THE FUNCTIONAL DEPENDENCE OF THE TOTAL HAZARD FROM AN AIR POLLUTION INCIDENCE ON THE ENVIRONMENTAL PARAMETERS

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A general case of release to the atmosphere of a pollutant is considered. Various chemical and radioactive hazards may result from inhalation of the pollutant, deposition, resuspension, ingestion and external and internal radiation, if the pollutant is radioactive. According to the ICRP-26 recommendations, the total risk summed over all pathways and tissues should not exceed a certain limit.

The total dose received (D_t) is a monotonous function of the source strength. However, in general, it does not vary monotonously with some of the physical processes involved. For instance, an increase in the deposition velocity results in larger deposition along the cloud's trajectory, which reduces the amount of activity reaching downwind distance X and thereby the cloud and direct inhalation dose. On the other hand, though less activity reaches X, more activity is deposited there (for higher V_d), increasing the doses from external radiation from deposited material, from inhalation of resuspension and from ingestion. Similarly, it will be shown that, taking into account previous deposition, D_t at X does not always increase with decreasing wind speed or with decreasing source height.

In the process of hazards evaluation one usually tends to estimate the processes involved conservatively so as to maximize the computed doses. The worst cases (which give maximum D_t) are not always easily identified (1). The present work helps to identify them. In addition a model of the total dose is presented and its variations are studied as a function of wind speed-$\bar{u}$, deposition velocity-V_d and source height-h. The value of each parameter giving the highest total dose as a function of the model's parameters is determined.

MODEL

This preliminary study is based on the simplest and widely used assumptions of an instantaneous, elevated point source; deposition is considered using the Chamberlain model through Van Der Hoven's curves (2). The external dose is calculated with the semi-infinite homogeneous approximation.

THE TOTAL DOSE EQUATION

$$D_t = \left(\frac{c\bar{u}}{Q}\right)\frac{Q_o}{\bar{u}}\left(\frac{Q_x}{Q_o}\right)\left(F_c + F_s^D V_d + B_r S_B^D\left(1 + \frac{F_r}{\lambda} V_d\right)\right)$$

$\left(\frac{c\bar{u}}{Q}\right)$ - normalized concentration at distance X.

Q_o - source strength.

$$\left(\frac{Q_x}{Q_o}\right) = \exp\left(-\sqrt{\frac{2}{\pi}}\,\frac{V_d}{\bar{u}}\int_o^x \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z}\,d\zeta\right)$$

σ_z-cloud's vertical standard deviation. $F_c \equiv 0.25$ E, E-γ energy, $F_S^D \equiv \frac{F_S}{\lambda} + \sum \omega_i F_I^i$, F_S-ratio of the γ dose from deposition to the surface contamination. λ-decay constant, ω_i-ICRP-26's weights, F_I^i-ratio of the dose from ingestion + drinking to the surface contamination, B_r-breathing rate, $S_B^D \equiv \sum \omega_i S_B^i$, S_B^i = specific inhalation dose for to organ i, F_r-resuspension factor.

METHOD

The dose equation was derived twice with respect to $\bar{u}$, V_d and h. Extremum and inflection points are identified, which enables to study the behavior of D_t.

RESULTS

A. Variation of D_T as a function of V_d:
Fig. 1 gives the results for $X < X_o$

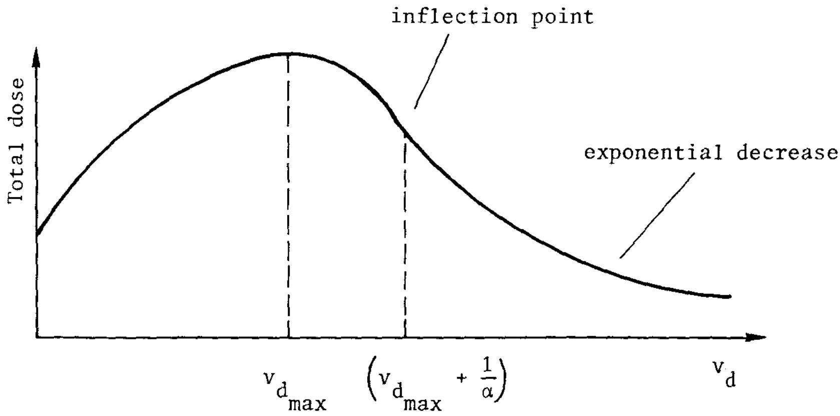

Fig. 1. Schematic representation of the variation of the total dose as function of the deposition velocity.

$$V_{d_{max}} = \frac{1}{\alpha} - \frac{1}{\alpha_o} \ , \quad \alpha \equiv \sqrt{\frac{2}{\pi}}\ \frac{1}{\bar{u}} \int_o^x \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z}\, d\zeta$$

$$\alpha_o \equiv \frac{B_r S_B^D \frac{F_r}{\lambda} + F_S^D}{F_c + B_r S_B^D} = \alpha \Big|_{X=X_o} .$$

For $X > X_o$ D_t decreases monotonously with increasing V_d.
Example: X = 9 km, stability D, $\bar{u}$ = 5 m/s, h = 10 m $\rightarrow \alpha = 24$ (from the Van Der Hoven curves). A very simple case: No γ energy $\rightarrow$ $F_c = F_S = 0$, no ingestion or drinking dose, only inhalation dose - $F_I^i = 0$. Taking $F_r = 10^{-4} m^{-1}$, $T_{1/2}$ - one week$\rightarrow \alpha_o = 87 \rightarrow V_{d_{max}}$ =3cm/s.

