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CFU and Bioaerosol Measurement in Hospital Environments and Indoor Contaminant Tracking

Guangyu Cao, Prof. PhD

Department of Energy and Process Engineering

Norwegian University of Science and Technology

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Table of content

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- Background
- Measurement of CFU
- Case study 1 CFU and airborne particle measurements in an OR with a laminar airflow system
- Case study 2 Effect of surgical clothing -Measurements of CFU in an OR with MV
- Case study 3 Effect of activities of surgical team - Measurements of CFU in an OR with MV
- Indoor Contaminant Tracking
  - Particle measurements

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Requirements for a laminar airflow (LAF)-equipped OR environment

Country	Supply Velocity (m/s)	Pressure difference (Pa)	Humidity (%)	Temperature (°C)	LAF diffuser size (m^2)	Maximum CFU/m^3
Austria	0.22-0.45	-	35-45	20-24	≥ 8 m^2	-
France	0.25-0.35	15 ± 5	-	19-26	-	10
Germany	≥ 0,23	-	30-50	19-26	≥ 3.2 × 3.2 m^2	4-10*
Netherlands	-	-	-	18-22	-	-
Norway	0.25-0.28	5-10	-	-	-	-
Switzerland	0.23-0.25	-	30	19-26	≥ 9 m^2	10
UK	0.38 m/s	25	35-60	18-25	≥ 2.8 × 2.8 m^2	10
USA	- *	4	20-60	20-24	≥ 3.0 × 3.0 m^2	-

(Aganovic A. 2019. PhD thesis)

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Microbiological Contaminants in Hospitals

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What are bioaerosols in hospitals?

Bioaerosols include:

- Bacteria
- Fungi (spores)
- Viruses (usually not culturable)
- Skin flakes carrying microorganisms
- Droplet nuclei from respiration, speech, surgery

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What are bioaerosols in hospitals?

Sources in hospitals:

- Medical staff and patients
- Surgical activity
- Ventilation systems
- Door opening and movement
- Outdoor air infiltration

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What is CFU in hospital air monitoring?

CFU (Colony Forming Units) represent the number of viable (living) microorganisms—typically bacteria or fungi—capable of growing into colonies under defined culture conditions.

- Units: CFU/m^3 (air) or CFU/plate
- Indicates microbiological cleanliness, not total particle load
- Widely used in operating rooms (ORs), ICUs, cleanrooms

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What is PFU in hospital air monitoring?

PFU stands for Plaque-Forming Units

PFU is a unit used to quantify viable viruses in air (or on surfaces).It represents the number of infectious viral particles capable of forming plaques (clear zones) in a layer of host cells grown in culture.

- Air is sampled (e.g., using impingers, filters, or cyclone samplers).
- Collected samples are placed onto a susceptible cell culture.
- Each infectious virus creates a plaque by killing or damaging cells.
- The number of plaques is counted → PFU

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Measurement methods of bioaerosols in hospitals?

Passive sampling (settle plates)

- Agar plates exposed for a fixed time (e.g. 1 hour)
- Measures **deposition**, not airborne concentration

Active air sampling (CFU/m^3)

- Air is actively drawn through or onto a collection medium.
- Common sampler types:
- Impaction samplers (most common)
  - Andersen, MAS-100, SAS
- Filtration samplers
- Liquid impingers

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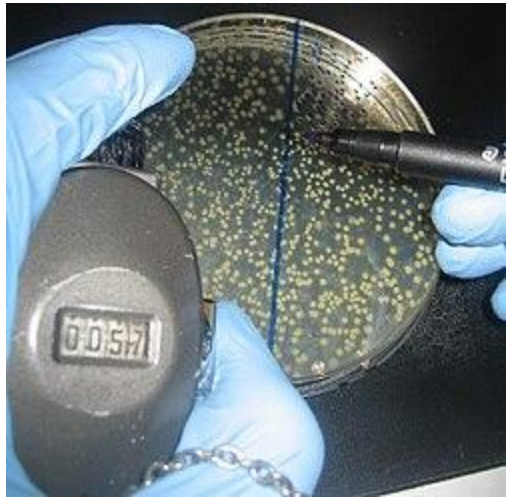
Measurement of bioaerosols

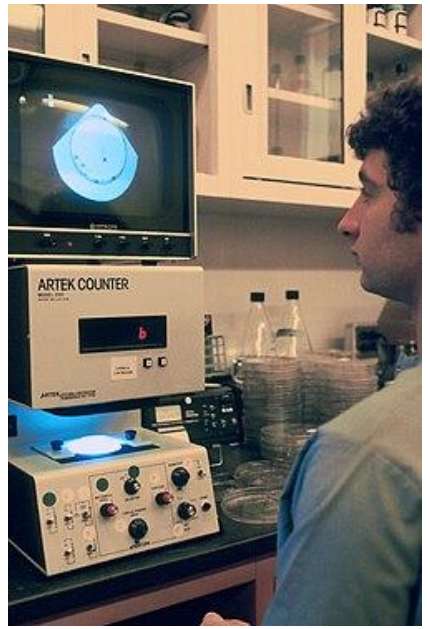
CFU counting

The traditional way of enumerating CFUs with a "click-counter" and a pen. When the colonies are too numerous, it is common practice to count CFUs only on a fraction of the dish.



Software for counting CFUs

- OpenCFU is a free and open-source program designed to optimise user friendliness, speed and robustness. It offers a wide range of filters and control as well as a modern user interface. OpenCFU is written in C++ and uses OpenCV for image analysis.
- NICE is a program written in MATLAB that provides an easy way to count colonies from images.
- ImageJ and CellProfiler: Some ImageJ macros and plugins and some CellProfiler pipelines can be used to count colonies.



Automated systems

- *https://en.wikipedia.org/wiki/Colony-forming_unit*

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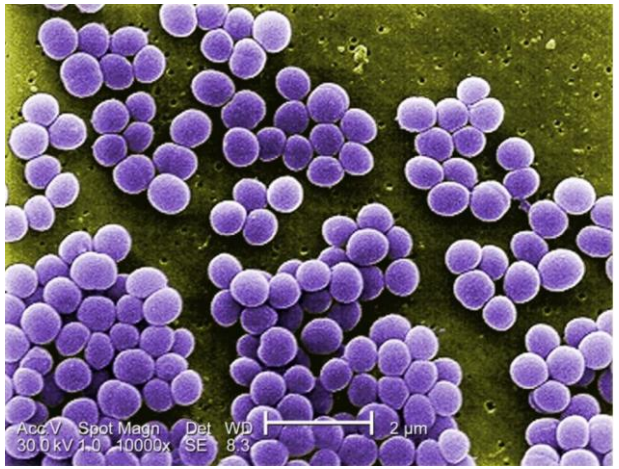
Most common bacteria in operating rooms

Staphylococcus species (most important)

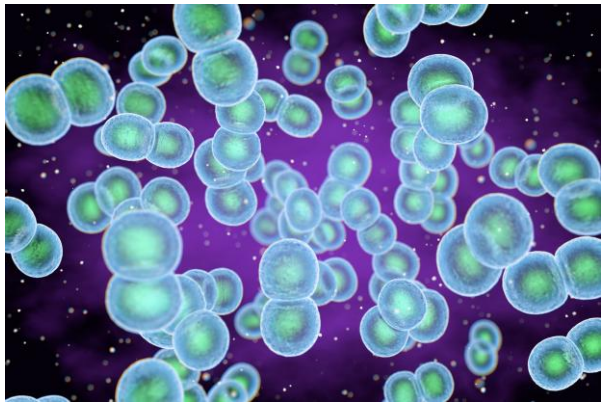
- Staphylococcus aureus
- Source: Skin, nose, hands of staff and patients
- Risk: Major cause of SSIs
- Includes MRSA (Methicillin-Resistant Staphylococcus aureus.)
- Causes:
  - Wound infections
  - Abscesses
  - Deep organ/space SSIs



https://www.lecturio.com/concepts/staphylococcus/

Coagulase-negative staphylococci (CoNS)

- (e.g. *Staphylococcus epidermidis*)
- Source: Normal skin flora
- Risk: Opportunistic pathogen
- Particularly important for:Implant surgery, Prosthetic joints, Catheters



https://www.infectiousdiseaseadvisor.com/ddi/coagulase-negative-staphylococcus/

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Other bacteria in hospitals

Streptococcus species

- Source: Mouth, throat, skin
- Transmission: Talking, coughing, breathing
- Can cause:
  - Soft tissue infections
  - Severe SSIs (less common than staphylococci)

Enterococcus species

- Source: Gastrointestinal tract
- Risk: Higher in abdominal and colorectal surgery
- Often antibiotic-resistant (e.g. VRE)

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Common bacteria in hospitals

Bacterial group	Frequency in OR air	SSI relevance
CoNS (*S. epidermidis*)	Very high	Moderate
Staphylococcus aureus	Moderate	High
Streptococci	Low–moderate	Moderate
Gram-negative rods	Low	High
Fungi	Low	Case-dependent

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Typical CFU limits?

$$\mathrm{CFU/m^3} = \frac{\text{Number of colonies}}{\text{Sampled air volume}}$$

Area	Typical guideline values*
Laminar-flow OR (at rest)	< 10 CFU/m^3
Conventional OR (at rest)	< 50–100 CFU/m^3
OR during surgery	< 180 CFU/m^3
ICU	< 100–300 CFU/m^3

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Experimental Measurement of Microbiological Contaminant

