Worked Example

Use of the CO2 ventilation model

Consider an office 27m × 20m × 2.8m(H) housing people at 9m^2/person and a design ventilation rate of 10L/s/person. What is the CO^2 concentration at different hours of the day assuming that office hour is 9am to 6pm with lunch time at 1pm to 2pm. The office is purged with fresh air after work.

c	=	concentration of carbon dioxide in the room (ppm)
Q'	=	fresh air supply rate per occupant (m^3/s)
V'	=	occupied volume in the room per occupant (m^3)
t	=	time after room is occupied (sec)
c_a	=	concentration of carbon dioxide in outdoor ambient air (take 300ppm)
$\dot{V}_c$	=	volume of carbon dioxide produced per occupant (take 4 × 10^{-6} m^3/s)
c_0	=	concentration of carbon dioxide in the room at time t = 0 (ppm)

$$c = \left[\frac{10^6 \dot{V}_c}{Q'} + c_a\right]\left(1 - e^{-\frac{Q't}{V'}}\right) + c_0 e^{-\frac{Q't}{V'}}$$

The occupied volume per person V' = 9m^2 × 2.8m = 25.2m^3

Consider after one hour (i.e. at 10am)

Substituting into the equation:

$$\frac{Q't}{V'} = \frac{0.01 \times 3600}{25.2} = 1.43$$

$$e^{-\frac{Q't}{V'}} = e^{-1.43} = 0.24$$

$$c = \left[\frac{10^6 \times 4 \times 10^{-6}}{0.01} + 300\right](1 - 0.24) + 300 \times 0.24 = 604\,\text{ppm}$$

Using similar calculation, the CO^2 concentration at different hours before lunch is given by:

10am = 604ppm

11am = 677ppm

12noon = 694ppm (near to steady state)

1pm = 699ppm

At lunch hour, assume no one inside the office, but ventilation remains at constant rate

$$c = \left[\frac{10^6 \times 0}{0.01} + 300\right](1 - 0.24) + 699 \times 0.24 = 396\,\text{ppm}$$

thus
2pm = 396ppm

The CO_2 concentration for afternoon office hour is done similarly except letting initial CO_2 concentration at 396ppm instead.

The actual air change rate for the office

$$= \frac{25.2}{0.01} \div 3600 = 0.7\,\text{ACH}$$

Exercise

For energy saving purposes, the office in the worked example has reduced the ventilation rate such that a steady state 1000ppm CO_2 concentration can be achieved. What should be the ventilation rate (in m^3/s/person or ACH)?

Try also to derive the equation in steps.