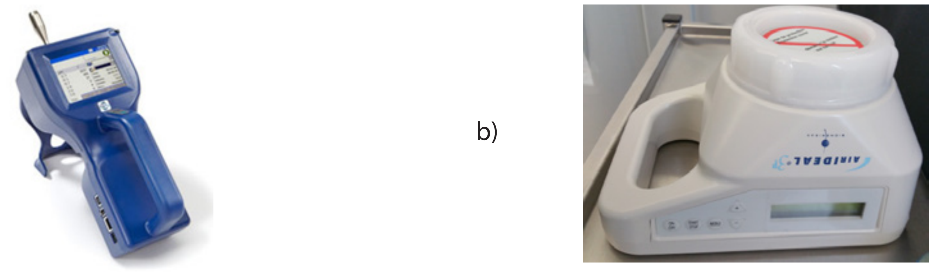

Figure 3. Measurement instruments, a) AEROTRAK™ Handheld Particle Counter Model 9306, b) CFU measurement device.

Results and discussion

Measured fine particle concentration and CFU

Figure 4 shows the measured fine particle concentration (0.3–1.0 micron) and CFU in all cases. The measured particle concentration (0.3–1.0 micron) in Case 1 is lower than other cases. It may indicate that the downward laminar airflow may dominate the operating table area regarding the fine particle control when the

