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A Model Of Analytical Theory For Indoor Radon Contemination In Sokoto Metropolis

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***Abstract*— The occurrence of radon in the indoor environment is attracting a growing concern due to its potency on inhabitant's health. To avert the reality of such radioactive gas, studies need to be spearheaded in this direction to understand the factors affecting the concentration in residential and occupational structures. In this paper we analyze the theoretical model using diffusion equation to account for both accumulations of radon as well as the possible dispersion due to mixing in of ambient air employing the experimental result. The paper finally modelled the spacial as well as the coordinate parameter of the contaminant relative to the human spacial fit to serve as the implication of the model.**

Keywords*— *Indoor-radon, Health, Theoretical-model and Diffusion.

I. Introduction

The health as well as the environmental impact of radon has been unveiled extensively since the last 16^{th} century's research on lung cancer related mortality. Radon has been implicated through a number of reports by different research work within residential and occupational indoor air as the major cause of lung cancer and other related ailments. Inhabitants exposure to radon gas have been identified to be building materials and soil as its occurrence is indoor as well as outdoor. But the undersized nature of indoor atmosphere is significantly responsible for indoor elevation than outdoor due to accumulation. This paper is therefore important to model the analytical indoor concentration using diffusivity approach adopting the the Eulerian diffusion equation.

A. Literature Review

Radon and its short-lived progenies (^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po) are well known radioactive indoor pollutants identified as the major radiation burden component [1] and [2]. In the studies reports by [3]; [4] it was revealed that the soil and building materials are the main source of indoor radon. But the point is that their indoor distribution depends on particle sources, ventilation and other parameters [4][5][6][7][8] [10] and in combination, it is described by the activity size distribution. This size distribution consists of three lognormal distributions (modes) each one contributing differently to the total [11][5][12][13][14]. The indoor air is considered the principal harbor by which human health as well as radioactive materials that are either released from building materials or other surfaces in most residential and occupational structures is exposed [15]. In the work of Borgoni [16], it was reported that Radon has been established to be a Group 1 and Group A human carcinogen, according to the classification used by the International Agency for Research on Cancer (IARC) and by the US Environmental Protection Agency (EPA), respectively. Similarly, other studies have aimed at investigating the radon-relative increase on incidence rate of cancer types other than lung cancer [17][18][26] and multiple sclerosis [19][25]. This provided information about the level of radon as an indoor contaminants present in the dwellings which have been implicated as a carcinogen to the lungs through ionizing radiations [20].

II. Methodology

A. Diffusion Model

Depending on the atmospheric conditions, exchange of indoor air between various components that make up the concentrations may occur. But the indoor concentrations depends on the contaminant sources, ventilations and other parameters [21][22][27]. This model adopts the Eulerian approach due to the applicability of its diffusion equation that describes the local mean concentrations gives as shown below in equation (1)

$$\overline{C} = \overline{C}(r,t) \quad (1)$$

But taking boundary condition to primarily event point of interest than

$$(r,t) = (x,y,z,t) \quad (2)$$

The conditions outlined radon gas arising from any contaminant point source, departing on time as a function of diffusion tendency, hence it could be represented as

$$\partial_t \overline{c} + \cup\nabla\overline{c} - \nabla^T k \nabla\overline{C} = S \quad (3)$$

When $U = \left(\bar{u}, \bar{v}, \bar{w}\right)^T$ is the vector field the average wind velocity, the diagonal matrix is given as

$$K = diag\left(k_x, k_y, k_z\right) \qquad (4)$$

This contains the eddy diffusivities and S is termed source that must be determined according to the scenario of interest (3) was tacitly related to the turbulent flexes termed $\overline{U^1C^1}$ to the gradient of the mean concentration as derive from eddy diffusivity as(K-theory)