Case study 1

Case study 1 – CFU and airborne particle measurements at St. Olavs Hospital

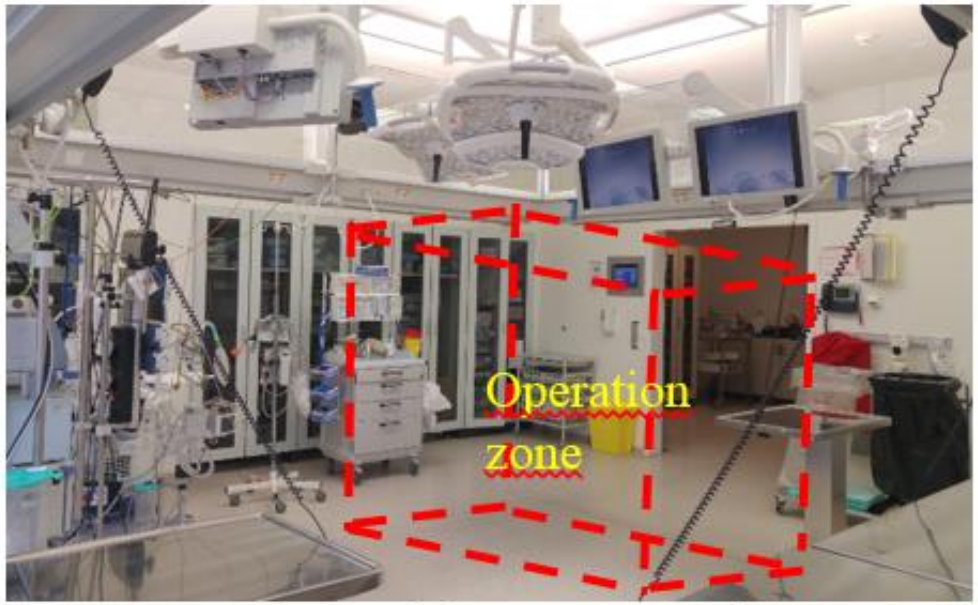

Figure 1 A photo of the operating theatre with all the medical equipment used in real operations

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

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Measurement conditions

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

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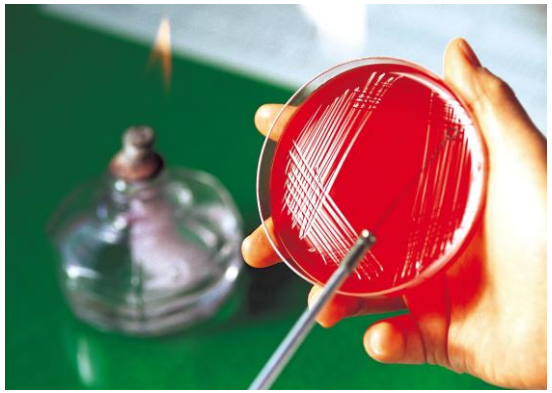
Measurement instrument

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



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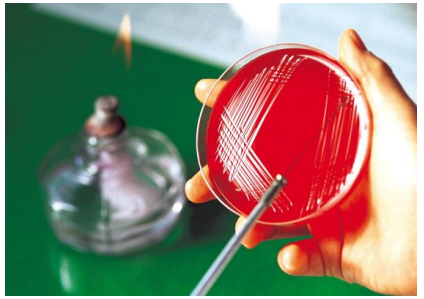
CFU Measurements

- *Air sampler Air-test Omega (LCB, France) at a flow rate of 100 L/min for 5 min*
- *Then the plates were covered with lids and taken to the laboratory in sealed plastic bags.*
- *Incubated at 35 ± 2 °C for a period of 2 days and then*
- *1 day at room temperature (23 ± 2 °C).*
- *A microbiologist at the laboratory of St. Olavs hospital counted the number of colonies formed per square meter of air sampled*



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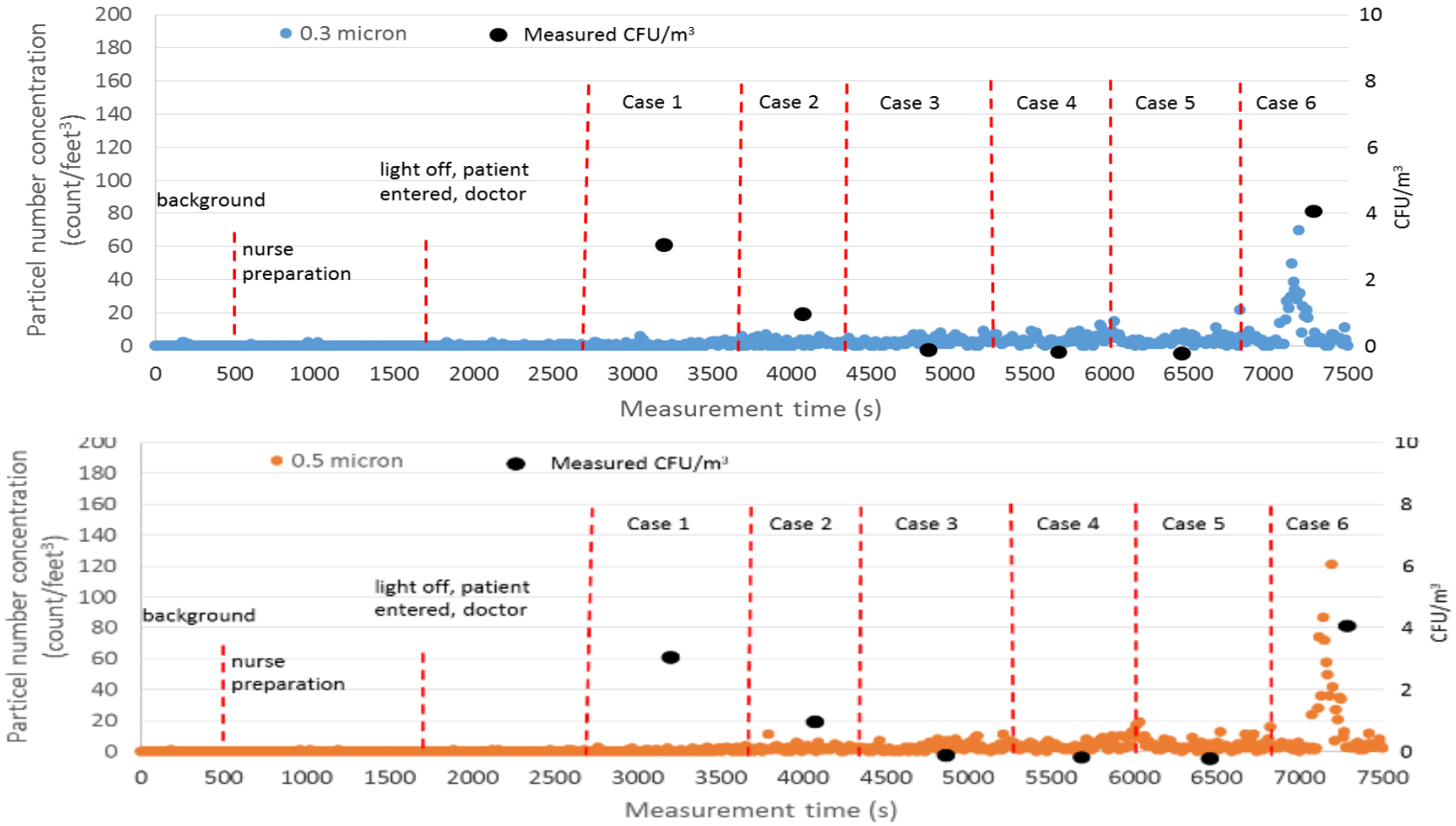
Measurement results



- *Figure 4 The measured fine particle concentration and CFU, I) 0.3-0.5 micron, II) 0.5-1.0 micron,*

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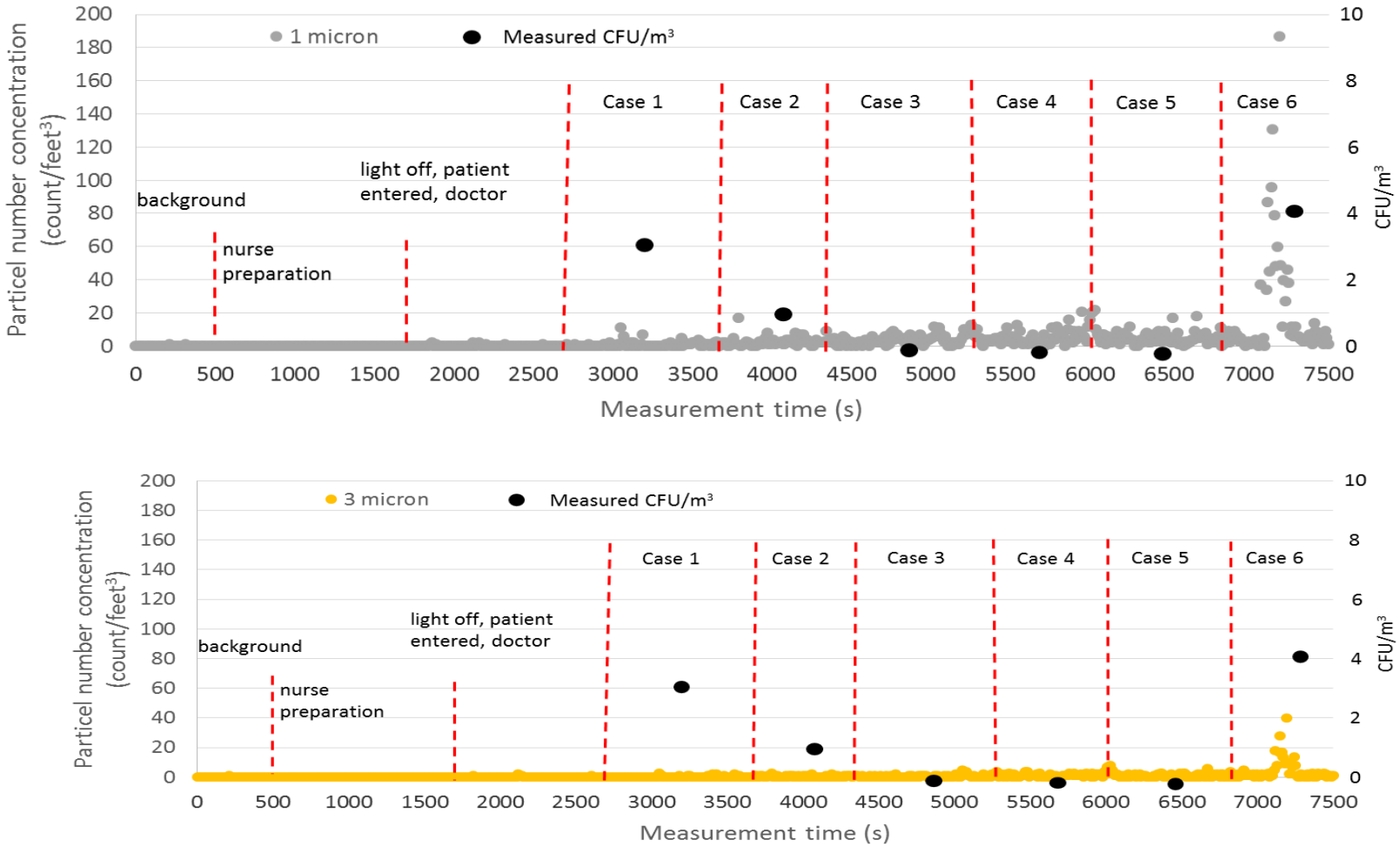
Measurement results



