# DEVELOPMENT OF A METHODOLOGY TO CHARACTERIZE THE EFFICIENCY OF VENTILATION IN OPERATING THEATRES

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# Current situation:

- High incidence of postoperative wound infections.
- The probability of the wound infection occurrence increases with the quantity of pathogens into the protection zone.
- Influence of the ventilation flow pattern in the quantity of pathogens

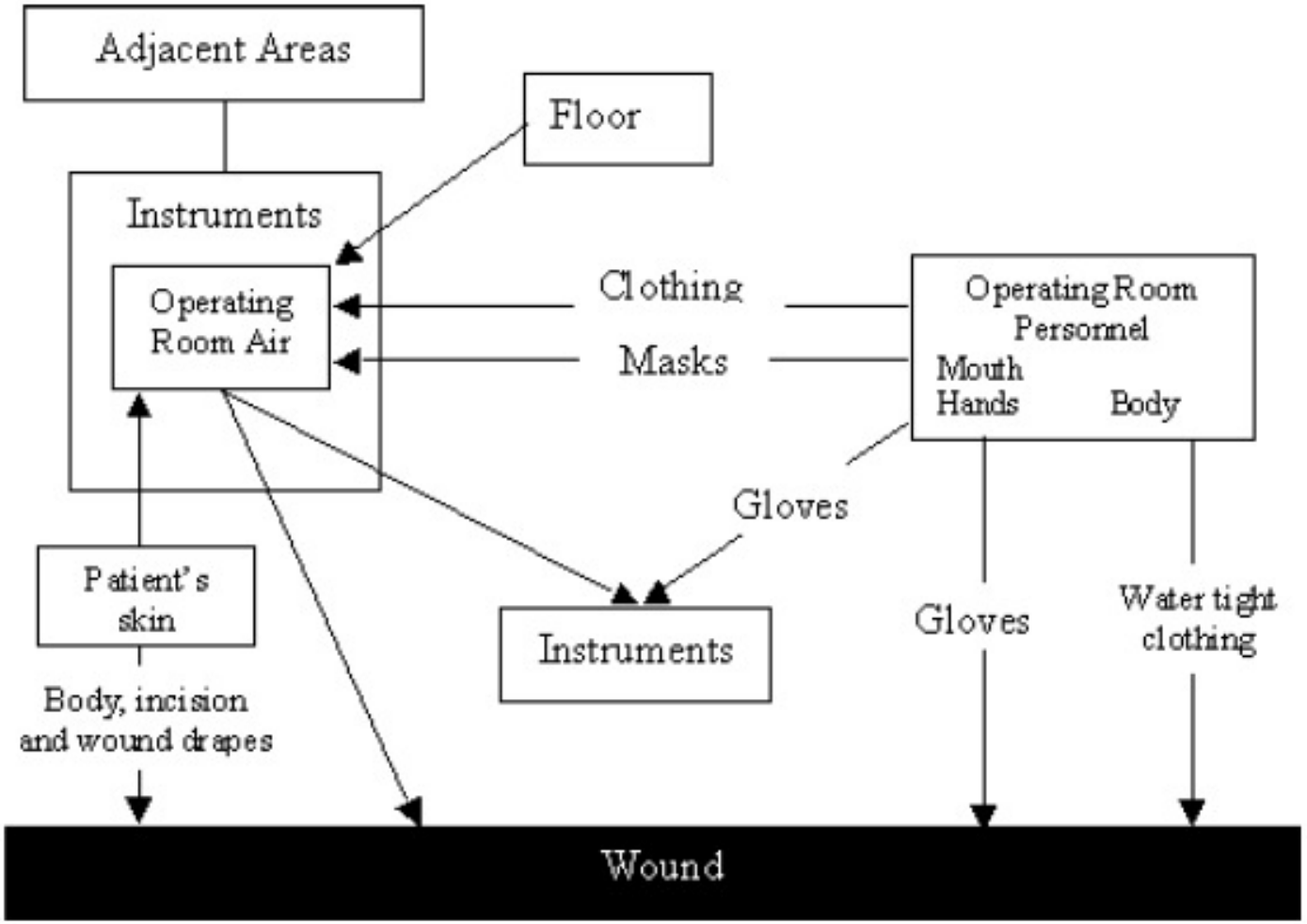



***Figure 1*** *Source and routes of infection in the operating room (Lewis 1993).*

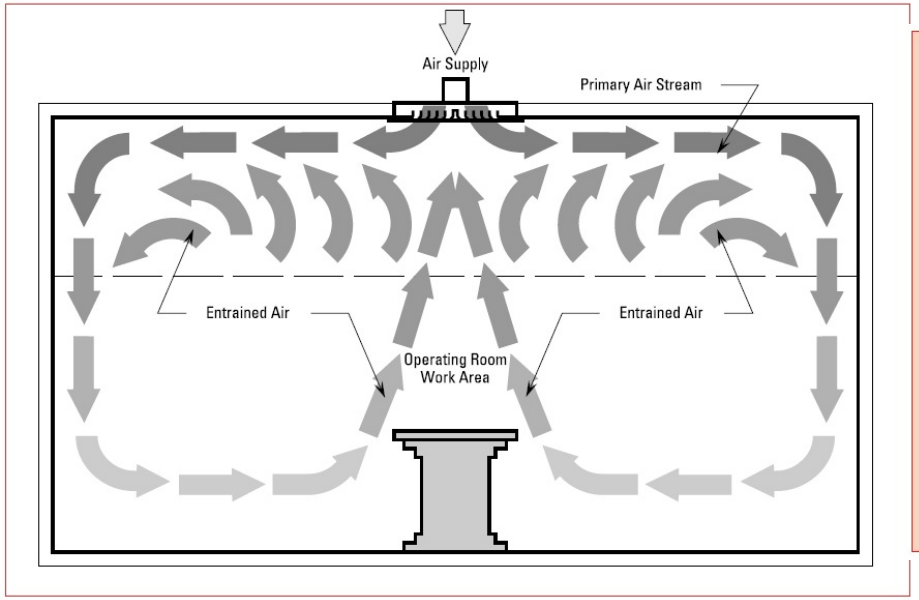
# Current situation:

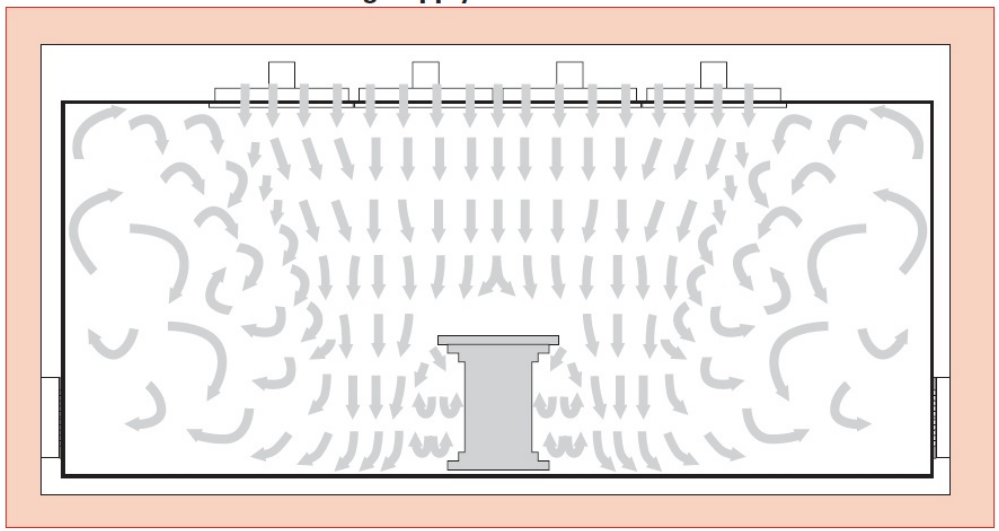
- Ventilation flowrate between 20 to 25 air changes per hour (ACH).
- HEPA filters are used.

- The activity of the operating theatre personnel is the main source of particles containing infections agents

# Current situation:

- There are two types of system ventilation in operating theatres:
  - The turbulent mixed-flow
  - The low turbulence displacement air flow.



# Objetives:

- In this work we present a methodology to characterize the efficiency of the ventilation in operating theatre by means of the concentration of active pathogens using CFD simulations.

# Ventilation quality

- The air changes per hour (ACH) is a very important parameter but is not sufficient
- The air exchange efficiency

$$\varepsilon_a = \frac{\text{minimum replacement time}}{\text{actual mean replacement time}} = \frac{V/Q_e}{2\,\bar{\tau}_a}$$

- The *contaminant removal effectiveness*

$$\varepsilon_c = \frac{\text{Mean concentration in the exhaust}}{\text{Mean concentration in the room}} = \frac{C_e}{\bar{C}}$$

# Infectious particles

- In the case of operating theatres the main contaminant is the skin scales
  - particles are shed continuously from exposed regions of skin on both staff and patients ($10^7$ per day)
  - particles are of the order of 10 microns
  - Approximately 10% will be colonized with microorganisms.

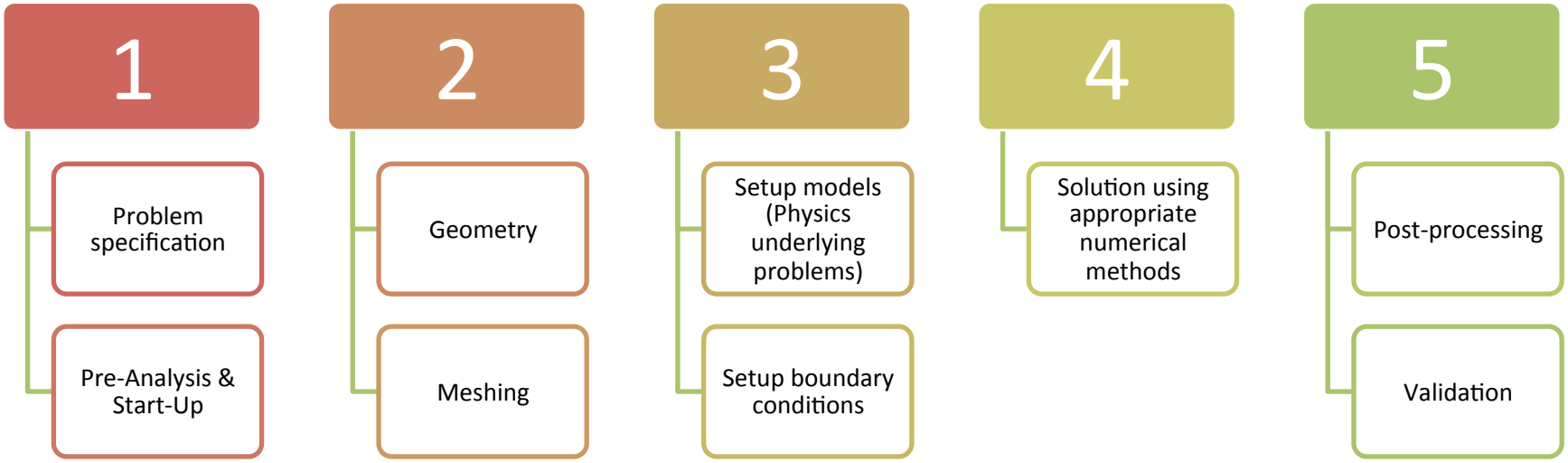
# Infectious particles model

- We model the contaminant like an aerosol formed of very fine particles which have pathogens stuck to them.
- We have chosen an Eulerian model,
- The skin scales are transported by convection of the air flow, and by the turbulent diffusion
- When the contaminant particles hit a solid surface they can stick on or bounce away from the surface
- We have also taken into account the viability of the pathogens

# Hypothesis

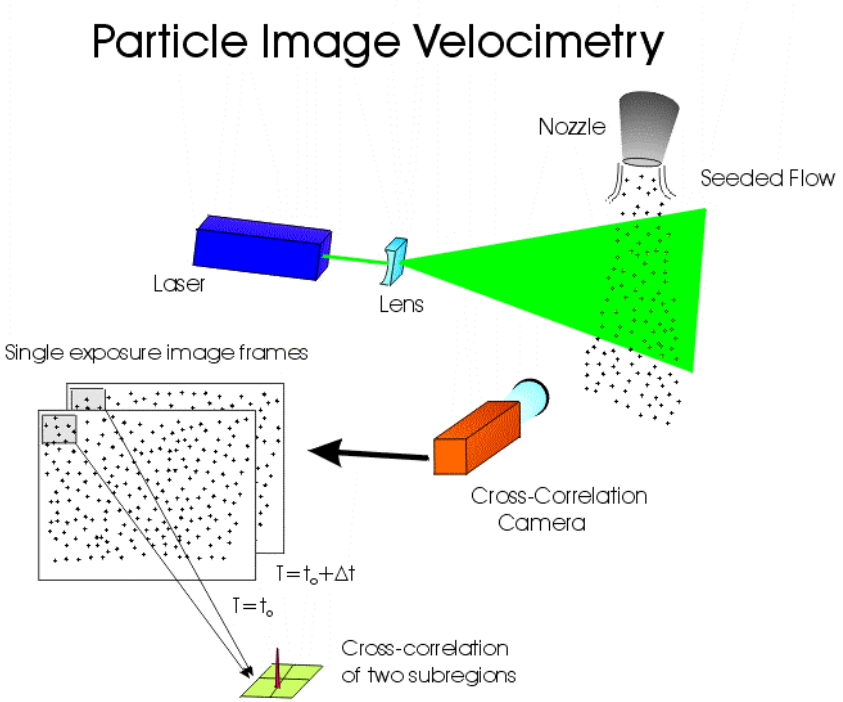
- The risk of contamination of the surgical site it will be proportional to the mean concentration of active pathogens in a *surgical volume* near the wound.

# Numerical simulation steps



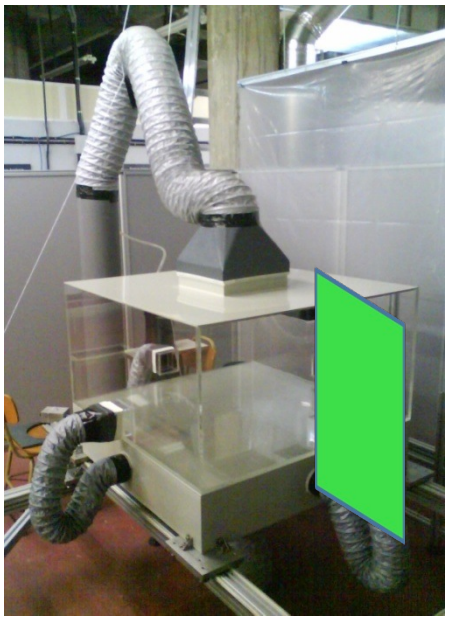
# Experimental set up

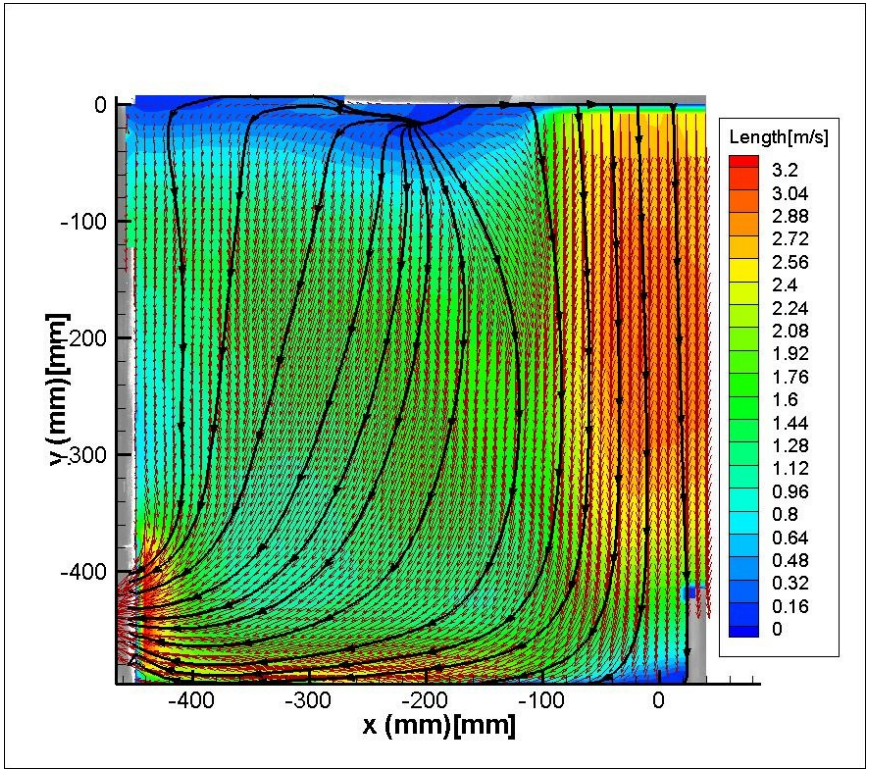
- To validate the numerical simulation of a ventilation flow pattern, in an operating theater type A, a scale 1:7 model was built



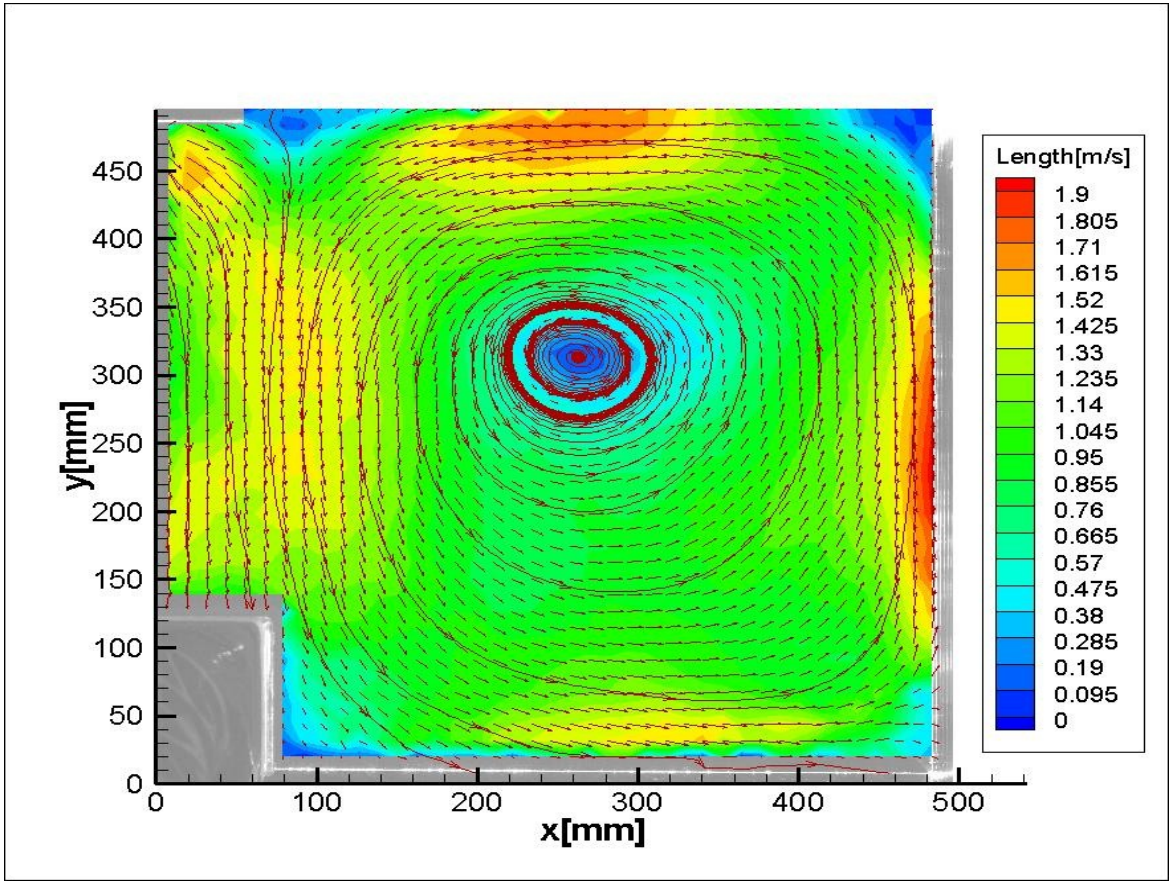
# Experimental results

- To validate the numerical simulation of a ventilation flow pattern, in an operating theater type A, a scale 1:7 model was built





# Experimental results

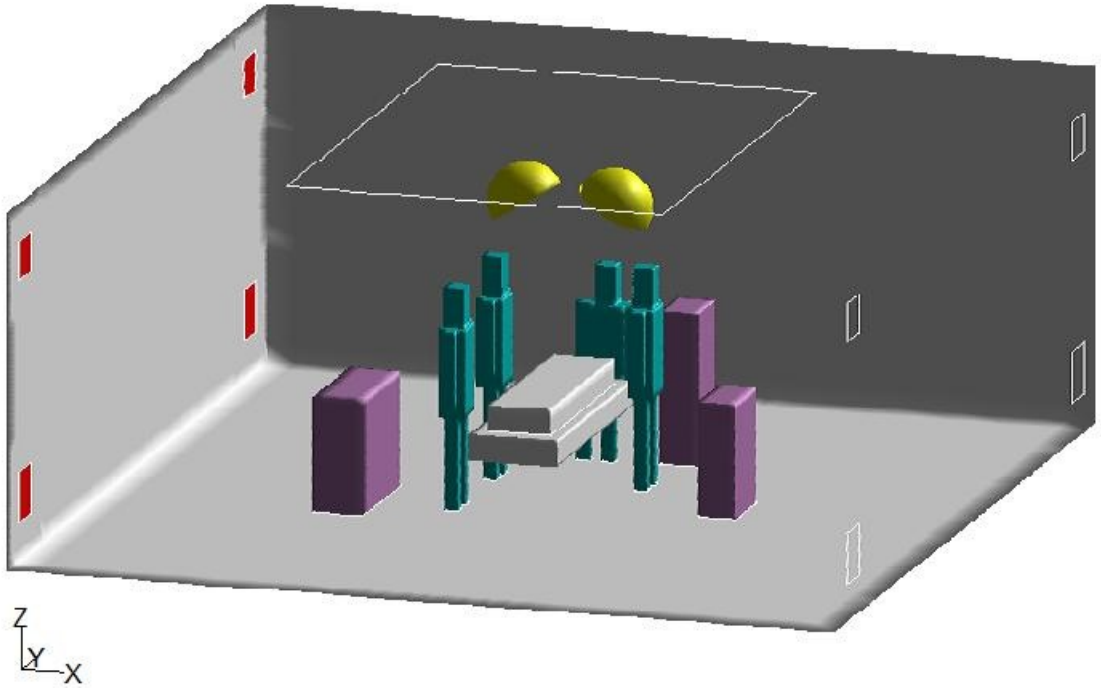


# CFD Numerical model

- Isothermal simulation
- The numerical model solves:
  - the continuity, momentum conservation equations
  - turbulence conservation equations (The RNG $k$-$\varepsilon$ turbulence model is used)
  - contaminant concentration conservation equation
  - mean age of air, mean age of contaminant conservation equations
- Once the age of the contaminant is calculated, the viability/survival model of micro-organisms can be applied and, thus, calculate the **concentration of active pathogens**

