BRITISH GAS

CENTRAL INDEX OF TRANSLATIONS

Translation No. T5093/BG/WH626/79

BERAKHA, R Ya

Method for calculating air exchange in domestic rooms.
Gig Sanit (2) 61-64 (1979)

20 DEC 1979

LIBRARY
59 Bryanston Street
LONDON W1A 2AZ

Tel: 01 723 7030/Ext.2640

Gig. sanit., 1979, (2), 61-64

R.Ya.Berakha (Institute of Hygiene and Industrial Diseases, Miditsin Academy, Sofia, Bulgaria)

METHOD FOR CALCULATING AIR EXCHANGE IN DOMESTIC ROOMS.

In health studies, it has been accepted that the frequency of air exchange S in domestic rooms should be determined from the concentration of carbon dioxide (CO_2). For calculating S, A.A.Minkh, A.N.Marzeev, Seidel (cited by R.Mechkuev) and others have proposed different expressions, which when used without substantiation may lead to different (and sometimes to conflicting) health interpretation of the same experimental data.

The purpose of the present work is to give a general derivation of the value S, and on the basis of this to clarify the applicability of the formulae proposed by the above-mentioned authors for calculation of air exchange frequency S.

We will consider a room with volume V (in cubic metres) and a CO_2 concentration at the start of the experiment K_1, K_b being the CO_2 concentration in air entering the room from outside (K_b normally in the range 0.03-0.04%), and C the quantity of CO_2 produced in 1 h by people in the room. The quantity of air entering the room over 1 h will be SV. Let n be the average number of exhalations of the people in the room over 1 h. After a time $\frac{1}{n}$ (after the first exchange) the average quantity of CO_2 in the room will increase by the value $\frac{C}{n}$. After the same time, the air entering the room (volume $\frac{SV}{n}$) will contain $\frac{SV}{n}K_b$ carbon dioxide, and the air leaving the room $\frac{SV}{n}K_1$. Thus, the average CO_2 concentration in the room after the first exchange (after time $\frac{1}{n}$) will be:

$$K_{1.1} = \frac{(V-\frac{SV}{n})K_1 + \frac{C}{n} + \frac{SV}{n}K_b}{V} = (1-\frac{S}{n})K_1 + \frac{1}{V}\frac{C}{n} + \frac{S}{n}K_b.$$

For an average concentration $K_{1.2}$ of CO_2 in the room after a second exchange (after time $\frac{2}{n}$) we similarly have:

$$K_{1.2} = (1-\frac{S}{n})K_{1.1} + \frac{1}{V}\frac{C}{n} + \frac{S}{n}K_b = (1-\frac{S}{n})^2 K_1 + \frac{1}{V}\frac{C}{n}(1+(1-\frac{S}{n})) + \frac{S}{n}K_b(1+(1-\frac{S}{n}))$$

and so on. At the end of the first hour for a CO_2 concentration in the room $K_{1.n}$ we obtain

$$K_{1.n} = (1-\frac{S}{n})K_{1.n-1} + \frac{1}{V}\frac{C}{n} + \frac{S}{n}K_b = (1-\frac{S}{n})^n K_1 + (\frac{C}{V} + K_b)(1-(1-\frac{S}{n})^n).$$

From physiological data, n is greater than 300. This makes it possible to simplify the upper expression and to obtain the following formula for calculating average CO_2 concentration in the room K_2 after t hours from the start of the experiment:

$$K_2 = K_1 e^{-St} + (\frac{1}{S}\frac{C}{V} + K_b)(1-e^{-St}). \quad (1)$$

In expression (1), K_1, K_2, K_b, C and t are known from the experimental data, and the single unknown value is the air-exchange frequency S.

Equation (1) obtained by us agrees with the solution of the Lenz differential equation (cited by A.N.Marzeev), which was obtained on the basis of the assumption that liberation of CO_2 by a source in the room was continuous. Thus, expression (1) should be utilised for calculation of air-exchange frequency S whatever the type of source.

If the experiment continues for 1 h, then

$$K_2 = K_1 e^{-S} + (\frac{1}{S}\frac{C}{V} + K_b)(1-e^{-S}). \quad (2)$$

Figure 1 gives nomograms for graphic determination of air-exchange frequency S from equation (2) in relation to the values K_2 and $\frac{C}{V}$ for a CO_2 concentration in outside air of $K_b = 0.035\%$ and an initial concentration of CO_2 in the room of K_1 equal to 0.035, 0.045, 0.055 and 0.065%. For example, if $K_1 = 0.035\%$, $\frac{C}{V} = 0.10\%$ and $K_2 = 0.078\%$, we find from the first nomogram that S = 2. If the initial concentration in the room K_1 does not coincide with the data given in Fig. 1, the air-exchange frequency S may again be found from the nomograms in Fig. 1 by linear interpolation. For example, let $K_1 = 0.042\%$, $\frac{C}{V} = 0.07\%$ and $K_2 = 0.09\%$. From the first nomogram ($K_1 = 0.035\%$) we find that $S_1 = 0.5$, and from the second nomogram ($K_1 = 0.045\%$) that $S_2 = 0.7$. Then

$$S = S_1 + (S_2-S_1)\frac{0.042-0.035}{0.045-0.035} = 0.5 + 0.2\text{x}0.7 = 0.64.$$

From formulae (1) and (2) it is possible to obtain expressions for calculation of S which can be used in health practice and to indicate their applicability. If $St \gg 1$, from equation (1) we obtain the formula proposed by A.A.Minkh and A.N.Marzeev $S = \frac{C/V}{K_2-K_b}$, which is thus its asymptotic solution.

Fig. 1. Nomograms for graphic determination of air-exchange frequency S.

Fig. 2. Example of change in carbon dioxide concentration (K_2) in relation to time spent by people in the room (t) for an initial CO_2 concentration in the room K_1=0.045% and air-exchange frequencies S = 0.5, 1, 2 and 3.

Figure 2 illustrates change in concentration K_2 in dependence on time t at $K_b = 0.035\%$, $K_1 = 0.045\%$ and $C/V = 0.08\%$. As an example, we will consider the curve S = 0.5. After the first hour (at t = 1) the average CO_2 concentration in the room $K_{2.1} = 0.1046\%$, after the second hour $K_{2.2} = 0.1398\%$, $K_{2.3} = 0.1615\%$, $K_{2.4} = 0.175\%$, $K_{2.5} = 0.183\%$, and so on. The steady-state value of CO_2 concentratio in the room will be $K_2 = 0.195\%$. If we now calculate the air-exchang frequency S from the Minkh formula, we find that after the first hour

$$S_1 = \frac{0.08}{0.1046-0.035} = 1.15,$$

after the second $S_2 = 0.76$; $S_3 = 0.63$; $S_4 = 0.57$, and $S_5 = 0.54$. In fact, the air-exchange frequency is unchanged and is equal to 0.5. Thus, when using the Minkh formula for calculating air-exchange frequency S, air should be sampled at equal time intervals until the calculated values of S differ only insignificantly, or the applicability of the Minkh formula should be checked by the criterion $St > 2.5$. In fact, the said method of air sampling corresponds to the solution of equations (1) and (2) by the method of successive approximations. This method is a general method of solving equations (1) or (2). Clearly, when using equation (1) or (2) for calculating air-exchange frequency S such a sampling procedure is not required. It may be carried out only for the sake of checking the constancy of the parameter S when carrying out an experiment.

If there are no CO_2 sources in the room (for example, people are in the room before the experiment and leave the room at the start), from expression (1) at C = 0 we obtain

$$S = \frac{1}{t}\ln\frac{K_1-K_b}{K_2-K_b}$$

or at t = 1

$$S = \ln\frac{K_1-K_b}{K_2-K_b} (K_1 > K_2).$$

The expression obtained coincides with the formula proposed by Seidel for calculation of air-exchange frequency S.

Thus, the results obtained permit the substantiated use of formulae known in the literature for calculation of air-exchange frequency in rooms, using CO_2 concentration as an indicator. However, expression (1) is also suitable for those cases when any other chemical substance serves as the indicator.

BIBLIOGRAPHY

Marzeev A.N. Kommunal'naya gigiena (Public health). Moscow, 1951.

Minkh A.A. Metody gigienicheskikh issledovanij (Health investigation methods). Moscow, 1967.

Received 20.VII.1978