AIR DUMMIES

Airflow Simulation Report

Classroom

July 31, 2025

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1. Overview

1.1. Case Summary

The case setup is summarized in the following table:

Table 1. List of case summary

Input	Value
Room dimensions (X,Y,Z) [m]	(8.0, 5.0, 3.0)
Number of air supplies	0
Number of air returns	0
Outdoor temperature [C]	20.0
Fresh Air Percentage	80

1.2. Results Summary

The primary simulation results are summarized in the following table:

Table 2. List of results summary

Input	Value
Ez Factor	0.0
Room Air Changes per Hour (ACH) [1/h]	0.0
Breathing Zone ACH [1/h]	0.0
Average Breathing Zone Temperature [C]	8.7
Average Breathing Zone PMV	-4.8
Average Breathing Zone PPD	100.0
Average CO2 [ppm]	1053
Average MAA [s]	1

2. Methodology

This section briefly explains the key methods used in the numerical simulation, along with the formulas applied to calculate various parameters.

2.1. Computational Fluid Dynamic (CFD) Settings

Computational Fluid Dynamics (CFD) is used to analyze fluid and gas behavior in settings such as aerospace, meteorology, and industrial design. This report uses OpenFOAM, an open-source CFD package that employs the finite volume method (FVM) to solve fluid flow problems.[1] The simulation settings are listed in the following table:

Table 3. List of settings of the CFD simulation

Parameter	Value	Description
Turbulence model	K-Omega SST	K-Omega SST is a versatile turbulence model with good convergence behavior and is widely used in the CFD industry.
Convergence criteria	10e-6	The convergence criterion represents the acceptable error level in numerical solutions. A value of 1e-6 was chosen based on prior case studies.
Buoyancy effect	Boussinesq Approximation	The Boussinesq approximation[2] accounts for buoyancy effects and is accurate when temperature differences are small (<30°C or 54°F).[3]

2.2. Definitions

Definitions of the key parameters used in this report are provided below:

2.2.1. Breathing Zone

The Breathing Zone refers to the space between 3 inches and 72 inches (75 mm to 1800 mm) above the floor and more than 24 inches (600 mm) away from walls or fixed air-conditioning equipment.[4] This region is critical when evaluating air quality.

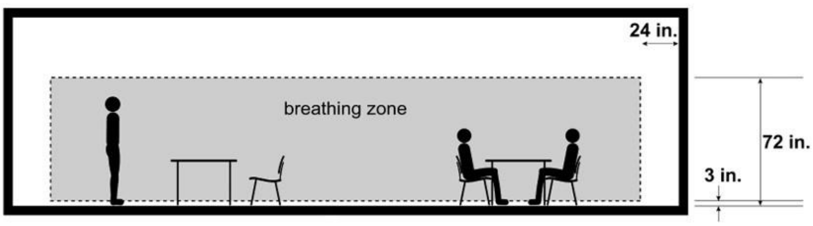

Figure 1. Display of the Breathing Zone[5]

2.2.2. Mean Age of Air (MAA)

The Mean Age of Air (MAA) represents the average time it takes a particle (e.g., a molecule) to travel from an air inlet to the measurement location.[6]

2.2.3. Ez Factor

Air Distribution Effectiveness (Ez) measures how effectively the supply air maintains acceptable air quality in the Breathing Zone.[4] It is calculated as (Return - Supply) / (Breathing Zone - Supply).

2.2.4. Safe Exposure Time

Safe Exposure Time is defined as the maximum period a person can remain in a space while minimizing infection risk.[7]

$$t = \frac{N_{b,critical}}{C\dot{V}_b} = \frac{50}{C\dot{V}_b}$$

Where C is the contaminant concentration, and V_b is the breathing rate (assumed to be 0.7 CFM or 0.33 L/s).
$N_{b,critical}$ is the number of particles needed to cause infection, conservatively assumed to be 50.[8]

2.2.5. Predicted Mean Vote (PMV)

The Predicted Mean Vote (PMV) index estimates the average thermal sensation on a scale from +3 (hot) to -3 (cold), with 0 being neutral. It is based on ANSI/ASHRAE Standard 55[9]. To ensure comfort, PMV values should remain between -0.5 and +0.5.