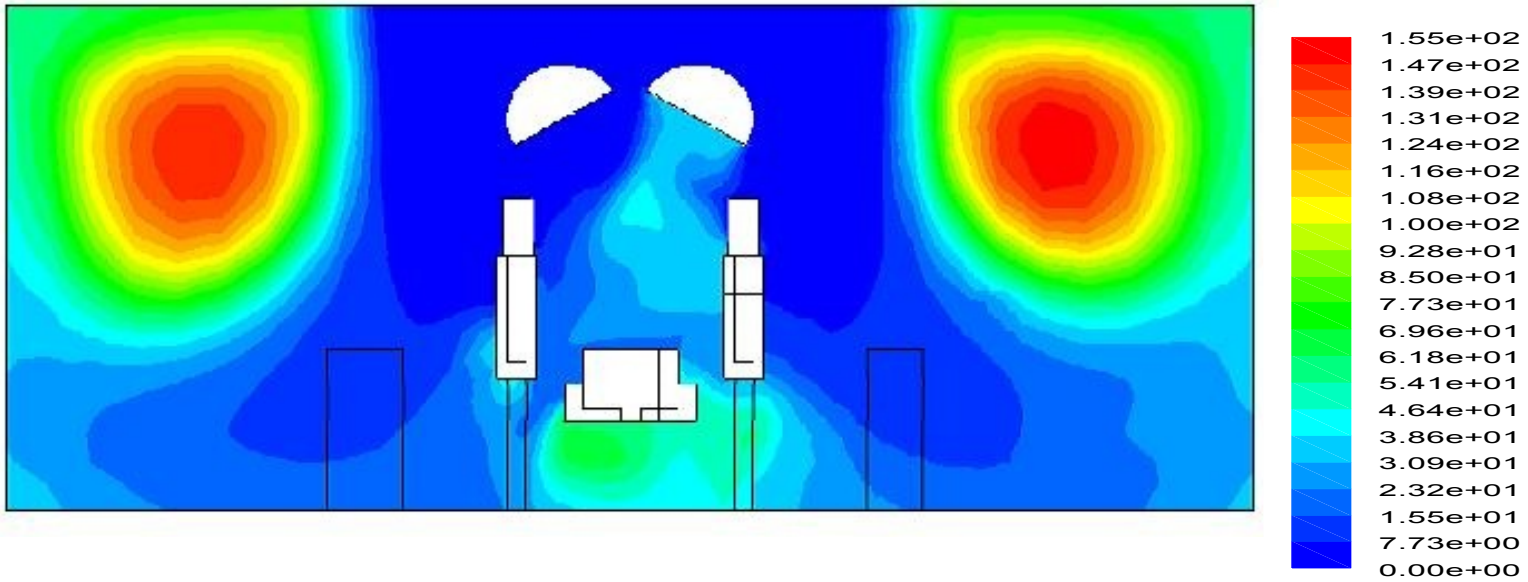
# Computational domain

- 6mx6mx3.5 m operating room
- laminar inlet diffuser, 8 exhaust grilles



# Results

Age of the air in a vertical plane y= 0.5 m



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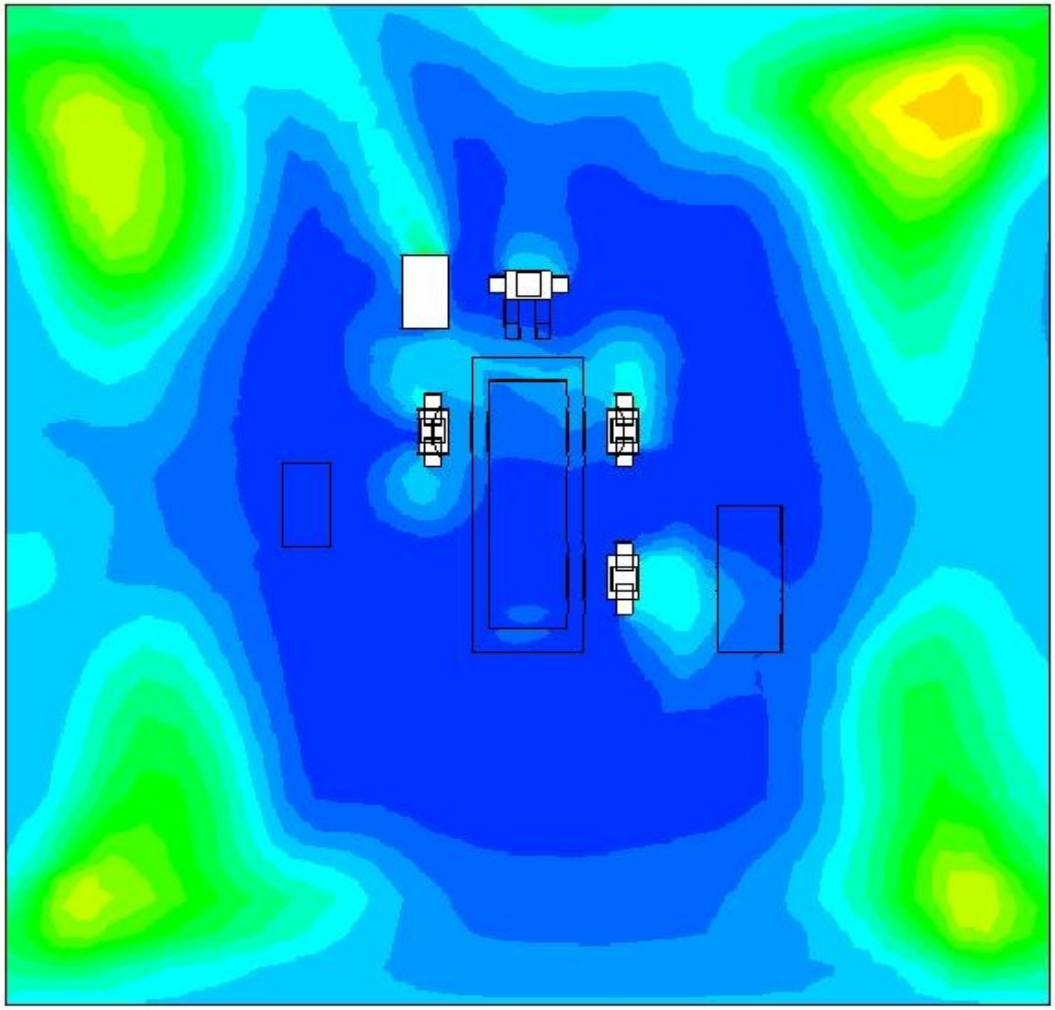
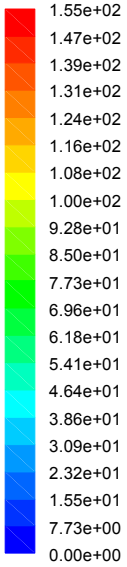
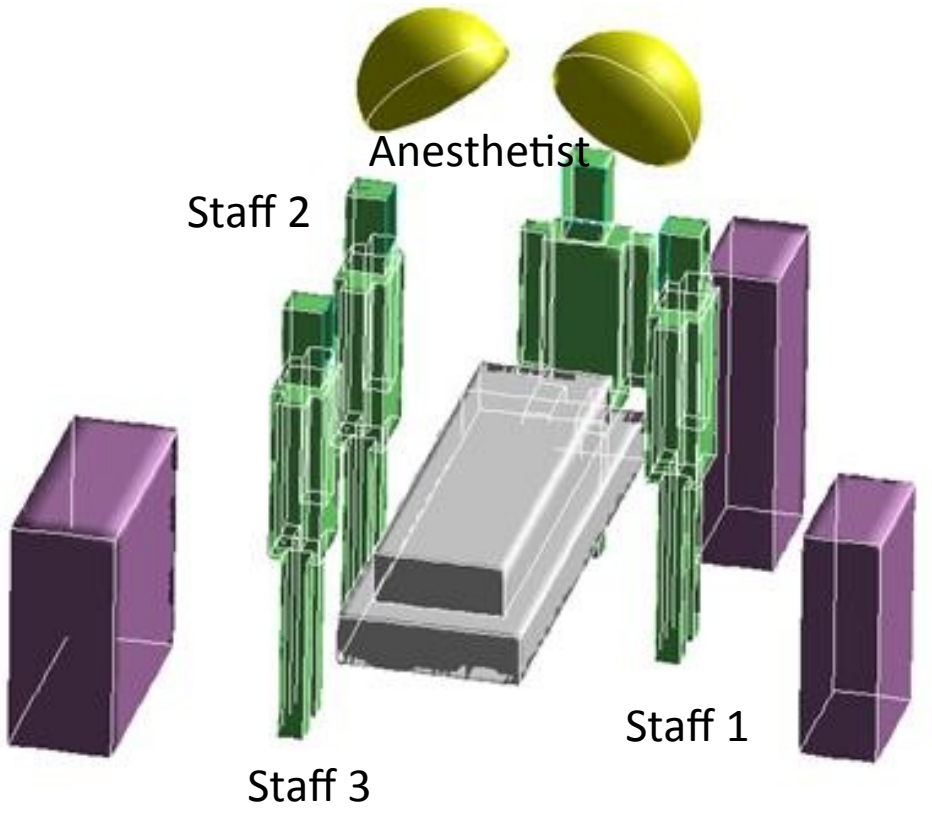


