Worked Example

Use of the CO_2 ventilation model

Consider an office 27m × 21m × 3m(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) (10L/s/person = 0.01m^3/s/person)
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 380ppm)
$\dot{V}_c$	=	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)

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

Volume of room = 27m × 21m × 3m = 1701m^3

The occupied volume per person V' = 9m^2 × 3m = 27m^3

Since the room is purges with fresh air overnight, therefore, it can be assumed that the CO_2 concentration at the start of the working at 9am = outdoor concentration = 380ppm

Consider after one hour (i.e. at 10am, t = 3600s)

Substituting into the equation:

$$\frac{Q't}{V'} = \frac{0.01 \times 3600}{27} = 1.33$$

$$e^{-\frac{Q't}{V'}} = e^{-1.33} = 0.264$$

$$c = \left[\frac{10^6 \times 4 \times 10^{-6}}{0.01} + 380\right](1 - 0.264) + 380 \times 0.264 = 674\,\text{ppm}$$

Using similar calculation, the CO_2 concentration at different hours before lunch is given by:

10am = 674ppm

11am = 752ppm

12noon = 773ppm

1pm = 778ppm

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

$$c=\left[\frac{10^6\times 0}{0.01}+380\right](1-0.264)+778\times 0.264=485\,\text{ppm}$$

thus
at 2pm = 485ppm

The CO_2 concentration for afternoon office hour is done similarly except putting the initial CO_2 concentration at 485ppm instead of 380ppm in the morning.

The outdoor air change rate for the office

$$=\frac{0.01\times 3600}{27}=1.33\,\text{ACH}$$

<u>Exercise</u>
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 L/s/person or ACH)?

Try also to derive the equations in steps.
<u>Solution</u>
Using

$$c=\left[\frac{10^6\dot{V}_c}{Q'}+c_a\right]\left(1-e^{-\frac{Q't}{V'}}\right)+c_0e^{-\frac{Q't}{V'}}$$ and inserting the necessary parameters

$$1000=\left[\frac{10^6\times 4\times 10^{-6}}{Q'}+380\right](1-e^{-n})+380e^{-n} \quad \text{where} \quad n=\frac{Q't}{V'}$$

For steady state, $e^{-n}\to e^{-\infty}\to 0$

$$1000=\left[\frac{4}{Q'}+380\right]$$

Thus
$Q'=0.00645\,\text{m}^3$/s/person = 6.5L/s/person
Air change rate

$$=\frac{0.00645\times 3600}{27}=0.86\,\text{ACH}$$