2.2.6. Predicted Percentage of Dissatisfied (PPD)

The Predicted Percentage of Dissatisfied (PPD) estimates the proportion of occupants likely to feel thermally uncomfortable. It ranges from 0% to 100%. According to ASHRAE Standard 55, PPD should be kept below 20%.[9]

3. Simulation Case

This section describes the room geometry, furniture, occupants, and HVAC system components including supplies, returns, and air purifiers (if any).

3.1. Ventilation System

A schematic of the ventilation system is shown below:

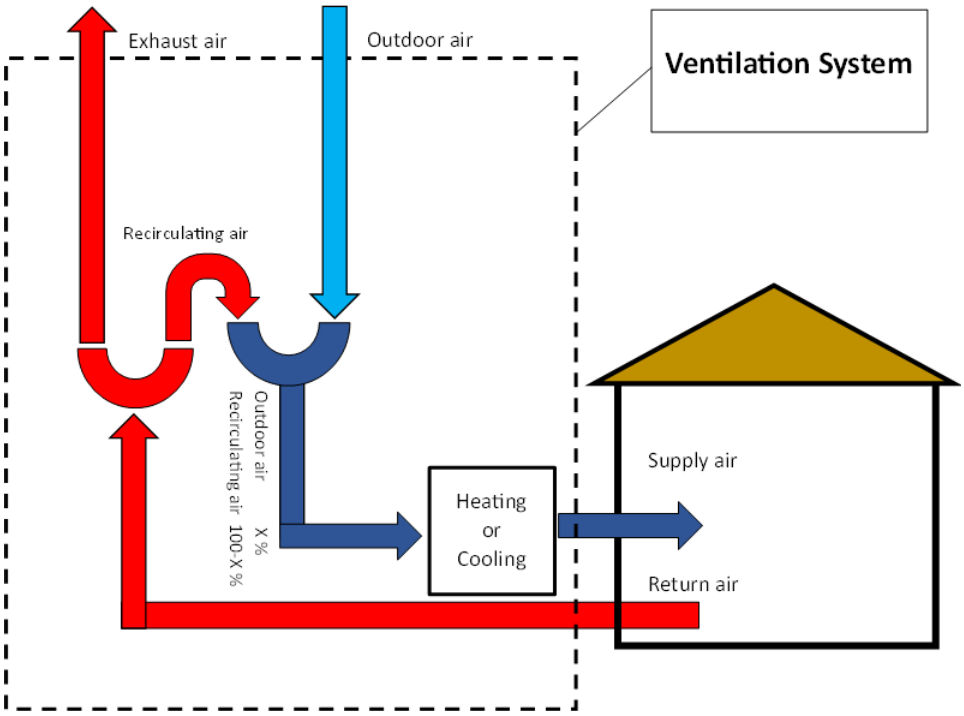

Figure 2. Preview of the working ventilation system

As shown in the figure, the system uses 80.0% outdoor air and 20.0% recirculated air.

3.2. Room's Geometry

This section provides specifications of HVAC components including supplies, returns, and air purifiers (if applicable).