Age of the air in a horizontal plane z= 0.9 m



# Results



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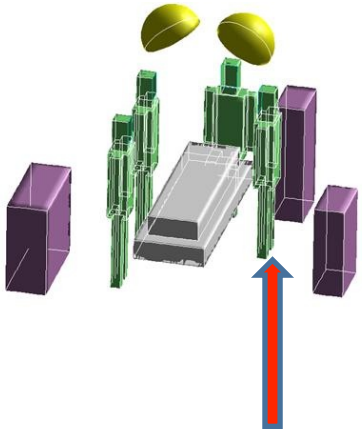
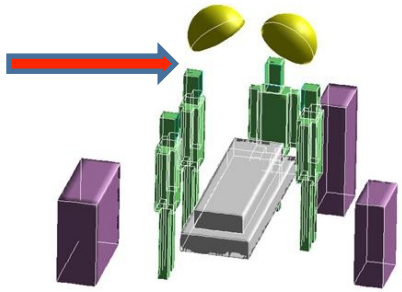
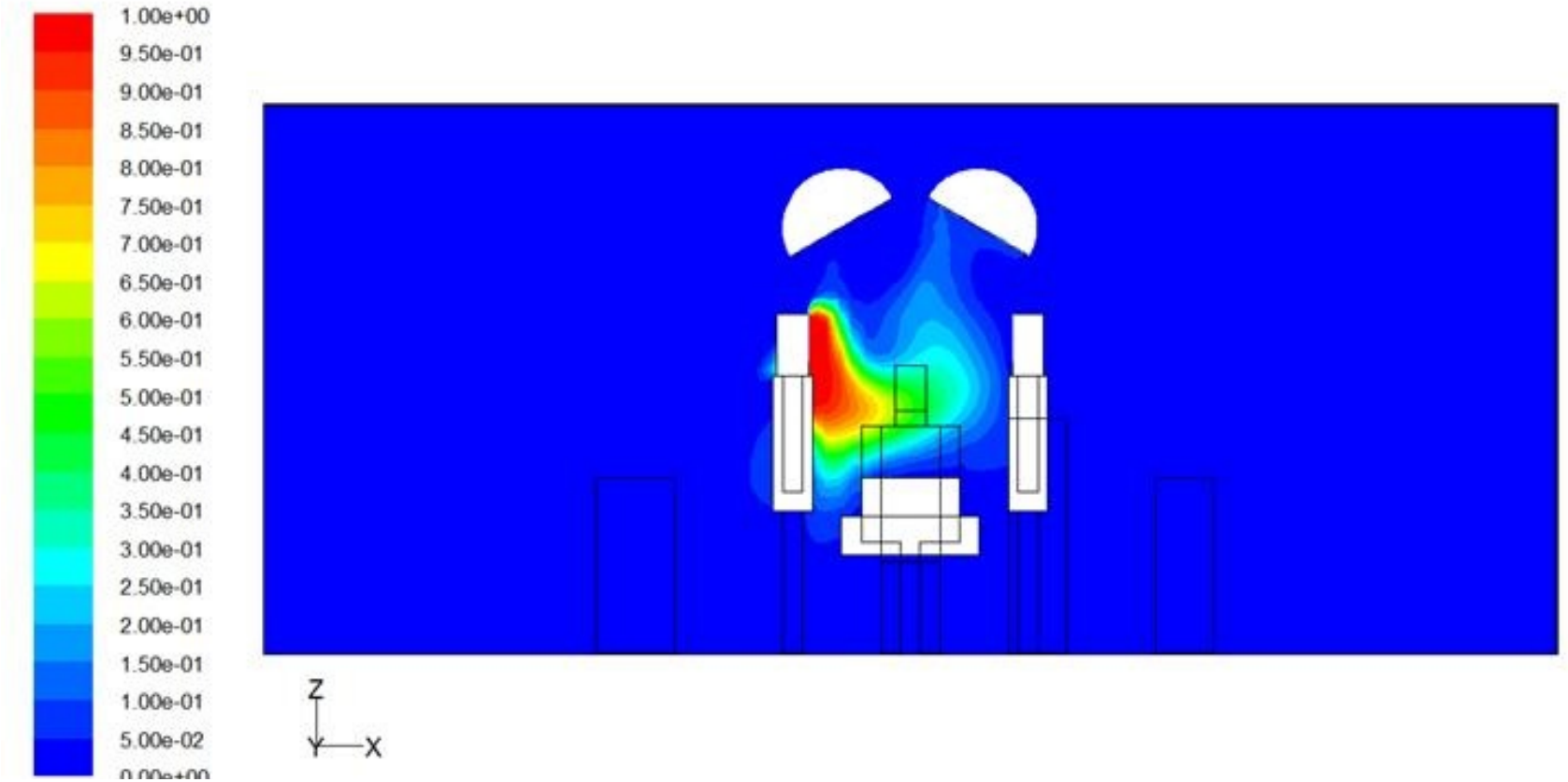