- *Figure 5 The measured coarse particle concentration and CFU, I) 1.0-3.0 micron, II) 3.0-5.0 micron,*

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Measurement results

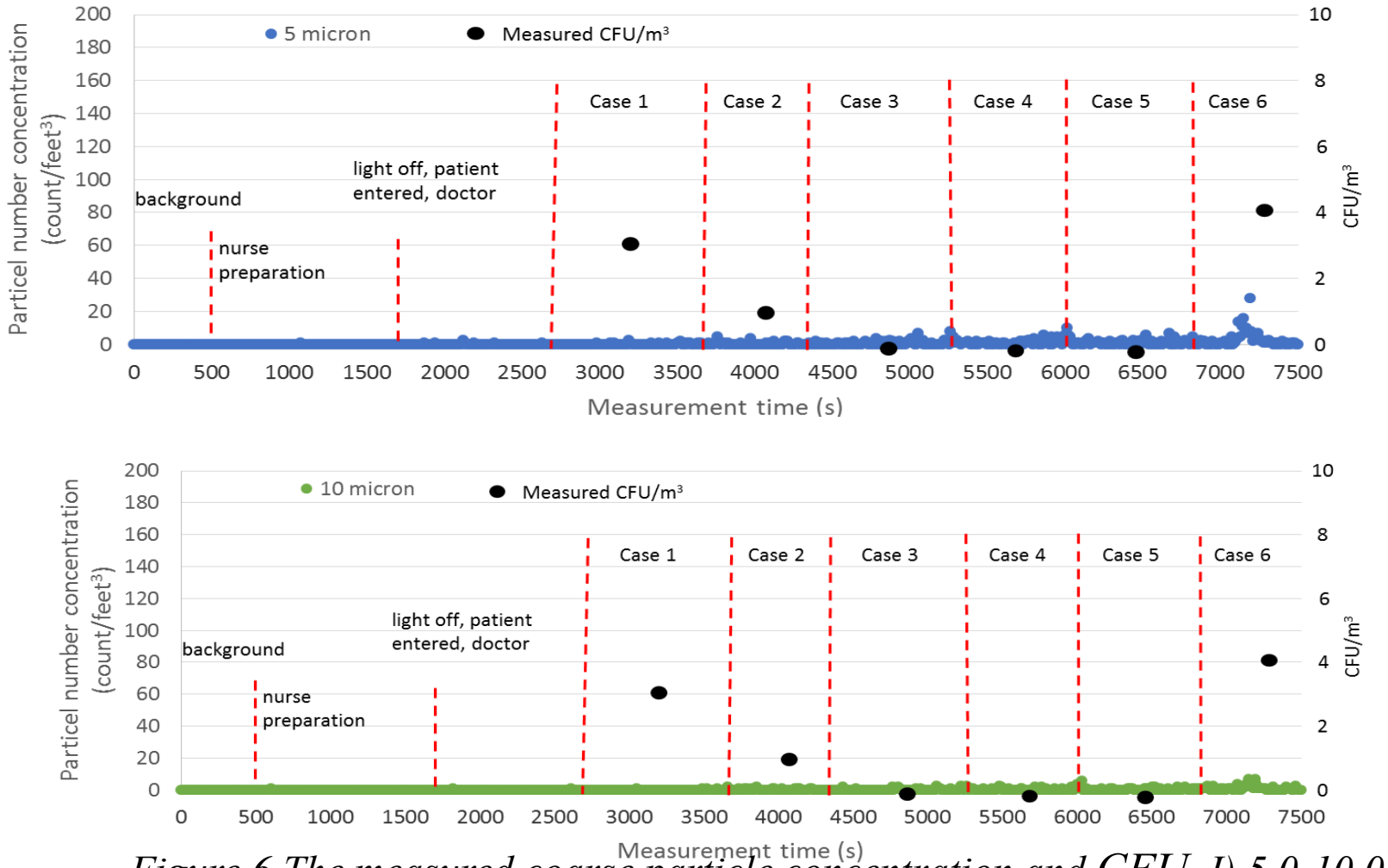

Figure 6 The measured coarse particle concentration and CFU, I) 5.0-10.0 micron, II) 10.0-14.0 micron,

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Experimental Measurement of Microbiological Contaminant

Case study 2

Case study 2 – Effect of surgical clothing - Measurements of CFU in an OR with MV

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Methodology

- Mock-up surgery performed in an operating room equipped with MV, at St.Olavs hospital in Trondheim, Norway
- Bacterial measurements taken of the air surrounding the surgical wound, during the simulated surgery
- A predefined movement and action plan for each member of the surgical staff → Simulate the movement and activities taking place during real total hip arthroplasty surgeries
- Mock-up can be divided in three phases, according to activity level; Incision phase(low activity), joint replacement phase(high activity) and wound closure phase(low activity)

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Experimental setup

Controlled parameters:	Control measure:
Movements and activity level	A predefined movement and action plan for each member of the staff
Number of people present	5 staff members and 1 patient
Door openings	0
Talking	All staff members say the alphabet out loud every 7th minute
Operation length	2 hours
Type of clothing used	**Patient:** Disposable clean air suit and surgical cap **Surgeons and sterile nurse:** Disposable clean air suits, surgical cap, surgical hood, double tie-on masks and a surgical gown **Distribution and anaesthetic nurse:** Same as surgeons, but did not wear a surgical gown

a) Clothing worn by Surgeons and sterile nurse

b) Clothing worn by distribution and anaesthetic nurse

c) Clothing worn by patient

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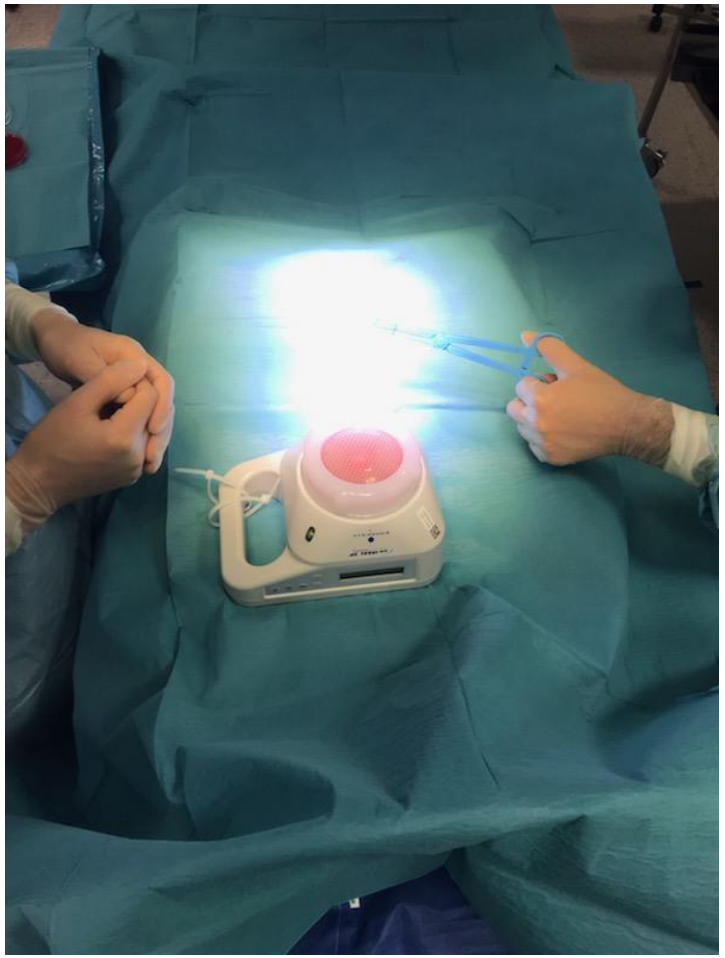
CFU sampling

- Active air sampler placed on the stomach of the patient, to simulate the surgical wound
- Surgical activities performed 10-20cm away from the sampler
- 10min sampling interval



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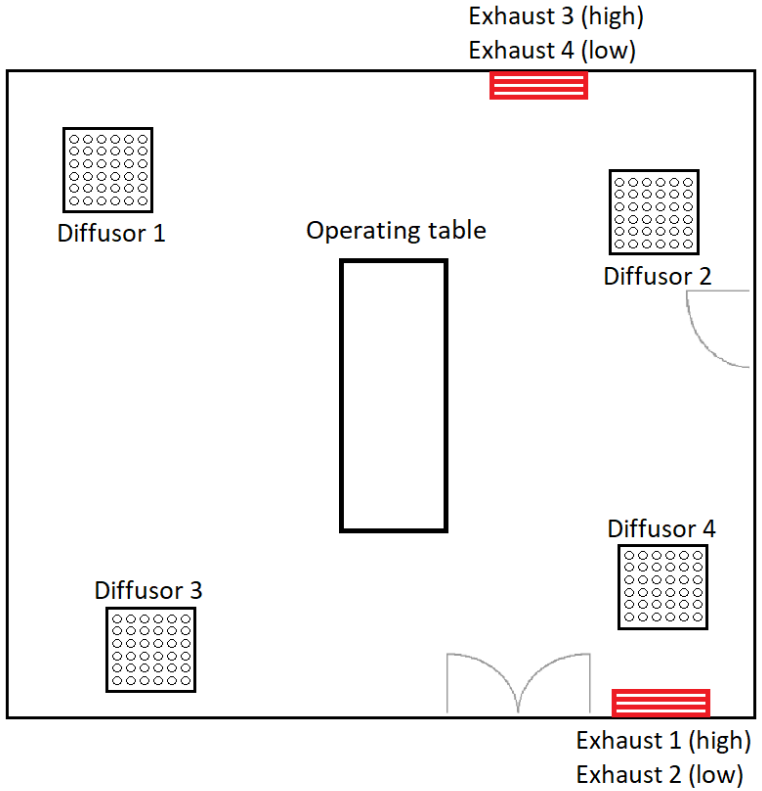
Ventilation in an OR with MV

- Mixing ventilated operating room, located at the emergency, hearth and lung centre at St.Olavs hospital, Trondheim, Norway
- 22.5 air changes per hour
- 5 Pa overpressure in relation to surrounding rooms
- Four ceiling mounted radial diffusers
- Two exhaust locations in the room →One high and one low mounted exhaust grill at each location
- 23°C setpoint for room temperature
- CFU/m^3 measurements of empty room, showed 0CFU/m^3



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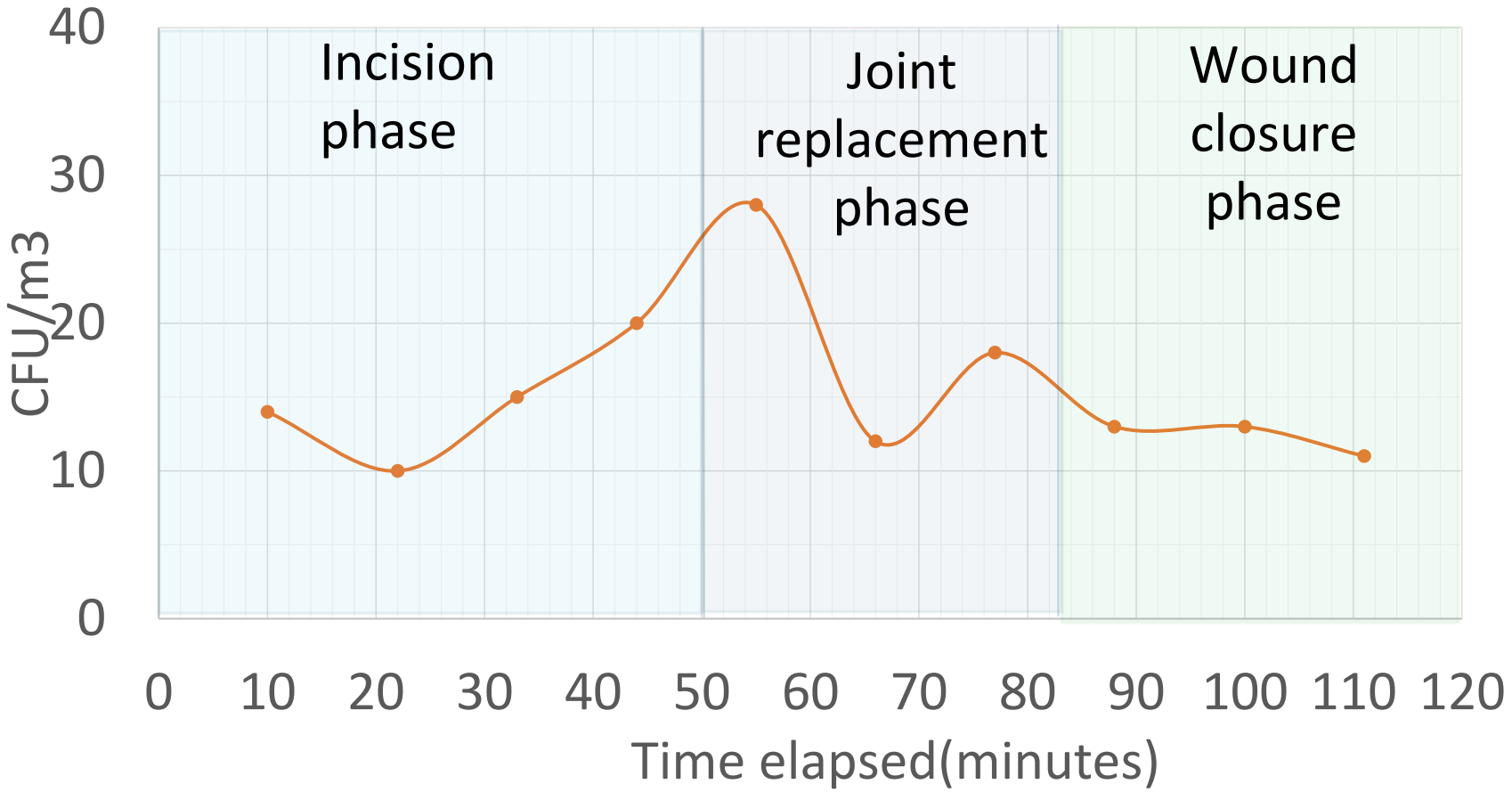
Results of measured CFU



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Experimental Measurement of Microbiological Contaminant

Case study 3

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Influence of Surgical Team Activity on Airborne Bacterial Distribution

CFU Measurement Processes and Results

St. Olavs Hospital Study | Cardiopulmonary OR Analysis

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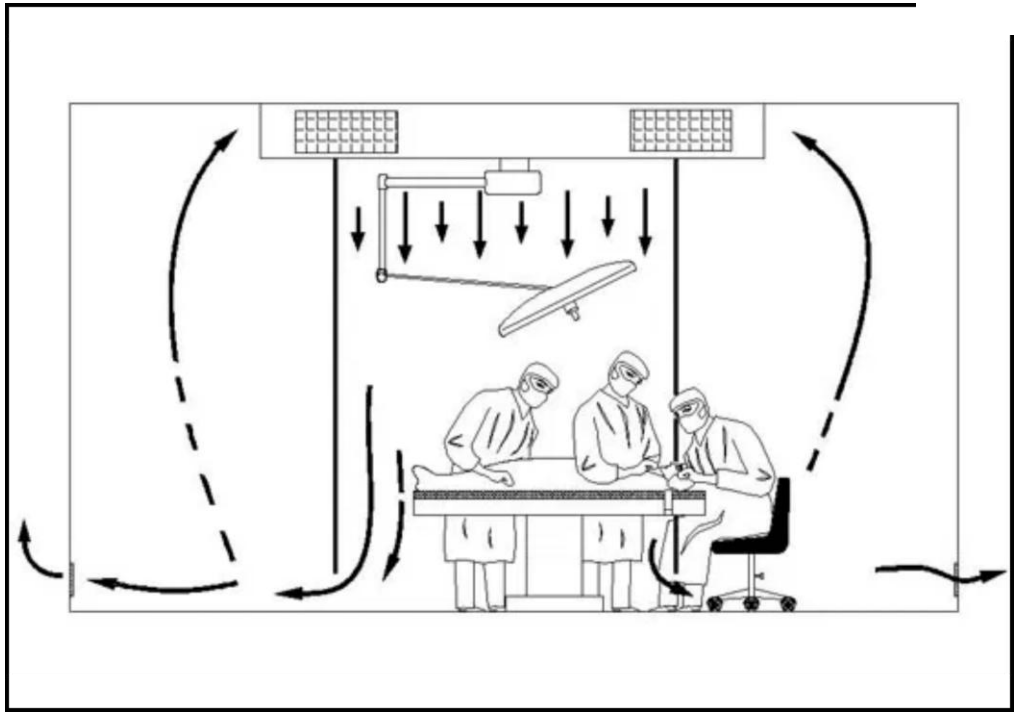
Study Overview and Objectives

Operating rooms (ORs) are subject to stringent cleanliness standards to mitigate the risk of surgical site infections (SSIs).

While ventilation systems are designed to maintain sterile environments, human activity remains the primary source of airborne micro-organisms.

This study aims to utilize novel depth registration sensing technology to identify surgical staff activities and investigate their specific effects on the distribution of airborne bacterial contamination, measured as Colony Forming Units (CFU).



SETTING: Cardiopulmonary OR at St. Olavs Hospital, Norway. Mixing ventilation system analysis.

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Measurements of CFU in an OR with MV (influenced by movement of surgical staff)