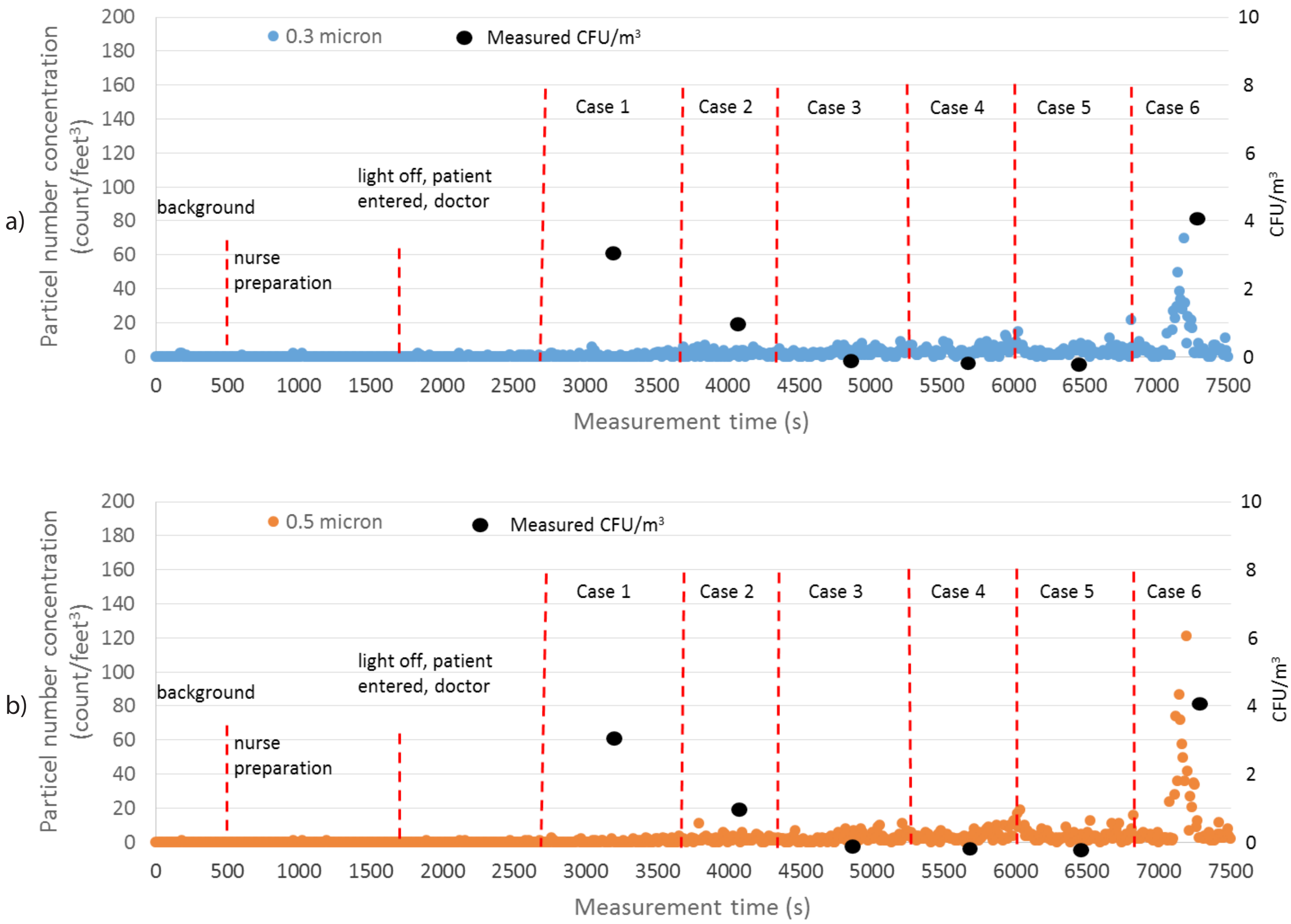

Figure 4. The measured fine particle concentration and CFU, a) 0.3–0.5 micron, b) 0.5–1.0 micron.

lamps were located at the height of 1.92 m. However, the measured value of CFU in Case 1 is higher than the values in case 2–4. In addition, **Figure 1** shows that the installation angle of the operating lamp may not affect the dispersion of airborne fungus in Case 3 and Case 5.

Measured coarse particle concentration and CFU

Figure 5 shows the measured fine particle concentration (1.0–14 micron) and CFU in all cases. It shows the measured particle concentrations (1.0–3.0 micron) in Case 3–5 are higher than other cases. The results

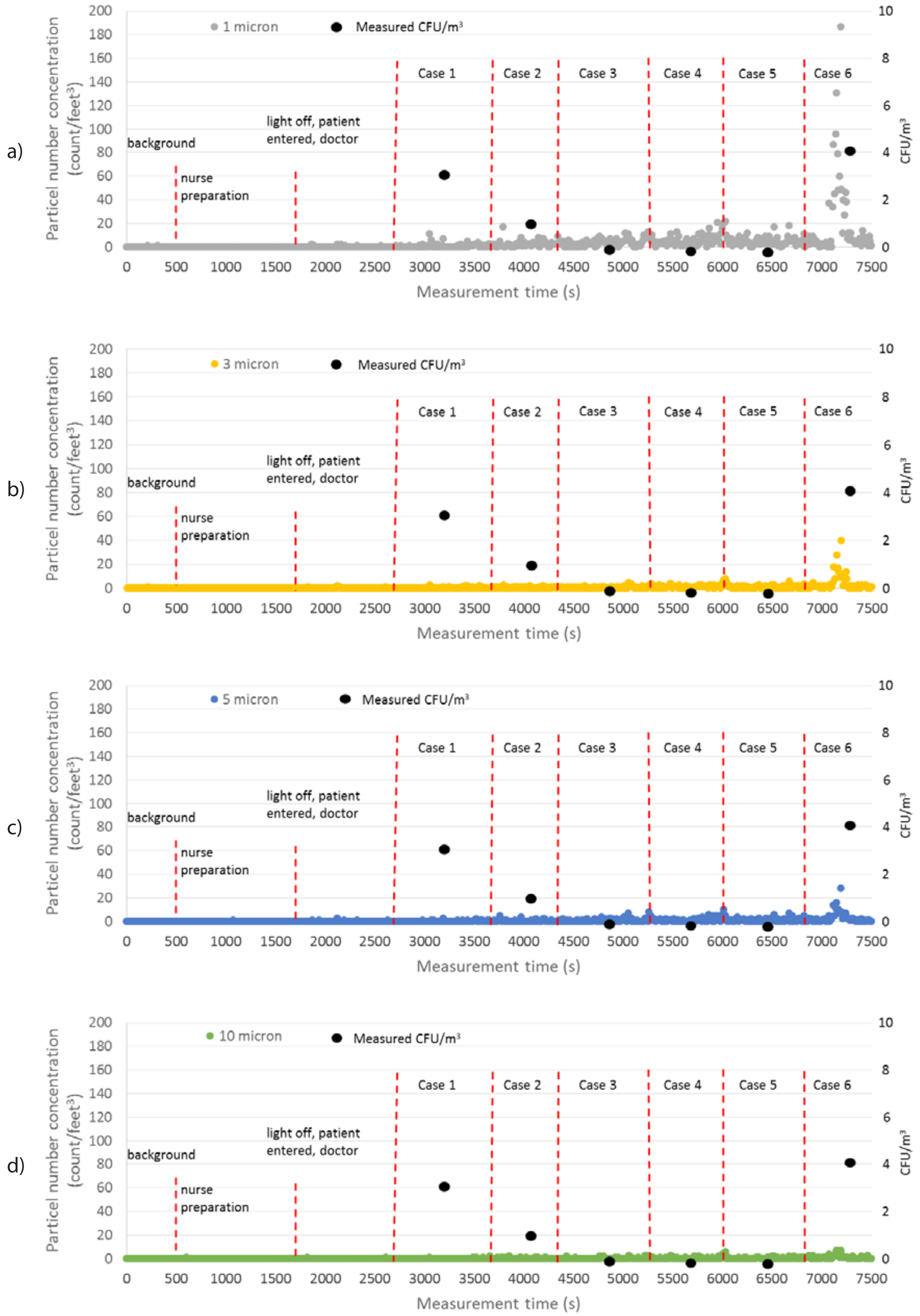

Figure 5. The measured fine particle concentration and CFU, a) 1.0–3.0 micron, b) 3.0–5.0 micron, c) 5.0–10 micron, d) 10–14 micron.

may indicate that the downward laminar airflow may be disturbed by the lamp near the operating table area when the lamps were located at the height of 1.75 m regardless the installation angle. However, the measured CFU is lower in case 3–5 than in other cases. However, the lower CFU may be caused by the reduced number of door opening, which may be the factor that induce more bacteria from outside of OT.

Figure 5a shows that the height of the lamps has different effect on particles with different sizes. When the height of the lamps was 1.92 m from the floor, the particle concentration (1.0–3.0 micron) is higher than other particle sizes: 0.3–1.0 micron and 3–14 micron. On the other hand, the particle concentration (1.0–3.0 micron) is higher in all cases than other particle sizes. This may indicate the increased CFU may be associated with particles with the size of 1.0–3.0 micron. However, this needs to be confirmed by more measurements due to the limited measured cases.

Conclusions

In operating theatres, many factors, including the number of staff, clothing, different airflow schemes, ventilation systems, supply airflow rate and the use of portable ultra-clean airflow unit, may influence the indoor air quality in the operating microenvironment and SSI. Earlier studies have reported that the increased airflow rate and the use of laminar ultra-clean airflow may make contribution to reduce the SSI. However, few studies have reported the influence of surgical lights on the air distribution in the operating microenvironment. This study found that the height of the operating lamps may influence the particle concentration at level of the operating microenvironment. The measured CFU shows nonetheless the opposite trend. The angle of the operating lamps may also affect the particle concentration at level of operating table. The particle concentration (0.3–3.0 micron) increased when the angle of the operating lamps was changed from 45° to horizontal. However, the change of the measured particle concentration did not result in the increase of measured CFU in the operating microenvironment. The limited measurement cases may not find out the correlation between the measured particle concentration and CFU. More field measurements in different cases should be carried out in the operating microenvironment to receive a better understanding of the effect of operating lamps together with other factors on measured particle concentration and CFU close to the operating table. ■

Acknowledgment

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