B. Variation of D_t with wind speed: Defining

$$\gamma \equiv \left(\frac{2}{\pi}\right)^{\frac{1}{2}} V_d \int_0^x \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z} d\zeta \quad , \quad \text{we receive Fig. 2:}$$

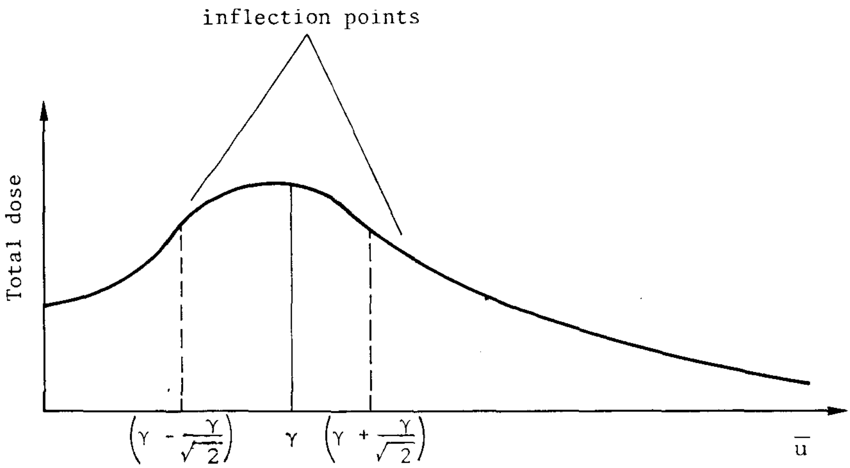

Fig. 2. Schematic representation of the variation of the total dose as a function of wind speed.

Example: The conditions are the same as above - D_t is maximal for $\bar{u} = \gamma = 3.6$ m/s, for $V_d = 0.03$ m/s.

C. Variation of D_t with h: A single maximum D_t exists when:

$$\frac{1}{\delta\sigma_z(X)} = \int_0^x \frac{\exp(-h^2/2\sigma_z^2)}{\sigma_z^3} d\zeta \qquad [1] \qquad ; \qquad \delta \equiv \sqrt{\frac{2}{\pi}} \frac{V_d}{\bar{u}} \ .$$

The numerical solution for stability D is given in graphical form in Fig. 3.

Example: same as above, for $V_d = 0.03$ m/s, $\bar{u} = 3.6$ m/s $h_{max} \approx 80$ m.

CONCLUSIONS

A. D_t does not vary monotonously as a function of V_d or $\bar{u}$ or h. A maximum total dose exists for certain values of these variables, which is a function of the stability, X, the other parameters of the model and the properties of the pollutant.

B. The worst cases (and corresponding $D_{t_{max}}$) can be determined and used in hazards evaluation.

C. Maximum D_t cannot exist simultaneously as a function of both $\bar{u}$ and V_d.

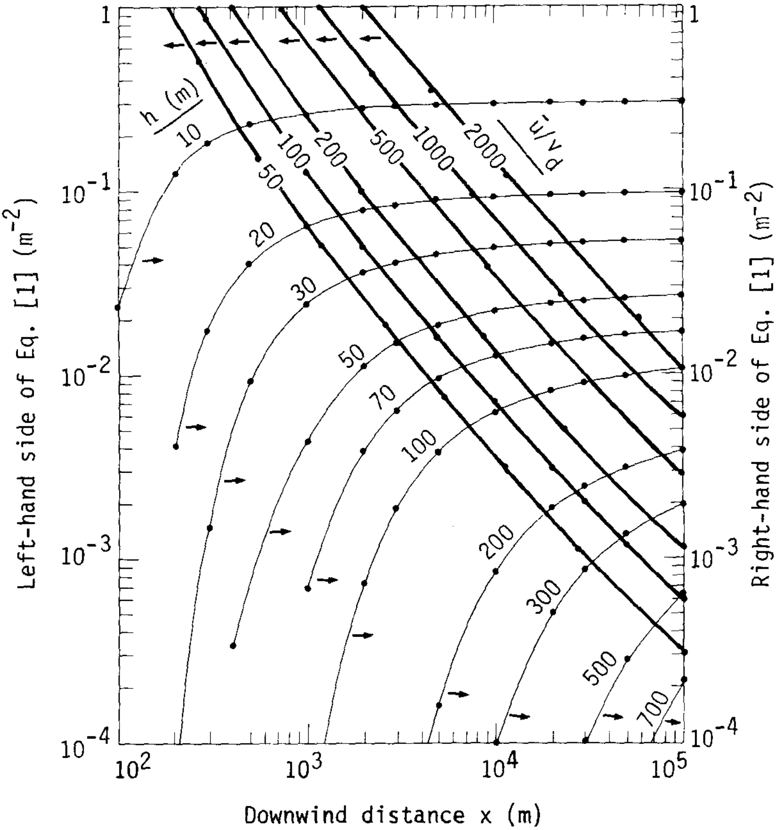

Fig. 3. Graphical solution of the equation for the height, which indicate the maximum D_t. The two sets of curves give the left and right hand sides of the equation for different $\bar{u}/V_d$ and h (respectively), as a function of X, for stability D.

D. In this preliminary study the simplest, widely used analytical model was used. Refinements may be incorporated when more information is obtained concerning the detailed analytical form of the dose equation.

REFERENCES

1. Skibin, D. (1972): J. Nucl. Sci. Technol. 9 (5), 58.
2. Van Der Hoven, I (1968): Ch. 5.3 in: Meteorology and atomic energy 1968, TID-24190.