$$\overline{U^1C^1} = -K\nabla\mathrm{E} \qquad (5)$$

The study have found the simplicity of the K-theory as a multination since it attracts wide spread use of this theory as basic for mathematical simulation for air pollution. But the limit is that it only works well dispersed material has a dimension larger than the size of turbulent eddies involved during diffusion [23]. Another beauty of the K-closure is that it is widely used in several atmospheric conditions due to its success in the description of diffusion transport in an Eulerian algorithm, where almost all measurements are easily cast into an Eulerian form, its applicability is in perfect result with experimental data as well as other more complex model, and it is computationally cheap and affordable [22]. The interest assumption of this model is that the associated advection-diffusion equation adequately describes a dispersion of radioactive contaminant. The resulting advection-diffusion equation is then solved by the Laplace transform technique according to [24]. This procedure will lead to a differential ordinary equation that is solved analytically by Laplace transform technique. But generally this model tried to improve further the solution of the diffusivity problem, assuring that eddy diffusivity and the ventilative profile are arbitrary functions on the special variables through the entire structure.

III. RESULTS

A. Model Analysis

From the above equation (3), it is considered in this model to be very valid in the domain of $\left(x, y, z\right)\mathrm{E}\Gamma$ bounded by 0<y<Ly (with Lx and Ly sufficiently large), 0< ≥ < h (here h is the boundary layer height) and subject to the following boundary and initial conditions.

The model here considered a point source located at an edge of the domain instead of specifying the source term as an inhomogenity of the partial differential equation, this is due to the source point $\gamma_s = \left(O, Y_o, H_S\right)$ is found at within the limit of the domain $\gamma_s = \mathrm{E}\int\Gamma$.Since the source term of the location is on the boundary, in the domain this term is zero everywhere. The model for the source for a time dependent contaminant is then given by

$$S = \oint ud\,\Sigma \qquad (6)$$

Here, N_s is the flux across closed surface that includes the source of contaminant and it is proportional to the source strength. The model also implements the solution as a superposition of an infinite number of solutions with instantaneous source represented in an initial condition. The solution for time dependent source of radioactive contamination assumes the following form

$$\bar{e}\left(t, x, z, t\right) = \int_0^t \bar{c}\left(t - t, x, z\right) d\Gamma \qquad (7)$$

With instantaneous initial condition

$$\bar{e}\left(o, x, y, z\right) = \overline{C_o}$$

$$= \frac{\lim}{\oint \Sigma d\Sigma \to 0 \oint w_s d\Sigma = Q\delta\left(x\right)\delta\left(z - H_2\right)} \qquad (8)$$

Here Q is the emission rate, H_s the height of the source, $\delta\left(x\right)$ represents the Cartesians piracy delta functional and Σ is a unit vector

Adopting the steps of Moreira in a related study, [22] and reducing the dimensionality by one and thus cast the problem into a less clumsy form, we then apply the integral transform technique in the y variable, and expand the assumed radon gas concentrations as a contaminant by

$$\bar{C}\left(x, y, z, t\right) = R^T\left(x, z, t\right)Y\left(y\right) \qquad (9)$$

Where $R = \left(R_1, R_2, ...\right)^T$ and $R = \left(R_1, R_2, ...\right)^T$ are vector in the space of orthogonal eigenfunctions, given by $Y_M\left(y\right) = \cos(\lambda my)$ the given eiganvalues

$$\lambda m = m\frac{\Lambda}{Ly} \; for \; m = 0, 1, 2, ...$$

To handle this with less inconvenience, the model uses some shorthand notations,

$\nabla_2 = \left(\partial x, O, \partial y\right)^T$ and $\partial y = \left(o, \partial y, o\right)^T$

So that equation (3) becomes

$$\left(\partial tR^T\right)Y + \bar{u}\left(\nabla_2 R^T Y + R^T \partial y\right) =$$

$$\left(\nabla^T K + \left(K\nabla\right)^T\right)\left(\nabla_2 R^T Y + R^T \partial y\right) \qquad (10)$$

$$\left(\nabla_2^T K + \left(K\nabla_2\right)^T\right)\left(\nabla_2 R^T Y\right) + \left(\partial_k^T k + \left(k\partial_y\right)^T\right)\left(R^T \partial_Y Y\right)$$

Where F is an arbitrary function and Λ stands for the dyadic product operator and making use of orthogonality renders equation (10) A matrix equation. The integral terms one now given as

$$B_O = \int_O^{ly} dy\, Y\left[Y\right] = \int_O^{ly} y^T \Lambda Y dy = Z =$$

$$\int_o^{Ly} dy\, Y\left[\partial y\, Y\right] = \int_o^{ly} \partial y\, Y^T$$

$$\Omega_1 = \int_o^{ly} dy\, Y\left[\left(\nabla_2^T K\right)\left(\nabla_2 R^T Y\right)\right] =$$

$$\int_o^{ly}\left[\left(\nabla_2^T K\right)\left(\nabla_2 R^T Y\right)\right]^T \Lambda Y dy$$

$$\Omega_2 = \int_o^{ly} dy\, Y\left[\left(k\nabla_2\right)^T\left(\nabla_2 R^T Y\right)\right] =$$

$$\int_o^{ly}\left[\left(k\nabla_2\right)^T\left(\nabla_2 R^T Y\right)\right]\Lambda Y dy$$

$$T_1 = \int_o^{Ly} dy\, Y\left[\left(C\partial_y{}^T K\right)\left(\partial_y Y\right)\right] =$$

$$\left[\left(C\partial_y{}^T K\right)\left(\partial_y Y\right)\right]^Y \Lambda Y dy$$

$$T_2 = \int_o^{Ly} dy\, Y\left[\left(K\partial\right)^T\left(\partial_y Y\right)\right] =$$

$$\left[\left(K\partial\right)^T\left(\partial_y Y\right)\right]\Lambda Y dy \qquad (11)$$

(Vihena et al., 2012)

The analytical beauty here is that, $B_o = \frac{Ly}{2} I$, where I is the identity, the element $(Z)_{mn} = \frac{2}{1 - n^2/m^2}\delta_{1,j}\ with\, \delta_{1,j}$ the kroneckar symbol and $j = (m+n)\text{mod}2$ is the nreminder of an integer division (i.e this is one for m+n odd and zero else). But also eddy diffusivity K is a function the integrals Li and T_i on a the specific form. In the study by Moreira [22] it was reported that integral of equation (14) could assume a general functions, but for a confined boundary as we have here due to indoor conditions purpose and for application to a case study we truncate the eigenfunction space and consider M component in R and Y only, this is to continue using the general nomenclature that remains valid. The obtained matrix equation determines new together with initial and boundary condition uniquely the components R; for i= 1,…..M following the procedure introduce earlier [22][29].

B. *Models' Implication*

The model was successful in parameterization of various dispersion terms adopted from Eulerian approach due to the applicability of its diffusion equation that also describes the local mean concentrations in equation (1). In order to illustrate the suitability of the model, we simulated the contaminant dispersion in the average indoor structure boundary. So that we could look at the source of indoor contamination of radon gas, which are to primarily the building raw materials, floor cracks and some openings [20][24][28].

In Ahijjo's work [20], it was shown that the result of an experimental finding could checkmate the occurrence of radon gas in residential and occupational structure. 30 samples were collected by random sampling and analyzed with the aid of NaI (TI) detector at the centre for energy research and training (CERT) zaria. The result consists of sample identity, count rate of radon and the activity concentration in Bq/M^3. To give correlation of the experimental analyzed data with the analyzed model result, it was shows with a simple way the spatial coordinate of the structure with respect to the average human special fit.
In this respect, it is important to point out that the peak corresponds to the strongest mixing and likely the minimum level of contamination at the average human height that occupies the indoor. So, it becomes evident that the model was able to analyze the result of both experimental data and the models implication to the human real world potential contamination.

IV. CONCLUSIONS

Taking into account all the implication of the analyzed model, we conclude that the dispersion in the indoor environment of the emission from radon gas is a function of the net peack area and inversely proportional to the special coordinates. The diffusive tendencies of both the radon gas and gama ray seem to be reducing with increase in the volume of indoor environment. The investigation into indoor accumulation of radioactive conterminants and its effect shows that relatively small structures are more vulnerable to special and geoaccumulation of radon gas. The recommended measured in this respect towards significant reduction in radioactive contamination is the relative and holistic analysis of the safety parameter indoor air and increase in dimensions of living structures and home

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