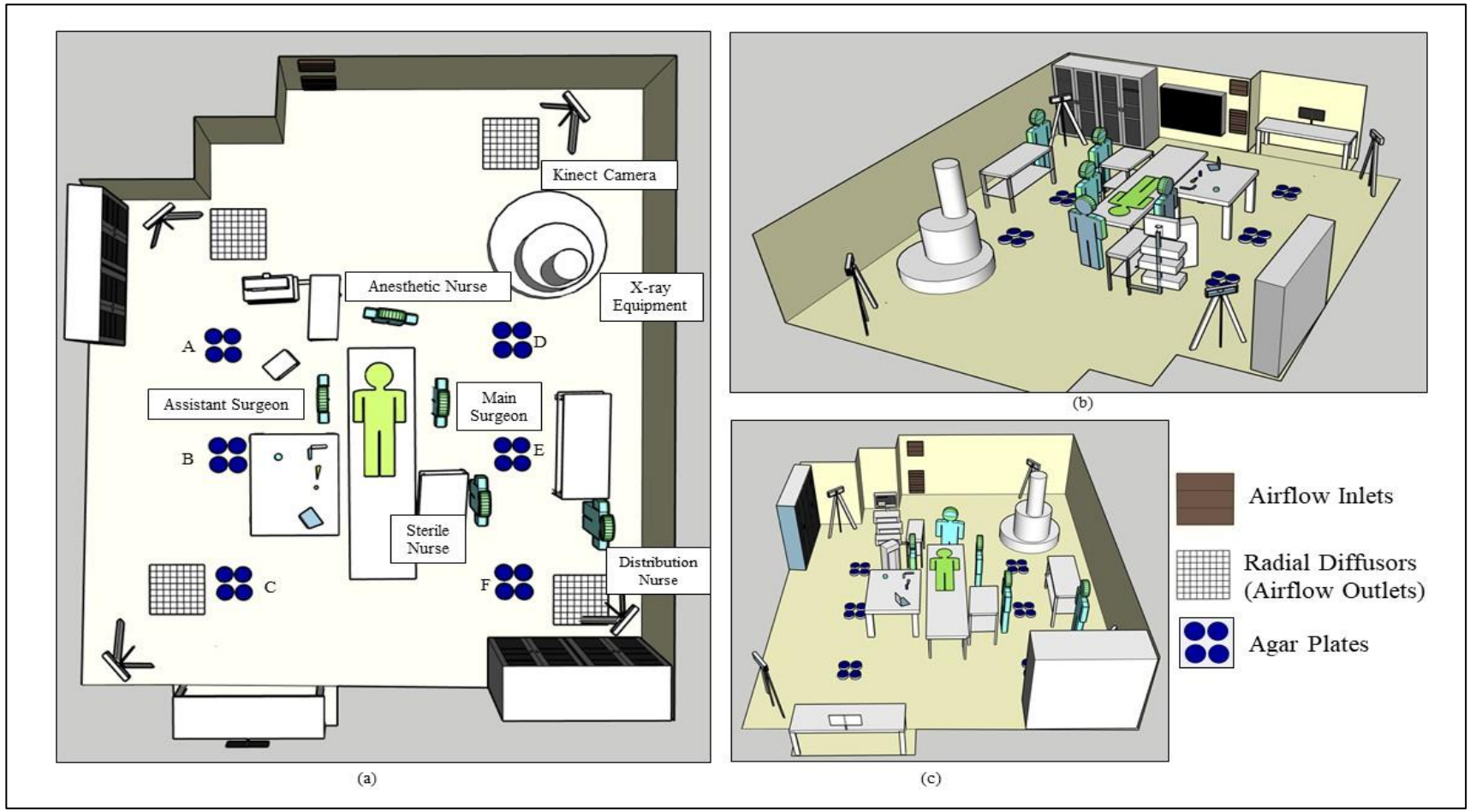

Fig. (a) Layout of the mock surgery experimental setup (Top View) (b) & (c) Bird's angle view of different perspectives of the setup

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Experimental Design and Participant Roles

A series of three mock hip arthroplasty surgeries were performed to ensure reproducibility. The setup involved six participants assigned specific roles to simulate a realistic surgical environment.

Role	Responsibilities in Study
Main Surgeon	Performed primary surgical actions at the wound site.
Assistant Surgeon	Supported the main surgeon with frequent arm and body movements.
Sterile Nurse	Managed instruments and maintained the sterile field.
Distribution Nurse	Handled supplies and moved between the cabinet and the surgical area.
Anesthetic Nurse	Monitored the patient with minimal movement.
Patient	Remained static on the surgical bed throughout the procedure.

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CFU Measurement Methodology

Passive Air Sampling

The study employed passive air sampling to evaluate the risk of microbial contamination. This method was selected for its direct relevance to wound infection risks, as it measures the rate at which bacteria-carrying particles settle onto surfaces.

A total of 24 passive agar plates were strategically placed at six locations (A-F) around the surgical bed at floor height to capture the spatial distribution of bacterial shedding.

Equipment Specification

24 Passive Agar Plates (85 mm Internal Diameter)

Processing & Analysis

Following exposure, plates underwent a standardized incubation protocol to ensure accurate colony development.

Incubation Phase 1

48 Hours @ 35 ± 2°C

Incubation Phase 2

24 Hours @ Room Temperature

Normalization Metric

CFU Density (cfu/m^2 per hour)

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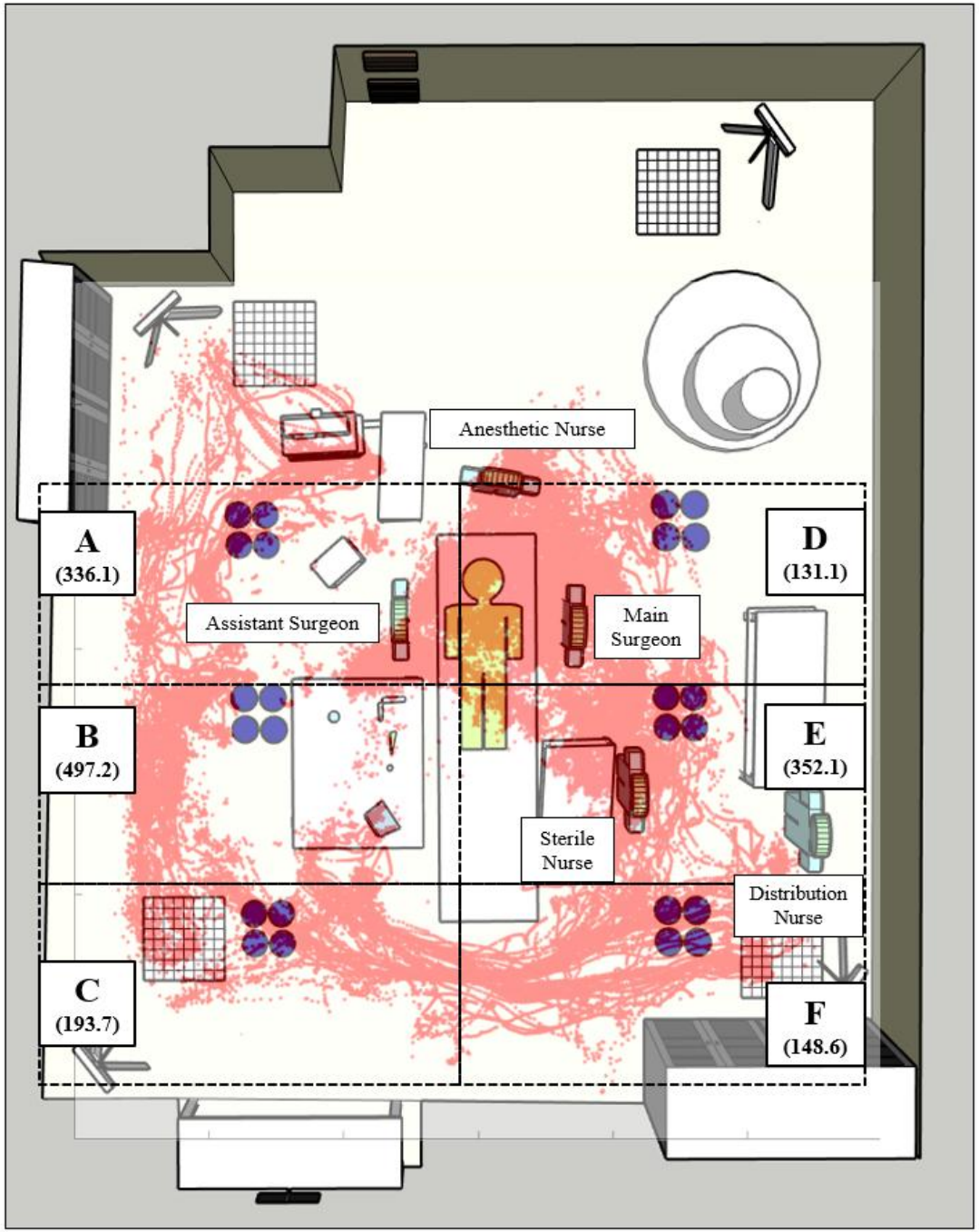
Mapping of human activities

The human activity from the depth registration measurements was in the form of a spatial activity distribution map.



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Analysis of CFU Density and Distribution

Bacterial contamination levels were not uniform across the OR. Locations in close proximity to the most active staff members consistently reported higher CFU densities.

Location	Avg CFU Density (cfu/m^2·h)	Associated Staff Activity
Location B	**1208.07 (Peak)**	Assistant Surgeon & Instrument Table
Location A	336.1	Main Surgeon
Location E	352.1	Sterile Nurse
Location C	193.7	Distribution Nurse
Location D	131.1	Anesthetic Nurse
Location F	148.6	General Perimeter

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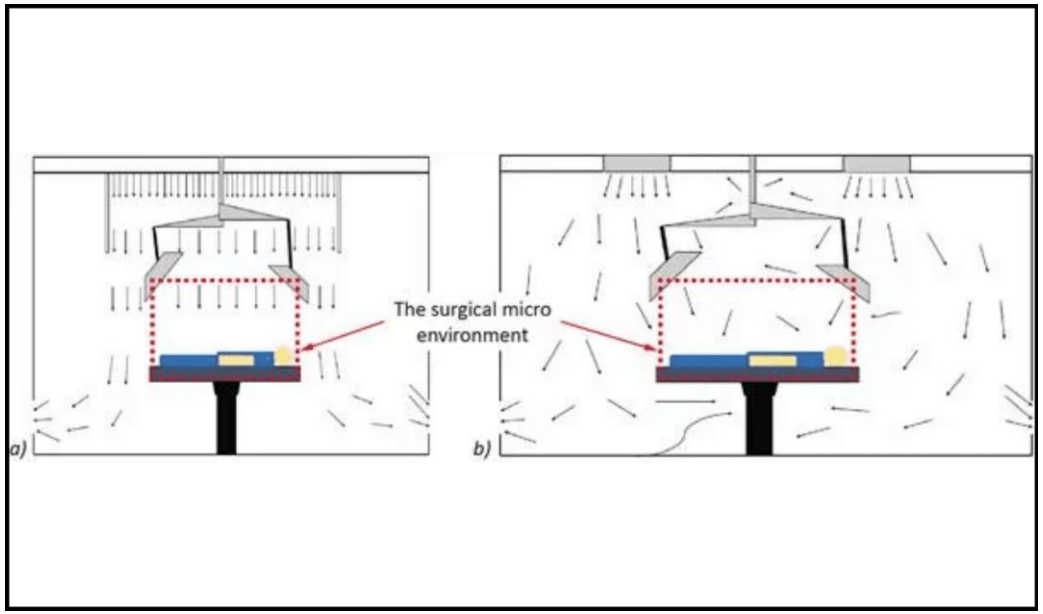
Correlation Between Activity and Contamination

A general correlation was observed between higher activity levels and increased CFU densities. High-intensity movements, such as the assistant surgeon's repeated squatting, were identified as significant contributors to particle shedding.

The study confirmed that movement transports skin scales into the OR air through pores in the fabric or openings at the wrists and neck.



Schematic of Airflow Patterns and Distribution

The "Pumping Effect"

Clothing movement creates air streams that actively pump micro-organisms from the skin surface into the sterile environment.

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Impact of Airflow Patterns and Obstructions

Airflow Interference

One of the most significant findings was the influence of physical obstructions on bacterial distribution. In mixing ventilation systems, airflow patterns are easily disrupted by equipment and personnel positioning.

In these "dead zones," airflow patterns are disrupted, allowing bacteria-carrying particles to accumulate rather than being cleared by the ventilation system.

The Case of Location B

Location B recorded the highest CFU density, which was attributed not only to staff activity but also to the presence of a large instrument table acting as a barrier.

Critical Insight

The effectiveness of an OR's ventilation is highly dependent on the spatial arrangement of equipment relative to airflow inlets and outlets.

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Indoor contaminant tracking in ORs

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Indoor contaminant tracking in ORs - Experimental / Measurement-based methods

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1.Tracer gas methods

- Use of CO_2, SF_6, or N_2O as surrogate contaminants
- Measure concentration decay, age of air, and removal efficiency
- Widely used for ventilation effectiveness studies in Ors

2.Particle tracking and aerosol measurements

- Optical particle counters (OPC)
- Condensation particle counters (CPC)
- Track size-resolved aerosol transport and removal

3. Biological surrogate tracers

- Bacterial aerosols or fluorescent-tagged particles
- Agar settle plates and air samplers
- Assess infection risk more directly

4.Smoke visualization

- Qualitative method using smoke or fog
- Identifies airflow direction, stagnation zones, leakage

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Indoor contaminant tracking in ORs - Computational / Modeling methods

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1. Computational Fluid Dynamics (CFD)

- Eulerian scalar transport models
- Lagrangian particle tracking (aerosol trajectories)
- High spatial resolution of contaminant dispersion

2. Coupled CFD–infection risk models

- Wells–Riley or dose–response models
- Quantifies probability of infection

3. Zonal or multizone models

- Simplified representation of OR and adjacent spaces
- Faster than CFD, suitable for system-level analysis

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Indoor contaminant tracking in ORs - Data-driven and advanced methods

1. Sensor-based real-time monitoring

- PM, VOC, CO_2, temperature, RH sensors
- Continuous tracking during surgery

2. Machine learning–assisted tracking

- Pattern recognition in contaminant dispersion
- Prediction of high-risk conditions
- Sensor fusion (IAQ + ventilation + occupancy)

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Indoor contaminant tracking in ORs - Data-driven and advanced methods

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3. Measurement–CFD validation frameworks
    - Use experimental data (PIV, tracer gas) to validate CFD models

4. Digital twins for OR ventilation
    - Real-time coupling of models with sensor data
    - Scenario testing (door opening, staff movement)

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Particle measurements - ISO 14644-1 Cleanroom standards

	Particles/m³					
Class	**0.1 µm**	**0.2 µm**	**0.3 µm**	**0.5 µm**	**1.0 µm**	**5.0 µm**
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1,000	237	102	35	8	
ISO 4	10,000	2,370	1,020	352	83	
ISO 5	100,000	23,700	10,200	3,520	832	29
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293
ISO 7				352,000	83,200	2,930
ISO 8				3,520,000	832,000	29,300
ISO 9				35,200,000	8,320,000	293,000

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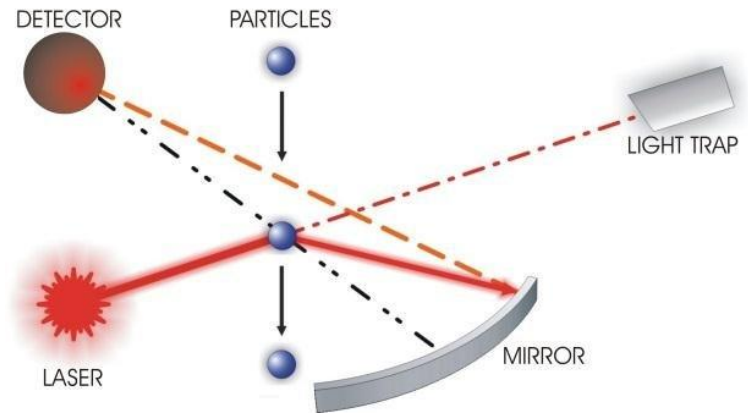
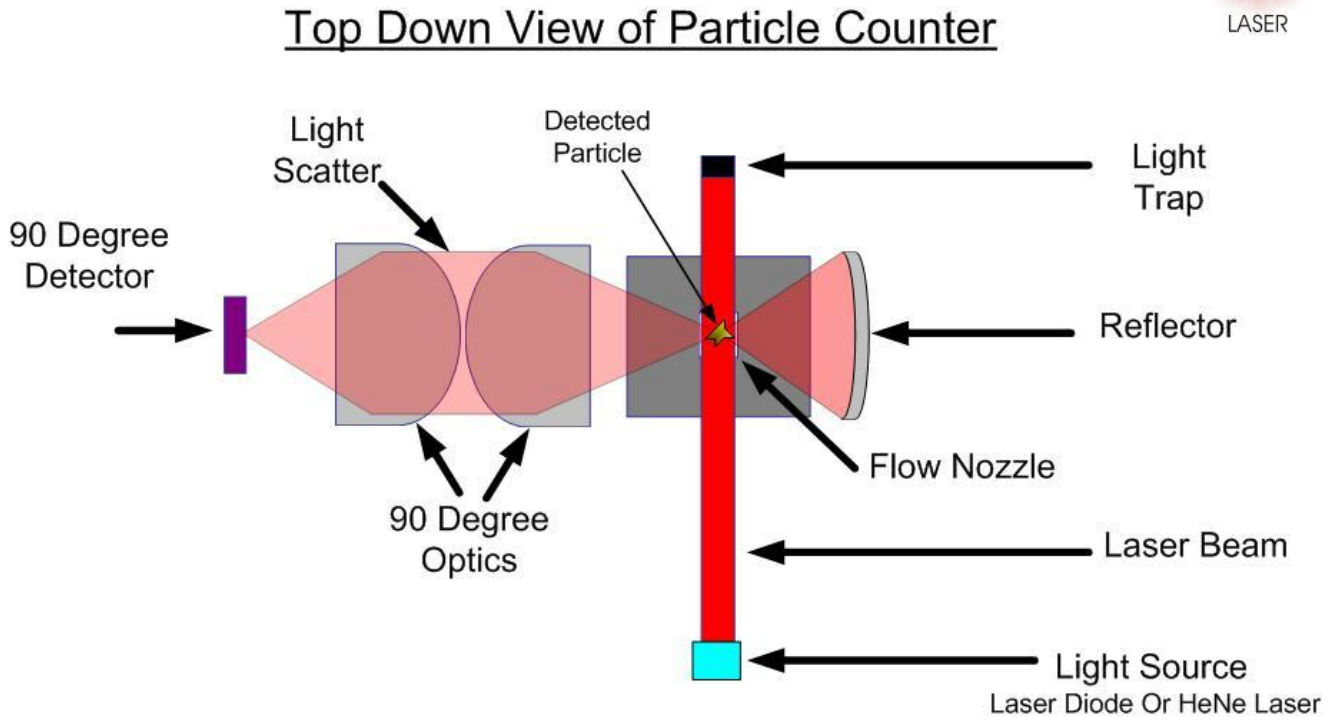
Particle measurement - optical counting

- light scattering
- light obscuration
- direct imaging





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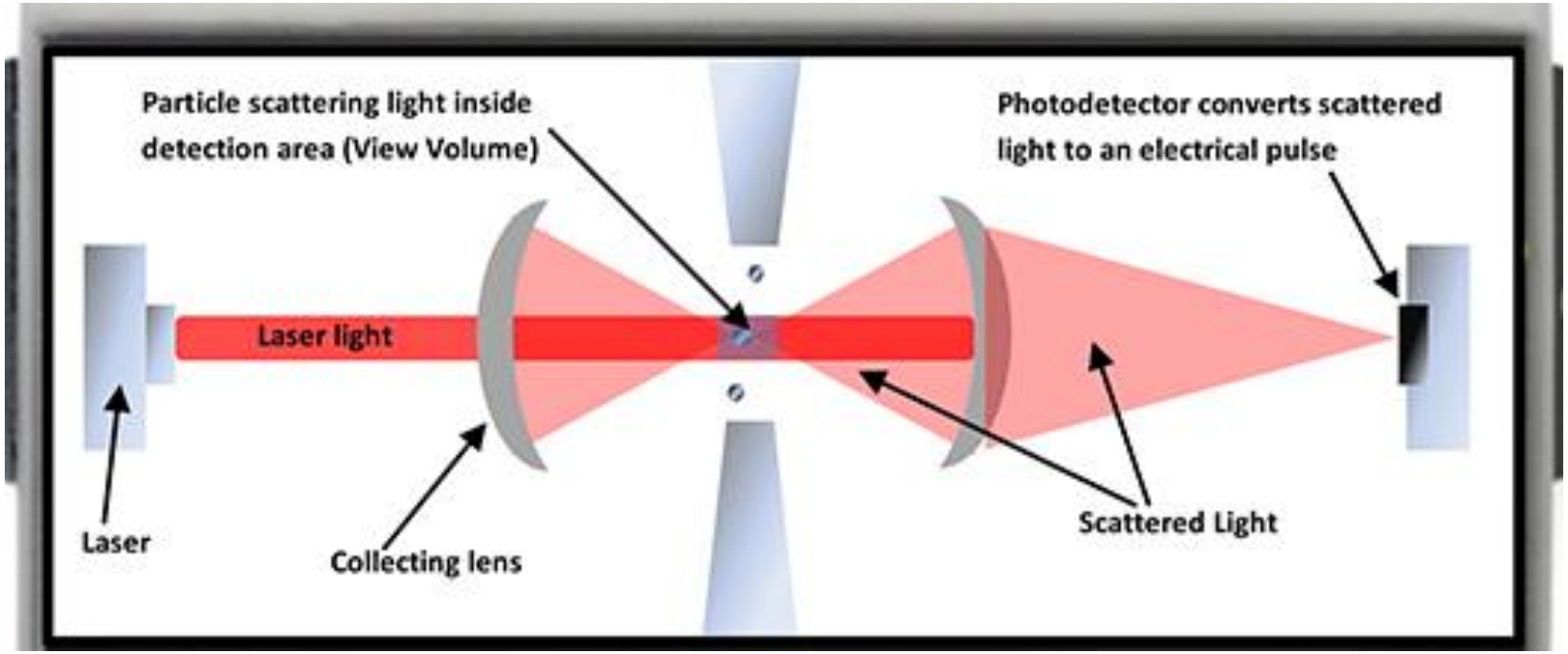
How does a particle counter work?



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TSI AeroTrak 9306 Model

Features and Benefits

- Complies with all requirements of ISO 21501-4
- 0.3 to 25 µm size range
- 0.1 CFM (2.83 L/min) flow rate
- Measures up to six channels of simultaneous data
- Model 9306-V2 provides unique variable binning option
- Integrated handle for one hand operation
- Removable, rechargeable Li-ion battery
- Long life laser diode
- USB and Ethernet output
- 10,000 sample record storage, 250 locations
- Local or remote configuration via web browser
- Provides Pass/Fail reporting on ISO 14644-1, EU GMP, and FS209E
- Compatible with TRAKPRO™ Lite and FMS 5 software packages
- Optional Temperature/RH sensor available

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Alphasense OPC-N2 / OPC-N3

http://www.aqmd.gov/aq-spec/product/alphasense

Features

- Dimensions: 75 (L) x 60 (W) x 63.5 (H) (mm)
- Weight: < 105g
- Battery: No
- Power supply: 175 mA (~ 5V DC) (180 mA for OPC-N3)
- Sensor lifetime: N/A
- Clock function: No
- Sampling mechanism: Fan
- Environmental operating conditions: -10 to 50 C Temp, 0 to 95 % RH
- Internal data logging: No
- Data connection/storage: SPI/micro-SD
- Weatherproof: No

User Manual: http://stg-uneplive.unep.org/media/aqm_document_v1/Blue%20Print/Components/Microcomputer%20and%20sensors/B.%20Dust%20Sensor%20Specifications/B.1%20Alphasense%20OPC%20N1/072-0300%20OPC-N2%20manual%20issue%203.pdf

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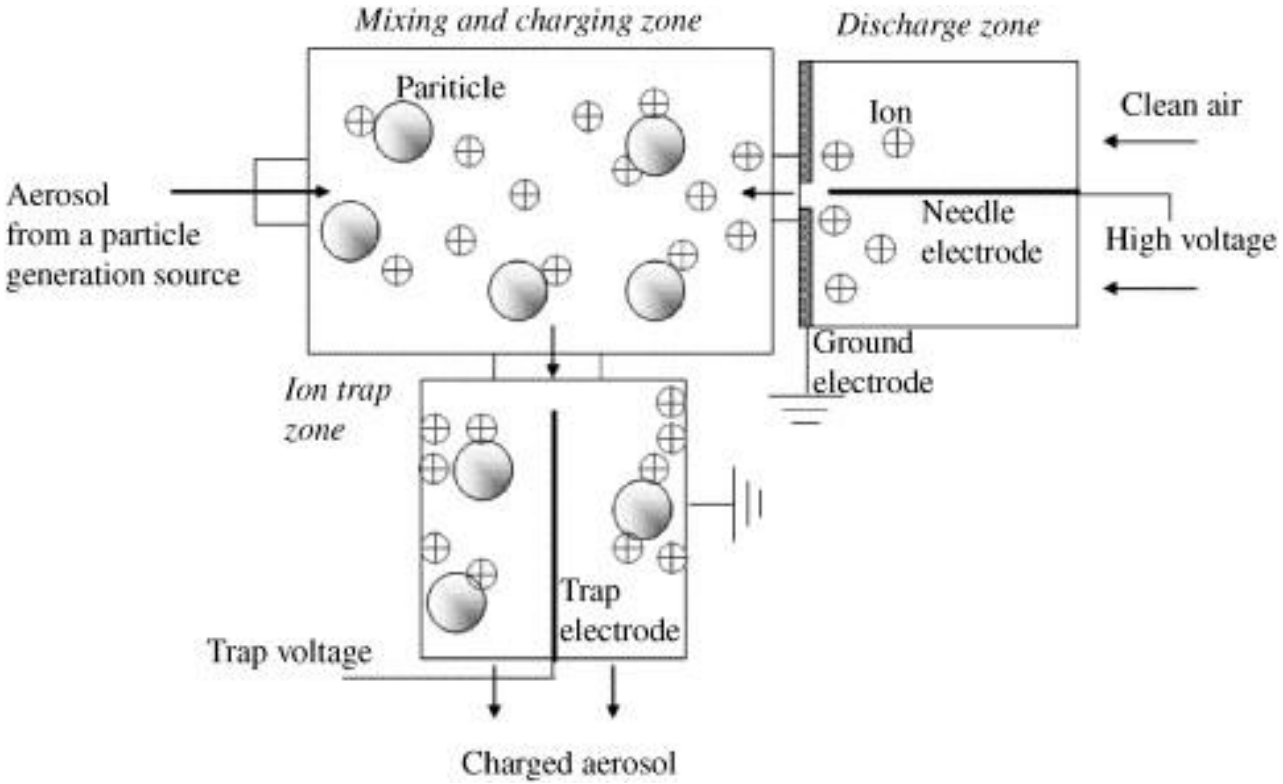
Diffusion charging principle



Park et al. 2007. Development and performance test of a unipolar diffusion charger for real-time measurements of submicron aerosol particles having a log-normal size distribution

https://doi.org/10.1016/j.jaerosci.2007.01.003

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WIBS measurements

- WIBS measurement of airborne particles refers to the use of the Wideband Integrated Bioaerosol Sensor (WIBS) to detect and characterize fluorescent biological aerosol particles (FBAPs) in real time.
- WIBS is a real-time aerosol instrument designed to identify potential biological particles in air based on their intrinsic fluorescence.
- For each airborne particle, WIBS measures:
- Particle size
  - Typically 0.5–20 µm (optical equivalent diameter)
- Particle shape
  - Using an asymmetry factor (AF)
- Fluorescence intensity
  - Excited by UV light at specific wavelengths
  - Emission detected in different spectral bands

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WIBS measurements

WIBS uses:

- UV excitation at ~280 nm and ~370 nm
- Emission detection in two bands (typically 310–400 nm and 420–650 nm)This allows classification of particles into fluorescence types (A, B, C, AB, AC, BC, ABC).

Typical WIBS outputs include:

- Total particle number concentration (#/cm^3 or #/m^3)
- Fluorescent particle concentration
- Size-resolved fluorescent biological airborne particles (FBAP) distributions
- Fluorescence type fractions
- Time-resolved bioaerosol events

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WIBS measurements

In WIBS measurements, particles are classified into fluorescence types (A, B, C, AB, AC, BC, ABC) based on which fluorescence channels respond when the particle is illuminated by UV light.These types do not represent specific microorganisms; they indicate fluorescence behaviour.

WIBS uses **two UV excitation wavelengths** and **two emission bands**:

Channel	UV excitation	Emission band	Typical fluorophores
A	~280 nm	310–400 nm	Tryptophan (proteins)
B	~280 nm	420–650 nm	Other biological fluorophores
C	~370 nm	420–650 nm	NADH, riboflavin

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WIBS measurements

Meaning of fluorescence typesWIBS uses **two UV excitation wavelengths** and **two emission bands**:

Type	What it means
A	Fluoresces only in channel A
B	Fluoresces only in channel B
C	Fluoresces only in channel C
AB	Fluoresces in both A and B
AC	Fluoresces in A and C
BC	Fluoresces in B and C
ABC	Fluoresces in A, B, and C

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WIBS measurements

Interpretation (important for IAQ & hospitals):

A, AB, ABC→ Often associated with protein-rich particles(e.g. bacteria, skin flakes, some spores)

C, BC, ABC→ Often linked to metabolically active material(e.g. bacteria, fungal spores)

ABC→ Strongly fluorescent in all channels→ Often considered most “biological-like”, but not definitive

Key caution

- Some non-biological particles (textile fibers, combustion aerosols) can fluoresce.
- WIBS indicates “bio-likeness”, not viability or species.

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WIBS measurements

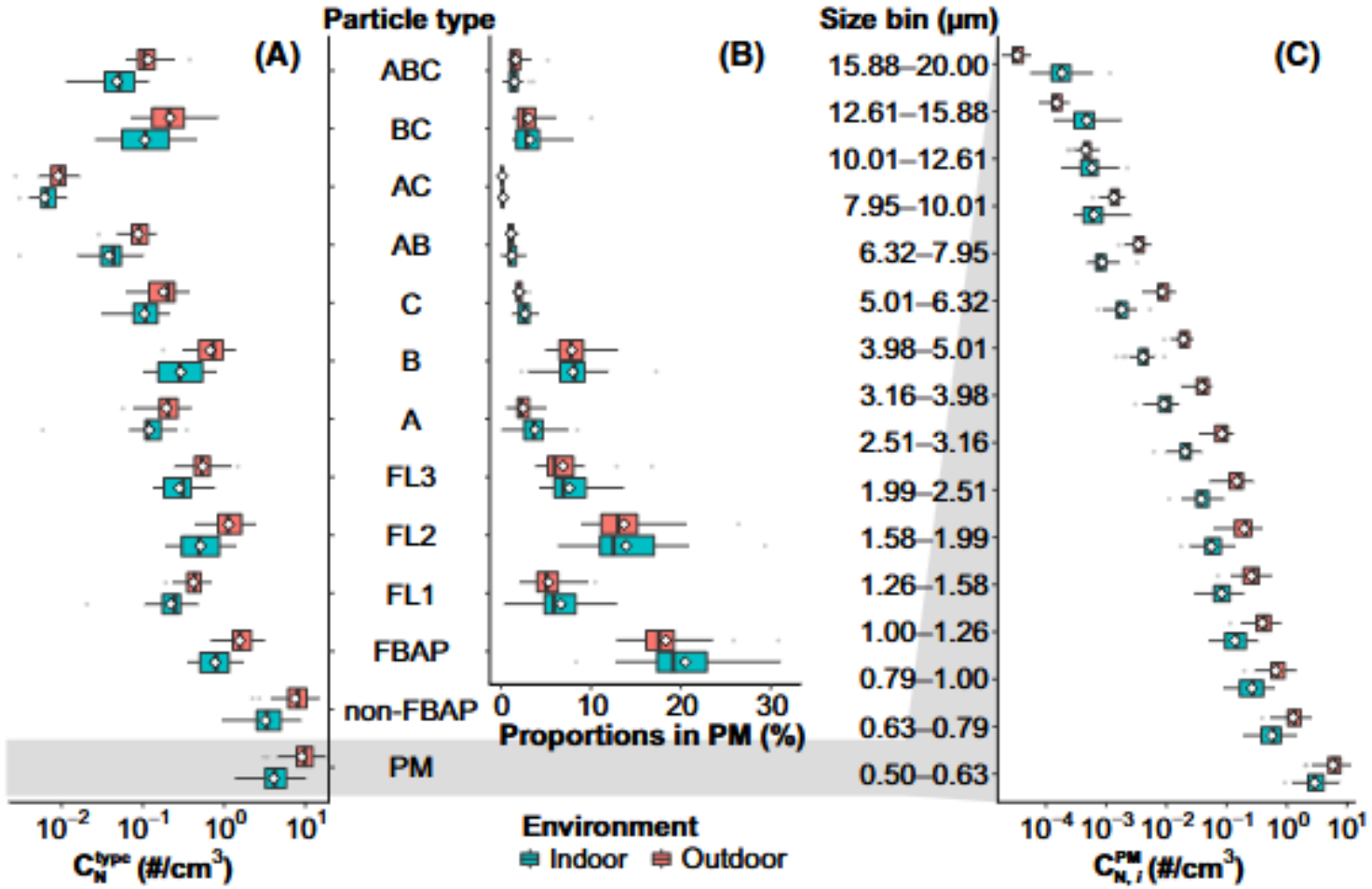

Fig. Indoor and outdoor aerosol number concentrations in different types (A), size bins (C), and the fractions of different fluorescent particles in the PM (B). The boxes colored in turquoise are the interquartile range (IQR) for indoor particles, and those colored in red are the outdoor particles.

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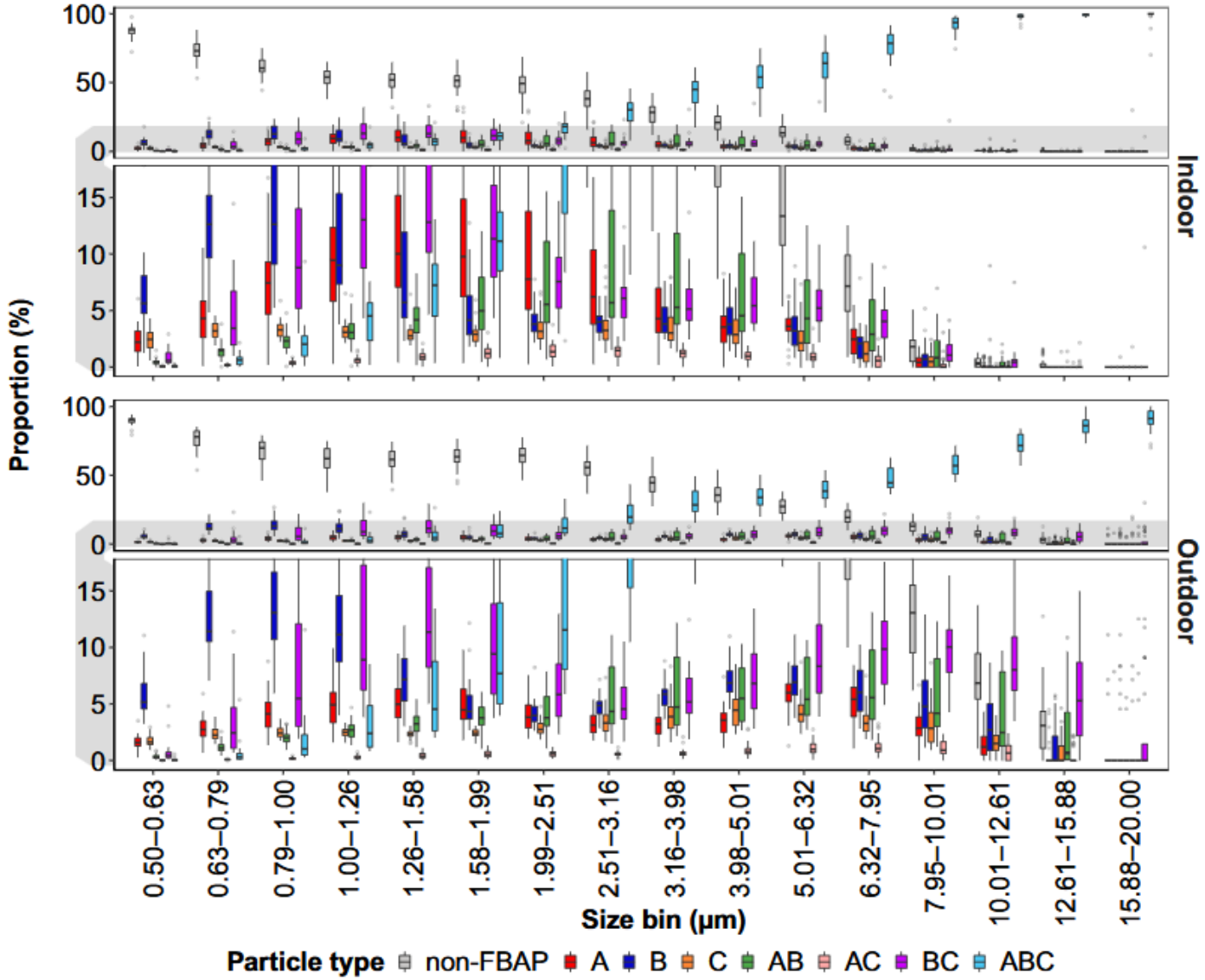
WIBS measurements



- Fig. Size-resolved proportions of non-FBAP and subtypes of FBAP in PM in the indoor and outdoor environments.
- Because there were always one or two types of particles which have much higher proportions than others for both indoor and outdoor environments, the lower parts of the plots have been enlarged (shown as the shaded region) to show
- them clearly.

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WIBS measurements

Main Findings

With the increase of particle size, concentrations of both FBAP and non-FBAP particles decreased but in different degrees. After 2 and 3.5 μm for the indoor and outdoor environments, respectively, the amount of FBAPs became larger than that of non-FBAPs.

For the particles within the first bin size (0.50-0.63 μm), around 89% and 91% particles were non-FBAPs for indoor and outdoor, respectively. The proportion of FBAP in PM for each size bin in indoors was always higher than that in outdoors. Especially for particles within 1.58-10.00 μm, the fluorescent proportions indoors were 10-17% higher than those in outdoors.

The occupant dominated the indoor source of both FBAPs and non-FBAPs. When awake or asleep, count- and mass-based emission rates were 45.9 (34.2) and 18.7 (18.4) × 10 6 #/h and 5.02 (7.28) and 2.83 (5.91) mg/h by mean (SD), respectively.

Based on the I/O ratios of FBAP under different conditions, indoor FBAPs larger than 3.16 μm were dominated by indoor sources.

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WIBS measurements

In healthcare settings, WIBS is used to:

- Monitor airborne biological particle dynamics
- Assess ventilation effectiveness in operating rooms and ICUs
- Study human activity impacts (movement, door opening)
- Compare HEPA filtration performanceSupport infection control strategies

WIBS does not identify specific microorganisms and cannot distinguish viable from non-viable particles. It detects fluorescence signatures only.

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HumanIC

Group discussions

1. What parameters that your project studies?

2. Which research method is suitable for your project?

3. Any interaction and synergy with other projects?

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Reference

- *Cao, Guangyu; Pedersen, Christoffer; Zhang, Yixian; Drangsholt, Finn; Radtke, Andreas; Langvatn, Håkon; Stenstad, Liv-Inger; Mathisen, Hans Martin; Skogås, Jan Gunnar. Can clothing systems and human activities in operating rooms with mixing ventilation systems help achieve 10 CFU/m3 level during orthopaedic surgeries?. Journal of Hospital Infection 2021. Volume 120, February 2022, Pages 110-116*
- *Masab Khalid Annaqeeb, Yixian Zhang, Jakub Wladyslaw Dziedzic, Kai Xue, Christoffer Pedersen, Liv-Inger Stenstad, Vojislav Novakovic, Guangyu Cao. Influence of the surgical team activity on airborne bacterial distribution in the operating room with mixing ventilation system: A case study at St. Olavs Hospital. The Journal of Hospital infection. 2021, 116:91-98. Published: August 14, 2021. DOI:https://doi.org/10.1016/j.jhin.2021.08.009.*
- *Aganovic A, Cao GY, Stenstad LI. Skogås JG, (2019) Experimental study on the effects of equipment on contaminant exposure of a patient in an operating room with unidirectional downflow. Building and Environment. 165 (2019) 106096. https://doi.org/10.1016/j.buildenv.2019.04.032*
- *Aganovic A, Cao GY, Stenstad LI. Skogås JG, Mathisen HM (2017) Impact of surgical lights on the velocity distribution and airborne contamination level in an operating room with laminar airflow. Building and Environment. Volume 126, December 2017, Pages 42-53*
- *Park et al. 2007. Development and performance test of a unipolar diffusion charger for real-time measurements of submicron aerosol particles having a log-normal size distribution*
- *https://en.wikipedia.org/wiki/Colony-forming_unit*
- *Li J, Wan MP, Schiavon S, et al. Size-resolved dynamics of indoor and outdoor fluorescent biological aerosol particles in a bedroom: A one-month case study in Singapore. Indoor Air. 2020;30:942–954. https://doi.org/10.1111/ina.12678*

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