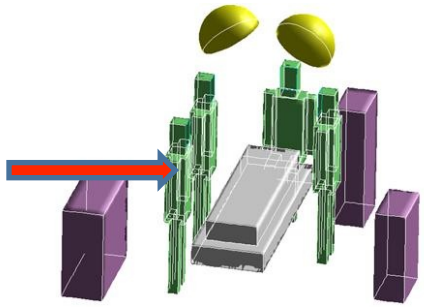

Distribution of concentration of active pathogens in a vertical plane. Contaminant staff 1

# Results

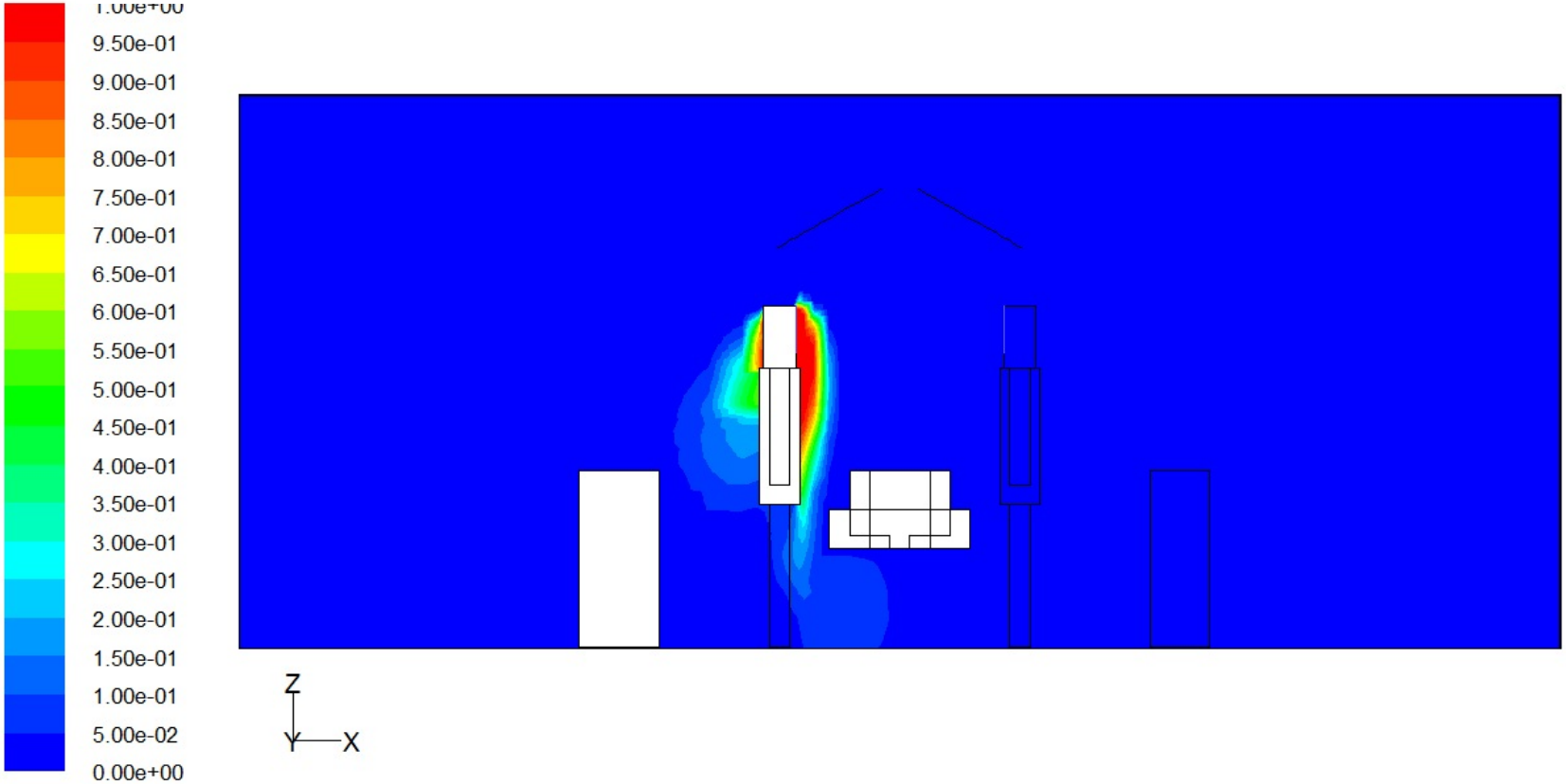




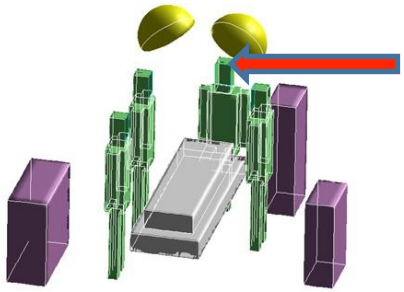

Distribution of concentration of active pathogens in a vertical plane. Contaminant staff 2



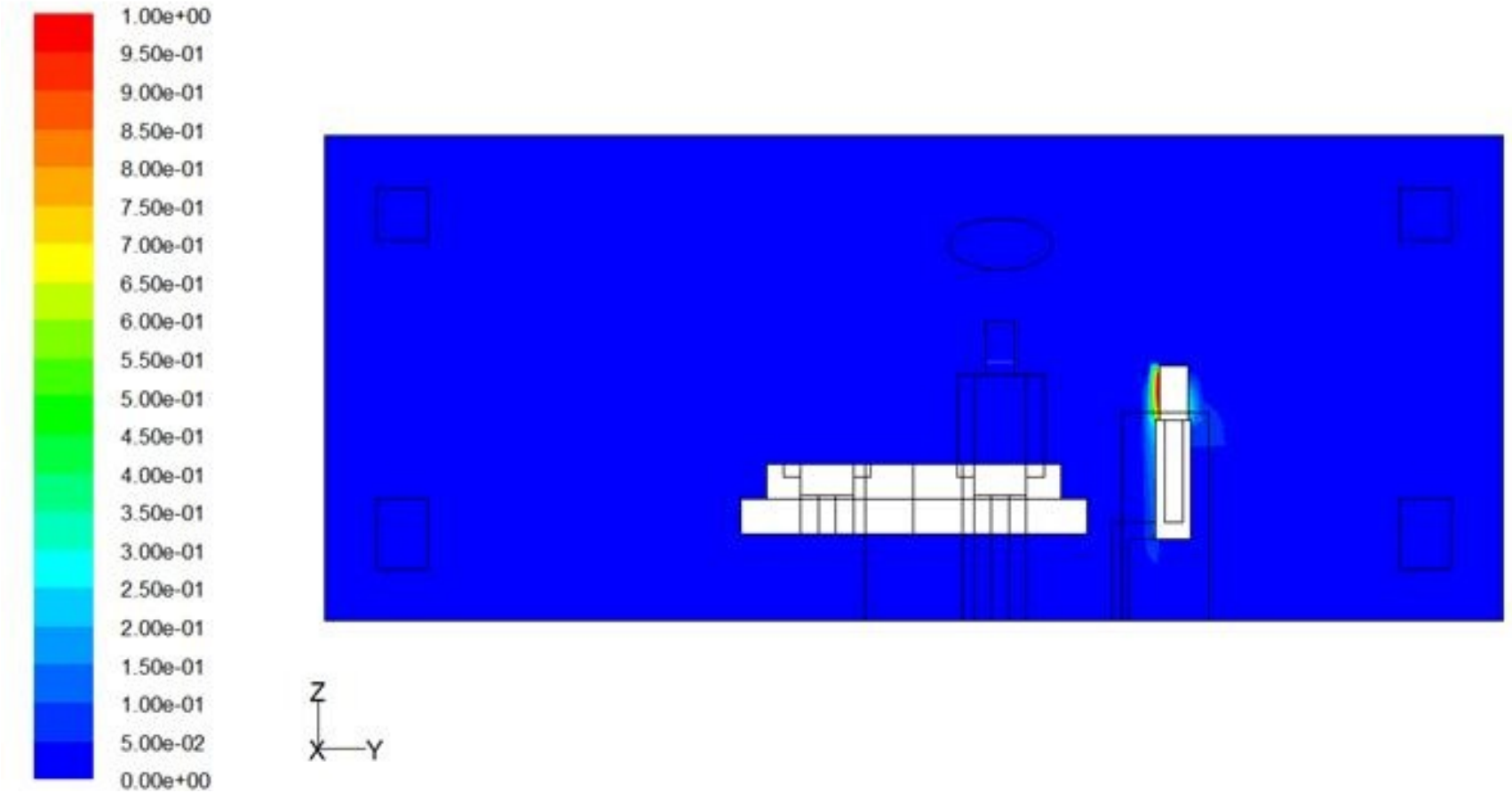
# Results




Distribution of concentration of active pathogens in a vertical plane. Contaminant staff 3

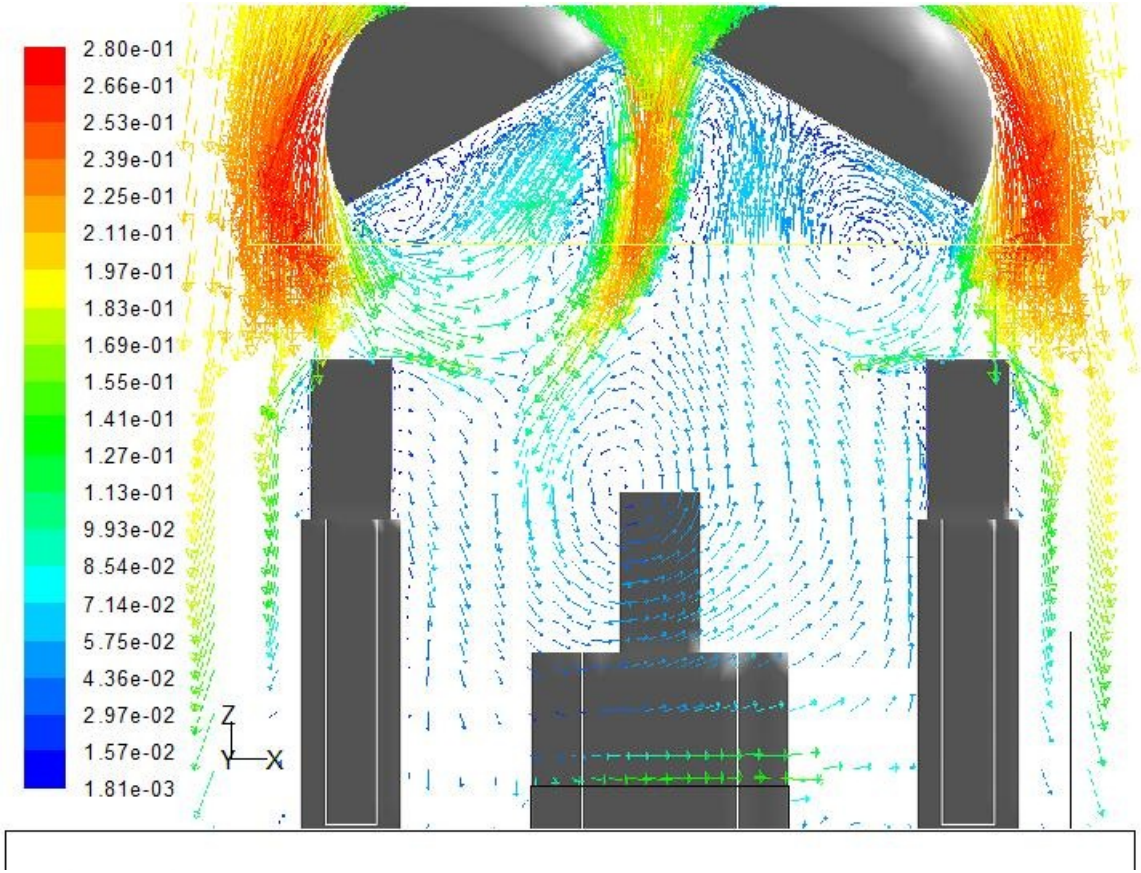


# Results




Distribution of concentration of active pathogens in a vertical plane. Contaminant anesthesist

# Results




Velocity field near the lamps

# Conclusions

- A methodology to evaluate the infection risk in an operating theater has been developed
- This methodology let us to compare different configurations of ventilation systems
- A 3D CFD model that calculates the concentration of active pathogens is used