I Congresso Geral
de Energia Nuclear

Rio de Janeiro, 17 a 20 de Março de 1986

ANAIS - PROCEEDINGS

# STUDY OF PREDICTION OF MIGRATION OF RADIOCESIUM AND RADIOSTRONTIUM IN SOIL FOR ENVIRONMENTAL CONTROL AROUND SHALLOW RADIOACTIVE WASTE DISPOSAL SITE*

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## Abstract

Distribution coefficients, migration velocity and dispersion coefficients for radiocesium and radiostrontium in soil were determined in laboratory while simulating some field conditions.

It is to highlight that if the time scale of breakthrough curve of a non-sorbing water tracer is multiplied by the time transformation factor of a waste radionuclide, then the resulting curve would be the predicted breakthough curve of the waste radionuclide. The experimental and predicted data of breakthrough of Cs-134 and Sr-(85+89) while using I-131 + 0.01 N KI to describe the hydrodynamic dispersion were in good agreement. Data of variation of dispersion coefficient with various carrier concentration of Cs and Sr are presented.

Similar studies in laboratory and in field for any shallow radioactive waste disposal site are recommended for an effective environmental control.

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* This work forms part of the Ph.D. thesis "Studies on Exchange and Movement of Isotopes in Soil and Water Media" of the author, (1973). University of Bombay, India.

## THEORY

The velocity Vi of an absorbing type radionuclide without considering dispersion relative to velocity of ground water Vw is given by

$$Vi/Vw = 1/( 1 + \rho/n.Kd) \text{ or } ti = t ( 1 + \rho/n.Kd )$$

were $\rho$ is the bulk density, n the pososity, Kd the distribution coefficient, ti and t the travel times of the radionuclide and water respectively. Travel time of a radionuclide is a constant times the travel/arrival time of the ground water. Thus the relative velocity factor RF can be defined as

$RF = Vi/Vw = 1/(1 + \rho/n.Kd)$ which is commonly used in chromatography. The general equation describing the movement of an absorbing type radionuclide considering dispersion theory(1) is given by

$$\delta c/\delta t = -(1-n)/n.\rho\delta q/\delta t + \delta/\delta xi\ (Dxi\delta c/\delta xi) - \delta/\delta xi\ (Vxi\ c) \qquad (1)$$

conc. in liquid phase = sorptive term + diffusive term + convective term

In other general equations, terms of fluid compression, radionuclide decay have also been included. Considering one dimensional case the transport equation reduces to $Kf\ \delta c/\delta t = D\ \delta^2 c/\delta x^2 - v\ \delta c/\delta x$ (2)

The solution of this equation with initial and boundary conditions

$c(x,0) = 0,\ x > 0;\ c(o,t) = co,\ t > 0,\ c(c\infty,t) = 0,\ t>0$ is

$$c/co = 1/2 \text{ erfc } ( 1 - \tau)/\ \tau/P \qquad (3)$$

where $P = V.x/4D$ and $\tau = V.t/Kf.x$ are dimensionless and $1/4P < 0.1$.

By defining $Kd = q/c$ and time transformation(2),

$$t = (1 + (1-n)/n\ .\ p\ q/c)\ T = (1 + (1-n)/n.\rho\ Kd)\ T = Kf.T$$

the sorptive term in equation (1) can be eliminated. Thus the transport equation reduces to a purely hydrodynamic expression. $Kf = (1-n)/n.\ \rho Kd$ is defined as time transformation factor. Therefore $dt = Kf\ dt$ and $Kf\ \delta c/\delta t = \delta c/\delta T$ . When assessment of environmental control i.e. migration of radionuclides at a waste disposal site is made, it is obvious that idea of movement of ground water determines the order of magnitude of the velocity of migration of the radionuclide. The hold up capacity of the medium (soil) for the radionuclides expressed numerically by Kd, is the second most important parameter to be evaluated and finally the evaluation of dispersion characteristies of the medium represented by the dispersion coefficient completes the geohydrological study of the site. Estimation and use of an average value of Kd and dispersion coefficient D, of a radionuclide which would best approximate field conditions, remains the ultimate aim of any practical study.

## EXPERIMENTAL PROCEDURE & RESULTS

In this work ionic tracer iodine $^{131}I$ with 0.01N carrier as KI has been used instead of $^{3}$H to describe the hydrodynamic dispersion. If the time scale of the breakthrough curve of $^{131}$I is multiplied by the time transformation factor of radiocesium and radiostrontium respectively then the resulting curves would be predicted curves for $^{134}$Cs and $^{85+8^{\circ}}$Sr. This approach for predicting movement of these radionuclides has been tested experimentally is this work.

The activity level of the radioactive solutions used was about $10^{-3}$ μCi/mℓ and carrier concentrations of cesium and strontrium were varied from 0.01 to 0.04/0.05 N.

Estimation of $^{134}$Cs, $^{85+89}$Sr and $^{131}$I in solutions was carried out by NaI(Tℓ) well detector at the appropriate settings of the spectrometer.

In batch experiments, Kd was determined using 5g of soil (-16+25) mesh B.S.S., 50 mℓ of solutions. Column experiments were carried out using 50g of soil in 2.2.cm ∅ and 10 cm heigh bed at constant volumetric rate of 4.5mℓ/min amounting to a linear velocity of 1.95 x $10^{-2}$cm/s. The s- shaped breakthrough curves were converted to straightlines using logarithmic probability graph .

The data of Kd, relative migration velocity, dispersion coefficient of the radionuclides are shown in Table-1. The predicted and experimental breakthrough curves are shown in Fig.1.

Table 1. Absorption,migration and dispersion data of Cs-134 and (Sr-85+89)

| Cs-134 | | | | Sr-(85+89) | | | |
|---|---|---|---|---|---|---|---|
| Carrier conc. N | Kd | Migration Velocity cm/s X$10^{-4}$ | D $cm^2/s$ X$10^{-4}$ | Carrier conc. N | Kd | Migration Velocity cm/s X$10^{-4}$ | D $cm^2/s$ X$10^{-2}$ |
| 0.01 | 63.3 | 1.69 | 4.89 | 0.01 | 27.1 | 3.91 | 1.22 |
| 0.03 | 24.1 | 4.38 | 9.77 | 0.03 | 7.5 | 13.4 | 1.22 |
| 0.05 | 11.4 | 9.06 | 24.4 | 0.04 | 5.7 | 17.3 | 1.22 |

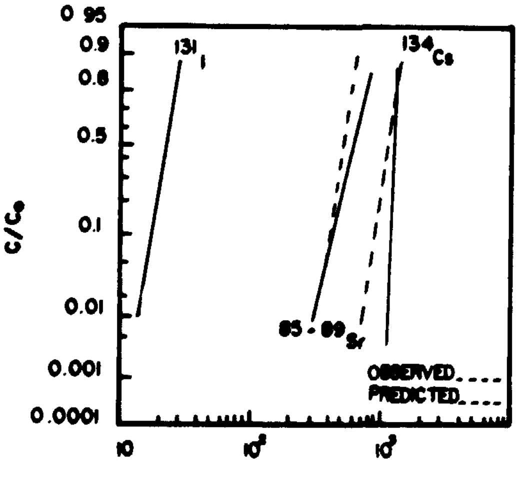

Fig. 1. Breakthrough of $^{134}$Cs, $^{85+89}$Sr.

For computation of dispersion coefficient series of theoretical breakthrough curves were obtained for c/co vs.τ from the equation(3) for different set of values of P. Calculation of c/co for various values of τ & P were done by computer using available error function subroutine of a BSEM-6 facility. The experimental curves were matched with the theoretical ones and the appropriate value of $P=Vx/4D$ was found, which consequently yielded the value of D. The data of variation of D with carrier concentration of Cs and Sr, not published in literature so far, are also shown in Table-1.

## CONCLUSIONS AND DISCUSSIONS

The important discussions/conclusions of the study are as following: 1) Migration velocity of $^{85+89}$Sr is about two times that of $^{134}$Cs(while neglecting dispersion) and the migration rates increase almost linearly with carrier(salt concentration) concentrations; 2) Sr suffers more dispersion than Cs ( see slopes in Fig.1 and values of D Table 1); 3) The extent of dispersion of tracer besides many factors would depend on its interaction with soil and water and this interaction would depend upon its state-whether molecular($^{3}H_2O$) or ionic (anionic $^{131}$I), upon its size and charge. The hydrated size of iodine is of the same order of magnitude as that of hydrated $Cs^+$, whereas,size of $H_3O^+$ is not comparable to that of $Cs^+$. Therefore the interaction of $H_3O^+$ and $I^-$ with soil water media are going to be different; 4) The low Kd of $^{131}$I (0.08) shows that it moves almost with the velocity of water. It can be used to describe the hydrodynamic dispersion and also to predict breakthrough of $^{134}$Cs and $^{85+89}$Sr. Further, the experimental and predicted data are in good agreement; 5) Incontrast to Cs, the dispersion coefficient of Sr remains constant in the range of carrier concentration studied, which needs further work to explain

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## ACKNOWLEDGEMENTS

Thanks are due to Mr.J.S.Bist and Mr. V.Ramchandran of Bhabha Atomic Research Centre,India for computational help and useful critical discussions.