Indoor Air and Air Exchange Rates

The air exchange rate (sometimes referred to as as the number of air changes per hour "ach") is a first order rate constant (k_e) for the ventilation of indoor air. It is related to the indoor air residence time (τ_e) as $k_e = 1/\tau_e$.

Taking into account air exchange processes only (i.e., no chemical loss mechanisms);

$$\text{Rate of infiltration of an outdoor contaminant} = \frac{d[X]}{dt} = k_e[X]_{outside}$$

$$\text{Rate of ventilation of an indoor contaminant} = \frac{d[X]}{dt} = -k_e[X]_{inside}$$

Taking into account both infiltration from outdoor sources and ventilation of indoor sources, the net rate of accumulation of a contaminant inside is given by;

$$\text{Rate} = d[X]/dt = k_e [X]_{outside} - k_e [X]_{inside}$$

The integrated form of the rate equation is given by;

$$ln ([X]_o - [X]_i) = - k_e t + \text{Constant}$$

At steady state, Rate in = Rate out

$$\text{Rate in} = k_e [X]_{outside} + \text{Rate of emission from an internal source}$$

and, assuming no chemical loss;

$$\text{Rate out} = k_e [X]_{inside}$$

Hence, at steady state;

$$k_e [X]_{inside} = k_e [X]_{outside} + \text{Rate of emission from an internal source}$$

1. An open fire in a well ventilated home produces VOCs at a rate of 30 mg m^{-3} h^{-1}. A complete exchange of air takes place every 5 minutes. The ambient outdoor air concentration of VOCs is 75 µg m^{-3}. Calculate the steady state indoor concentration of VOCs from this source assuming no chemical loss mechanisms.

[*Answer = 2.6 mg* m^{-3}]

2. In some rural communities, heating and cooking are often done with open fires. If the rate of emission of PAHs from indoor combustion is 3.5 ng m^{-3} h^{-1} and the outdoor concentration of PAHs is 0.60 ng m^{-3}, estimate the steady state indoor air concentration of PAH compounds if the air exchange rate is 2 h^{-1}. Assume that the only loss mechanism is by air exchange.

[*Answer = 2.4 ng* m^{-3}]

3. A one compartment home of volume 330 m^3 has an infiltration rate of 0.25 ach with doors and windows closed. During an episode of photochemical smog, the outdoor concentration of PAN is 85 ppb_v. If the family remains indoors and the initial concentration of PAN inside is 18 ppb_v, how long will it take before the PAN concentration inside rises to 45 ppb_v.

[*Answer = 2.0 hr*]

4. A mobile home has a volume of 100 m^3 and a ventilation rate of 0.28 ach. If the concentration of formaldehyde in the home has reached a steady state concentration of 11 ppm_v, what is the rate of emission of formaldehyde from the materials in the home in mg per hour?

[*Answer = 38 mg* h^{-1}]