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CLOTHING SYSTEMS USED IN OPERATING ROOMS –A QUESTION OF PATIENT SAFETY

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Abstract

The number of airborne bacteria carrying particles in the operating room is considered an indicator of the risk of infections to the operating patient. Today when the supply air in the operating room is HEPA-filtered, the main source of airborne microorganisms is people (patient and personnel). The filtration efficacy of the fabric in operating clothing system plays an important role. The design of the clothing system also affects the number of particles generated from people to the air of the operating room. In ultraclean operating rooms, the selection of clothing systems for the operating personnel can no longer be thought of in terms of comfort but in terms of patient safety.

Results from clothing systems evaluated in a body-box test chamber and in operating rooms will be presented. The influence of different clothing systems in the operating room with different air volume flows will be discussed.

1. Introduction

The hospital environment is contaminated by microorganisms, some of them antibiotic resistant. To stay in a hospital may present a serious risk of infection to patients. In many countries the number of people dying after infections in hospitals is in the same range as the number of people being killed in traffic accidents (Fedotov 2010).

The number of airborne bacteria carrying particles in the operating room is considered an indicator of the risk of infections to the operating patient. Today the operating rooms are supplied with HEPA-filtered air and have intensiv air exchange and the main source of airborne microorganisms are people (patients and personnelf).

Clothing and clothing systems for cleanrooms and associated controlled environments are mainly tested with regard to material properties such as particle generation, particle filtration, and resistance to wear and tear-related damage. Increasing cleanliness demands during operations of infection sensitive patients require in-depth knowledge regarding the performance of surgical clothing systems.

A dispersal chamber or "body-box" has been used to study cleanroom garment protection efficiency by, e.g., Whyte et al. (1976), Hoborn (1981), Whyte and Bailey (1985), Ljungqvist and Reinmüller (2004) and Whyte and Hejab (2007). Measurements are carried out in order to relate airborne dispersal of total particulates and/or viable particles to the quality of fabrics and the design of the evaluated clothing system.

The authors have performed tests on selected clothing systems with regard to the efficacy of clothing system to retain particles from people in a modified test cabin with a dispersal chamber. The principal arrangement is shown in Figure 1. The concentration of airborne particles is measured in the exhaust duct.

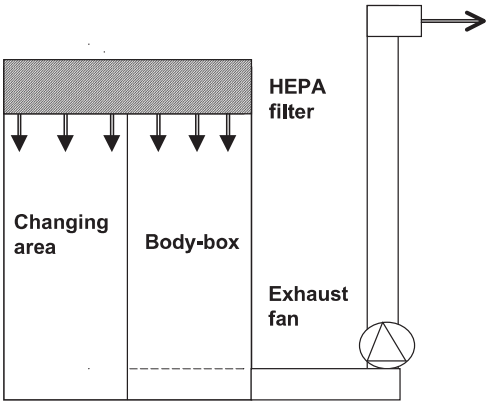

Figure 1 Principal arrangement of dispersal chamber (body-box).

With the assumption of no leakage into the dispersal chamber and the HEPA filters having the efficiency close to 100 percent, the simplest possible expression describing the source strength (q_s) becomes

$$q_s = c \cdot Q \qquad (1)$$

where q_s = source strength, outward particle flow (number/s), bacteria-carrying particle (CFU/s)
c = concentration; particles, number/m^3; bacteria-carrying particle, CFU/m^3
Q = total air flow (m^3/s)

Results are reported from tests carried out with cleanroom clothing systems and a surgical clothing system laundered and sterilized by steam 1, 25, and 50 times, respectively, see Ljungqvist and Reinmüller (2004). However, it should be mentioned that according to practice at Swedish hospitals surgical clothing systems need not be sterilized after laundering. Comparison of the source strengths for people dressed in various clothing systems are shown in Table 1.

The source strength is described as the number of total or viable (Colony Forming Units (CFU)) airborne particulates per second emitted from one person. Data are given as mean values based on several test subjects dressed in specific clothing systems.

It can be noted from Table 1 that the particulate levels reach higher values at 25 washes and sterilizing cycles than after 50. This might be explained by the fact that after certain number of washes and sterilizing cycles the fabric releases particles. With time, the particles released from the fabric seem to be washed away.

Table 1 *Comparison of data (mean values per person) of the source strength (number of particles per second and CFU per second) from people dressed in various clothing systems laundered and sterilized once, 25 times and approximate 50 times, respectively (from Ljungqvist and Reinmüller 2004 and 2008).*

Clothing system	Contaminant	Number per second from one (1) person		
		1 wash	25 washes	Approx. 50 washes
Food industry polyester (65%) and cotton (35%)	Particles ≥0.5 µm	99885		49531
	Particles ≥5 µm	2790		1780
	Particles ≥25 µm	738		506
	CFU	11.8		13.8
Food industry polyester (65%) and cotton (35%) in combination with special underwear; polyester (100%)	Particles ≥0.5 µm	24368		17249
	Particles ≥5 µm	1571		1048
	Particles ≥25 µm	462		329
	CFU	9.0		12.6
Surgical clothing system; polyester (50%) and cotton (50%)	Particles ≥0.5 µm	4,060	13,875	12,207
	Particles ≥5 µm	270	535	698
	CFU	1.7	4.2	9.0
High quality cleanroom clothing system; polyester (99%) and carbon fiber (1%)	Particles ≥0.5 µm	585	3,950	2,860
	Particles ≥5 µm	9	70	36
	CFU	0.38	0.49	1.14

2. Material and Methods

2.1 General

Containment tests in the dispersal chamber have been carried out to evaluate a cleanroom quality clothing systems for operation rooms - washed and sterilized 25 and 50 times respectively - by measuring the concentration of airborne particulates and viable particles (as aerobic CFU) in the exhaust air, see Ljungqvist and Reinmüller 2004.

During the measurements the test subjects (young men) performed standardized cycles of movements that included arm movements, walk in place and knee bends at a set speed. These movements are, in principle, comparable with those described in IES-RP-CC003.2 (1993). Prior to each cycle of movement, the test subject stood still to avoid the influence of particle generation from the previous test cycle. The evaluated clothing systems had five test subjects performing the standardized cycles of movements four times.

By using the air volume flow in the dispersal chamber and the measured concentrations, the source strengths of each clothing system was estimated. The source strengths reported are mean values per clothing system in total number of airborne particles (≥0.5 µm and ≥5 µm) per second and person and airborne aerobic colony forming units (CFUs) per second and person.

Both in the test chamber and in the operating room the total number of airborne particulates was determined using a particle counter (DPC; HiacRoyco 245), and viable particles collected using a slit sampler (FH3®, d_{50}-value 1.6 µm). All instruments were operated according to the manufacturers' instructions. Microbial growth medium for all tests was standard medium Tryptic Soy Agar (TSA) in 9 cm Petri dishes. The TSA plates were incubated for not less than three days at 32˚C followed by not less than two days at room temperature. The recorded number of CFU was characterized by phase contrast direct microscopy.

2.2 Clothing systems evaluated in test chamber

The clothing systems evaluated here are surgical clothing system, cleanroom quality, XR60 (99% polyester, 1% carbon fiber) in combination with special undergarment, XA80 100% polyester) and was supplied by Berendsen Textil Service AB, Sweden. The clothing systems were evaluated in the dispersal chamber after being laundered and sterilized by steam 25 and 50 times respectively.

2.3 Clothing systems evaluated in operating rooms

Measurements have been performed in one operating room during ongoing surgery with mainly the same operating team (7-9 people), dressed in three different clothing systems, and one system per operation. The operating room was supplied with HEPA-filtered air with an air volume flow of 0.65m^3/s. The air movements in the room could be characterized as turbulent mixing.

The three clothing systems were

- Common surgical clothing system, 70% cotton and 29% polyester and 1% carbon fiber.
- Common surgical clothing system, 50% cotton and 50% polyester.
- Surgical clothing of cleanroom quality (99% polyester, 1% carbon fiber) with underwear also tested in the test chamber.

3. Results

Table 3 presents data of the source strength from the evaluation in the test chamber of the surgical clothing system in cleanroom quality in combination with cleanroom undergarments.

Table 4 shows the source strength as mean values per person for the clothing systems based on measured concentrations in the operating room during ongoing surgery.

Table 3 *Data (mean values per person) of the source strength (number of particles per second and CFU per second) from people dressed in surgical clothing systems of cleanroom quality laundered and sterilized 25 times and 50 times, respectively (from Ljungqvist and Reinmüller 2004).*

Clothing system	Contaminant	Number per second from one (1) person 25 washes	50 washes
Operating room clothing of cleanroom quality with undergarments	Particles ≥0.5 µm	146	158
	Particles ≥5 µm	7	9
	CFU	0.2	0.2

Table 4. *Results from operating room (mean values per person) of the source strength (CFU per second) from people dressed in three clothing systems).*

Clothing system	Contaminant	Number per second from one (1) person
Common surgical clothing system, 70% cotton and 29% polyester and 1% carbon fiber	CFU	7.9
Common surgical clothing system, 50% cotton and 50% polyester	CFU	2.2
Surgical clothing cleanroom quality polyester (99%) with underwear;	CFU	0.2

4. Discussion and conclusions

The source strength varies with the clothing systems. Values of two clothing systems for food manufacturing are much higher than those for clothing systems used in operating rooms and in pharmaceutical cleanrooms. Furthermore, the comparison shows that the source strength values of the clothing systems for food manufacturing washed once and 40 times are in the same range and the results are comparable to surgical clothing systems (50% cotton and 50% polyester) washed 50 times. The evaluated clothing systems used in food manufacturing have poor product protection efficiency from the contamination source, people. Rather high amounts of particles equal and larger than 25 µm are emitted to ambient air.

The reported study shows that the commonly used protective clothing systems in operation rooms need to be upgraded when used during orthopaedic and trauma surgery (e.g., large bones and large joints with implantation of foreign material). When patients are highly sensitive to infections it is of vital importance that the concentration of airborne bacteria carrying particles is as low as possible through e.g., the use of clean air suits. Cleanroom clothing systems in combination with special undergarment offer a significant more efficient barrier against bacteria-carrying particles than commonly used surgical clothing systems.

Using equation (1), results from the study can be used to calculate expected concentrations of airborne aerobic colony forming units in the operating room when air flow rate, clothing system used and the number of people in the operating room are known.

When low concentrations of airborne bacteria-carrying particles are necessary to avoid hospital infection to the patient, surgical clothing system of cleanroom quality is preferable. How to be dressed in the operating room is no longer only a question of comfort but of patient safety. The technical development of clothing systems for e.g., pharmaceutical sterile manufacturing could be transferred to the ultra clean operating rooms.

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