3.3. Air purifiers

The following table lists characteristics of the air purifiers:

Table 4. List of the air purifiers

Number	Model	Airflow [m3/h]	X [m]	Y [m]	Z [m]
1	Sample	169.9	1.0	1.0	0.0

3.4. Room Furniture

The following table lists all objects present in the room:

Table 5. List of Furniture

Number	Object Name	X [m]	Y [m]	Z [m]
1	Whiteboard	0.0	3.0	0
2	Teacher Desk	1.0	3.0	0
3	Chair Dummy	3.0	3.0	0
4	Chair Dummy	4.0	3.0	0
5	Chair Dummy	4.0	2.0	0
6	Chair	3.0	2.0	0
7	Dummy Standing	6.0	3.0	0
8	Dummy Seating Sick	3.0	2.0	0

4. Results

This section explains the simulation results.
The following table shows the computed values for each metric:

Table 6. List of the result parameters

Parameter	Value	Description
ACH [1/h]	0.0	Air change per hour
Ez Factor	0.0	Average contaminant concentration in: (return-supply) / (breathing zone-supply)
Average Breathing Zone Temperature [C]	8.7	The average temperature in the breathing zone
Average Breathing Zone MAA [s]	1	Average Mean Age of Air

4.1. Energy

The total energy consumption of the ventilation system is 0.0 kW. Of this, 0.0 kW is lost through the exhaust and 0.0 kW through walls.

4.2. Velocity

The velocity distribution is shown in the following figures:

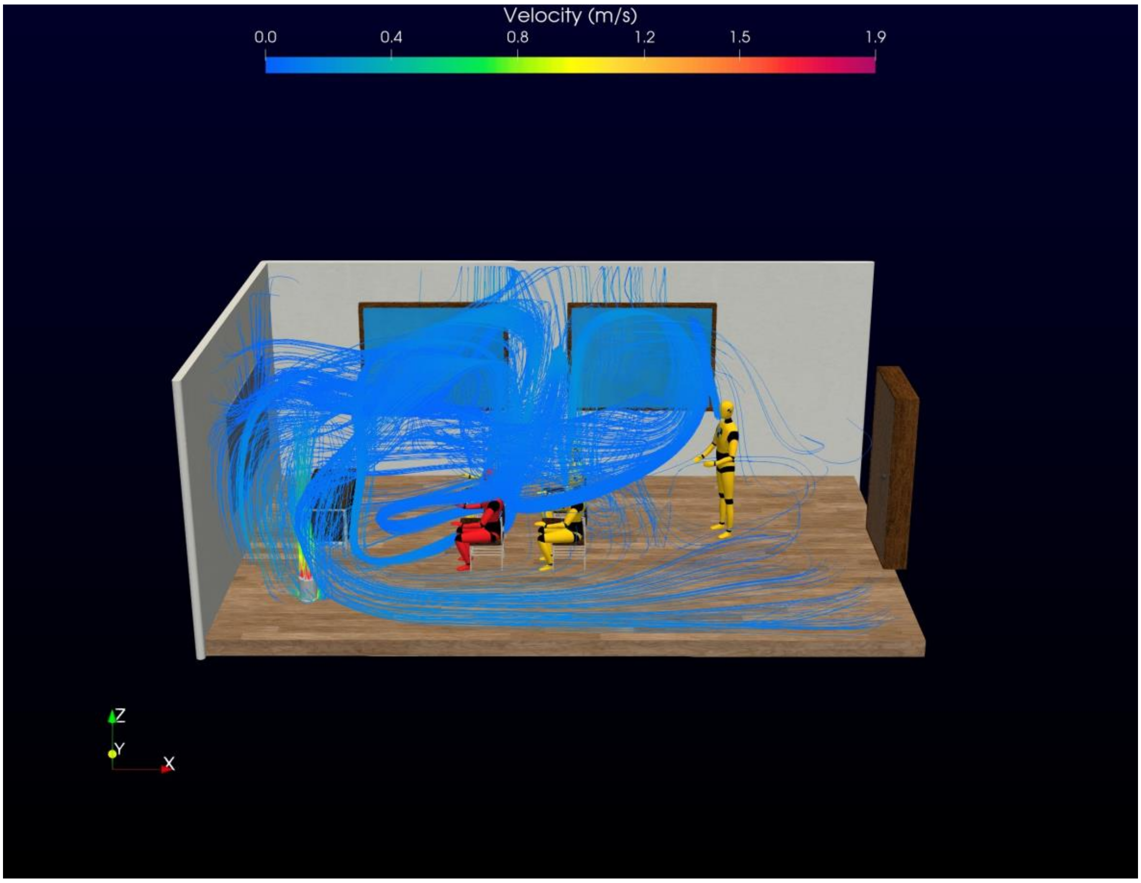

Figure 3. Velocity streamlines

4.3. Contaminant Particles

The concentration of contaminant particles is shown in the following figures:

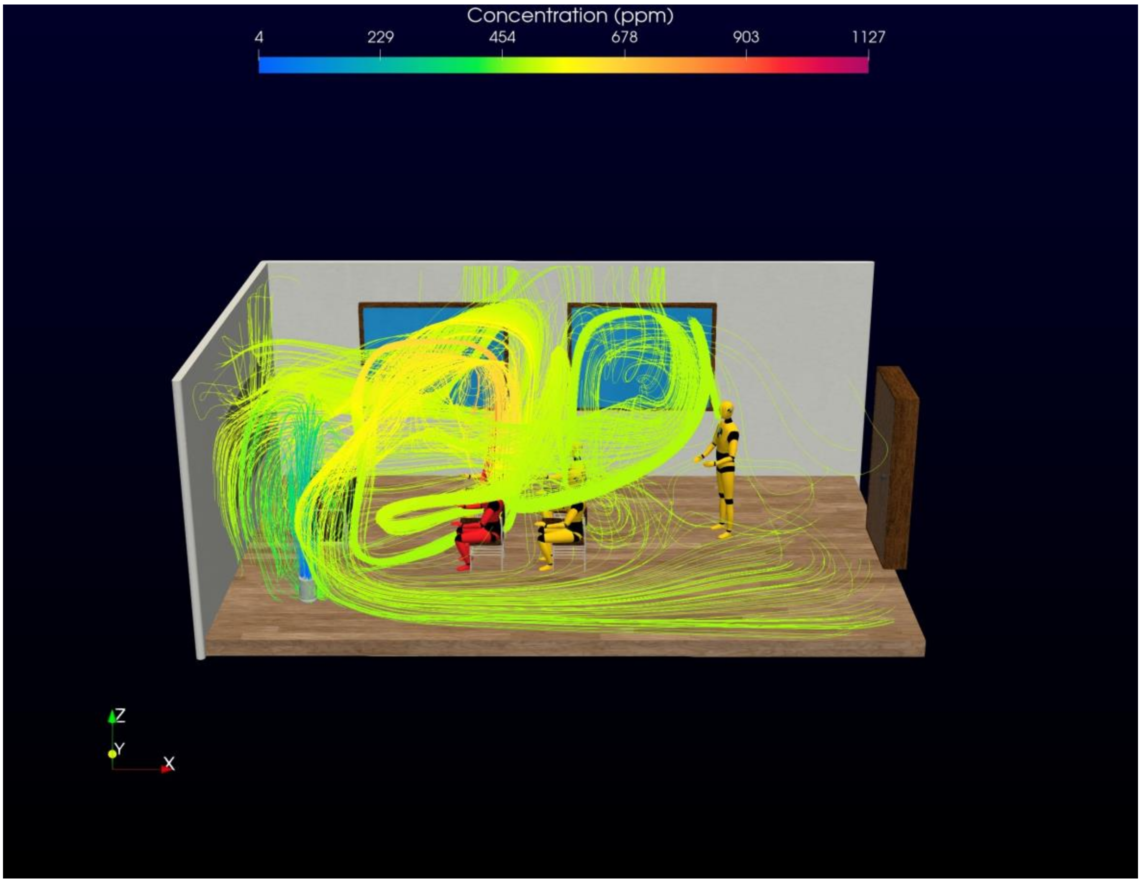

Figure 4. Contaminant Particles streamlines

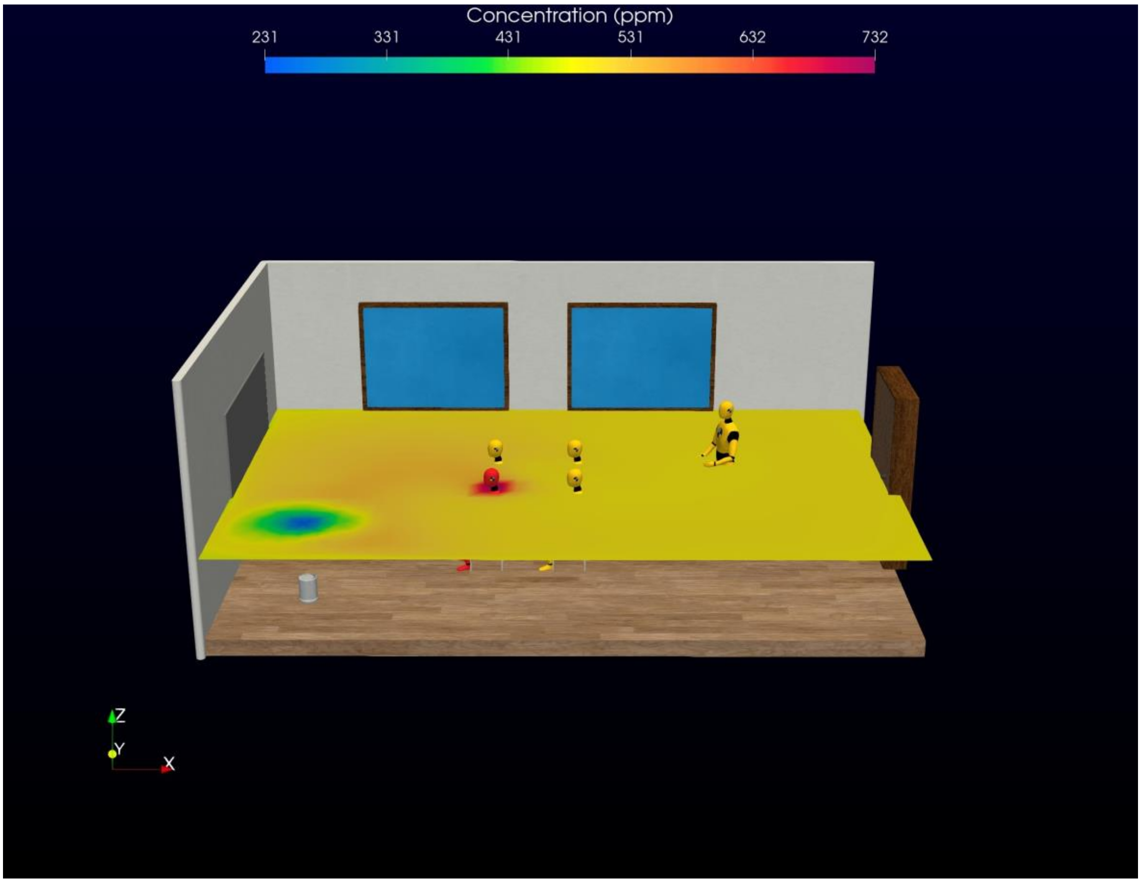

Figure 5. Contaminant Particles contour at Z=1.0 m with average value of 499.36 ppm and standard deviation of 25.4

4.4. CO2

ASHRAE recommends a maximum CO■ difference of 700 ppm between outdoor and indoor levels, with outdoor levels typically ranging from 300 to 500 ppm.[4] This leads to a widely accepted guideline of 1000 ppm for indoor CO■.[10] The CO■ concentration is shown in the figures below:

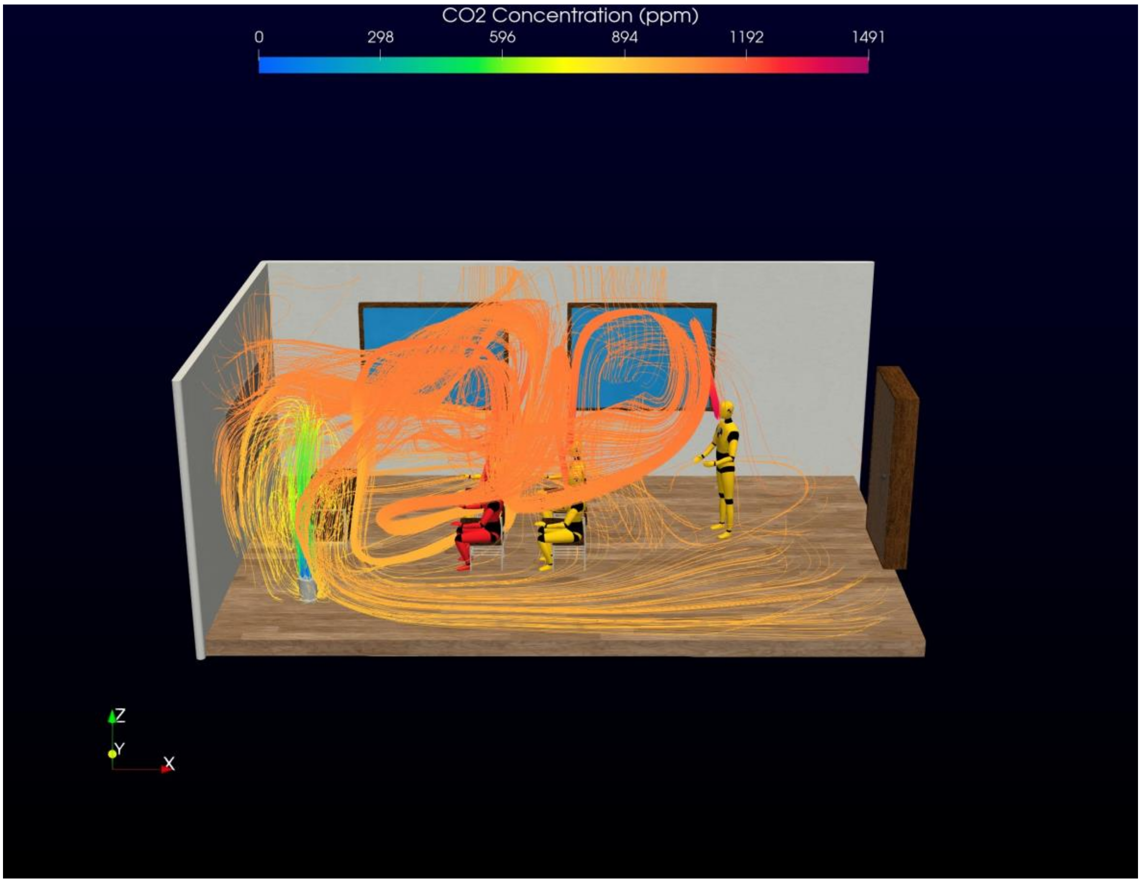

Figure 6. CO2 streamlines

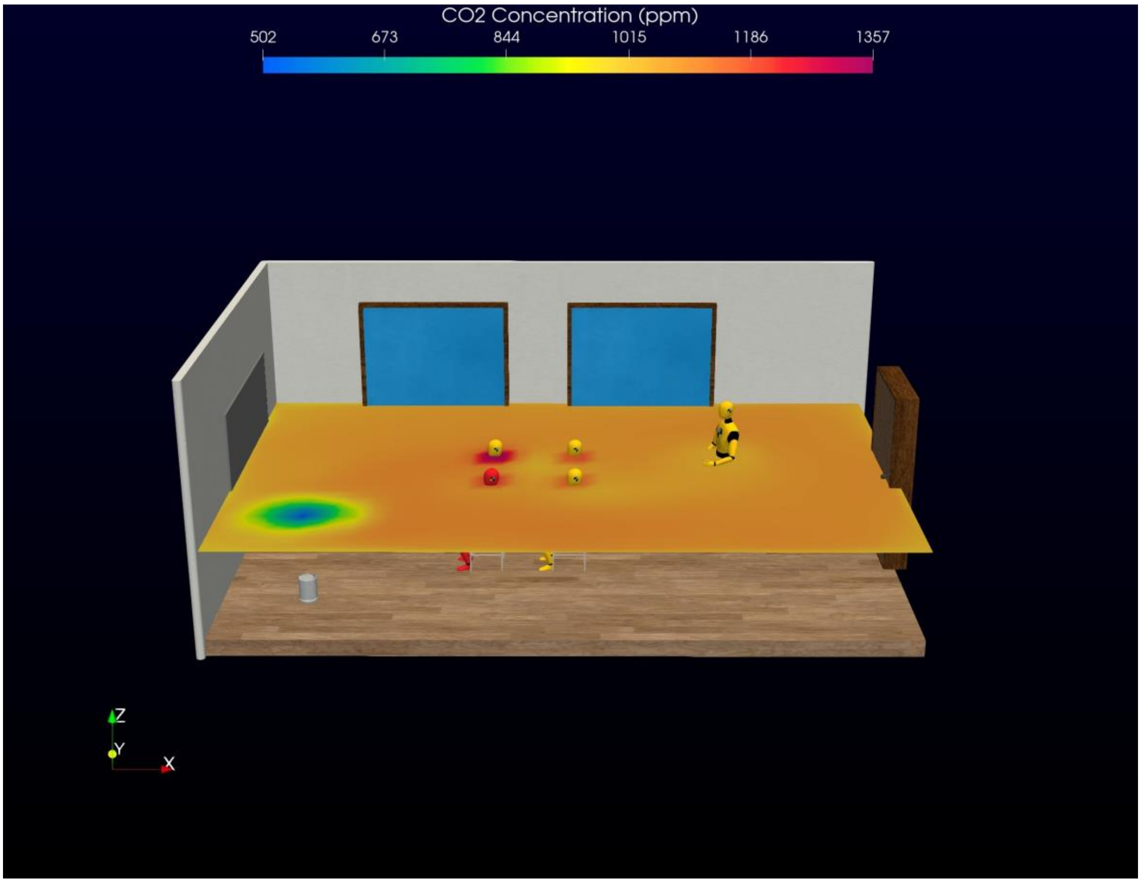

Figure 7. CO2 contour at Z=1.1 m with average value of 1058.69 ppm and standard deviation of 53.81

5. References

[1] https://openfoam.org/

[2] J. Boussinesq, Theorie Analytique de la Chaleur, Gauthier-Villars, Paris (1897)

[3] D. D. Gray and A. Giorgini. The validity of the boussinesq approximation for liquids and gases. International Journal of Heat and Mass Transfer, 19(5):545-551, 1976.

[4] ASHRAE 62.1-2019 "Ventilation for Acceptable Indoor Air Quality"

[5] https://ashraemontreal.org

[6] Federspiel, C.C. Air-Change Effectiveness, Theory and Calculation Methods. Indoor Air 1999, 9, 47-56.

[7] Z. Zhang, T. Han, K. H. Yoo, J. Capecelatro, A. L. Boehman, and K. Maki, "Disease transmission through expiratory aerosols on an urban bus," Physics of Fluids, vol. 33, no. 1, p. 015116, Jan. 2021, doi: 10.1063/5.0037452.

[8] J. M. Kolinski and T. M. Schneider, "Superspreading events suggest aerosol transmission of SARS-CoV-2 by accumulation in enclosed spaces," arXiv:2007.14807 (2020).

[9] ASHRAE 55-2020 "THERMAL ENVIRONMENTAL CONDITIONS FOR HUMAN OCCUPANCY"

[10] ASTM D6245-18 "Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation"