Indoor radon level has respiratory related influence on the human health. Radon and its decay products are responsible for about half the total population dose from natural sources of ionizing radiation as reported in UNSCEAR. The inhalated radionuclide deposited on the respiratory track gives dose to the deposited area. Two main mechanisms of indoor radon entry are diffusion and advection. Diffusion because of the radon concentration gradient and advection due to the pressure difference existing across the wall-indoor air interfacing. Indoor radon levels affected by the radon exhalation from the building material and existing ventilation rate. Radon is a radioactive indoor pollutant, present in living zone with different dispersion pattern and concentration levels.

Computational Fluid Dynamics based modeling of indoor air flow is a useful technique for indoor pollutant dispersion study. Computational fluid dynamics software is used to develop a model for to study the indoor radon behavior under different living condition. The boundary conditions were applied according to the condition of room whether it is open or closed. Present CFD model includes only radon source term from surface of model room. In the present study the variation of radon levels along the respective profile line at different time intervals has been demonstrated and discussed. There is a scope of further improvement in boundary condition for computational domain for optimization of results. Similar type of problem related to indoor radon study can be studied by using current CFD Model.

STUDY OF THE BEHAVIOR OF INDOOR RADON USING OF COMPUTATIONAL FLUID DYNAMICS (CFD) SOFTWARE

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Radon (Rn$^{222}$), the decay product of radium (Ra$^{226}$), in uranium decay series (U$^{238}$), which is also radioactive in nature and further produce daughter elements (Po$^{218}$, Pb$^{214}$, Bi$^{214}$ and Po$^{214}$). Inhalation of radon progenies cause respiratory related issues. So the measurements of the indoor radon levels are required time to time. Along with the experimental measurements, Computational Fluid Dynamics (CFD) based modeling is an important emerging technology to predict the indoor radon distribution and concentration levels. The verification of the developed model includes grid independency and analysis of conversion behavior. Computational fluid dynamics software MP-Fluidyn is used to develop a model for to study the indoor radon behavior. The boundary conditions were applied according to the condition of room whether it is open or closed. Present CFD model includes only radon source term from surface of model room. In the present paper the variation of radon levels along the respective profile line at different time intervals has been demonstrated and discussed. There is a scope of further improvement in boundary condition for computational domain for optimization of results. Similar type of problem related to indoor radon study can be studied by using current CFD Model.

MATERIAL AND METHODS

The CFD model included the physical phenomena of generation of radon from the room surfaces, dispersion and accumulation in indoor when the room was closed. The case study of an empty room of dimensions (3 m x 3 m x 3 m) was carried out for the spatial and temporal distribution of indoor radon concentration. There were three doors of dimensions (0.9 m x 1.7 m) having under door opening of (0.9 m x 0.02 m). This opening area is only responsible for the air circulation in room. In the present study all the doors are supposed to be kept closed. The room having three doors was selected for the variability of ventilation rate for the further studies. The door opening which is directly in contact with the outer environment was considered as inlet and other two were considered as outlet for the computational simplifications. The air change rate in the rooms corresponds to the volume of that room because the room was empty. Radon exhalation from the room surfaces (walls, floor and ceiling) was the only source term for the indoor radon increment. The details of CFD modeling of the model room is described elsewhere.

The geometry of model room is shown in Fig.-1. The Profiles Lines (PL) is the line along which the variation of radon concentration is plotted. The present study includes the variation of radon levels along the respective profile line at different time intervals. The present study can be utilized to understand the effect of presence of door or opening on the radon dispersion and indoor radon levels.

The CFD model included the physical phenomena of generation of radon from the room surfaces, dispersion and accumulation in indoor when the room was closed. The case study of an empty room of dimensions (3 m x 3 m x 3 m) was carried out for the spatial and temporal distribution of indoor radon concentration. There were three doors of dimensions (0.9 m x 1.7 m) having under door opening of (0.9 m x 0.02 m). This opening area is only responsible for the air circulation in room. In the present study all the doors are supposed to be kept closed. The room having three doors was selected for the variability of ventilation rate for the further studies. The door opening which is directly in contact with the outer environment was considered as inlet and other two were considered as outlet for the computational simplifications. The air change rate in the rooms corresponds to the volume of that room because the room was empty. Radon exhalation from the room surfaces (walls, floor and ceiling) was the only source term for the indoor radon increment. The details of CFD modeling of the model room is described elsewhere.

The geometry of model room is shown in Fig.-1. The Profiles Lines (PL) is the line along which the variation of radon concentration is plotted. There are 6 profile lines having i-d PL-1, PL-2, PL-3, PI-4, PI-5 and PI-6. The starting and
Fig.-1. Geometry of Model Room

Fig.-2. Positions of Profile Lines (PL-1, PL-2, PL-3, PL-4, PL-5, and PL-6) in the Horizontal plane at height 1.22 m

Termination coordinates of profile line are represented as below.

- PL-1: (0.61/0.00/0.61) to (0.61/3.00/0.61)
- PL-2: (0.00/0.61/0.00) to (3.00/0.61/0.61)
- PL-3: (2.44/0.00/0.61) to (2.44/3.00/0.61)
- PL-4: (0.00/2.44/0.61) to (3.00/2.44/0.61)
- PL-5: (0.00/0.00/0.61) to (3.00/3.00/0.61)
- PL-6: (0.00/3.00/0.61) to (3.00/0.00/0.61)
Fig.-3. Variation of Radon Levels Along Profile Line after Different Time Intervals
PL-6 (3.00/0.00/0.61) to (0.00/3.00/0.61) Temporal change of radon concentration along the lines having i-d, PL-1, PL-2, L-3, PL-4, PL-5, PL-6 Spatial Distribution variation with the time in plane at Z=1.22 m at 1 hr, 5 hr, 10 hr, 15 hr, 20 hr and 22 hr, respectively.

RESULTS AND DISCUSSION

Fig.-3 shows the variation of radon levels along the respective profile line after different time intervals. The results were obtained on the bases of simulation results are pointed below:

1. The distribution is not uniform in the room, because of flow field developed by the air entering through the door opening.
2. The radon distribution profile in plane at different time shows that the radon is trying to distribute uniformly as the time passes, will give rise in radon concentration in centre of the room as the steady state reaches, it is observed in experimental measurement.
3. Radon concentration along the PL-1 is lower in front of the door 2 and higher near the wall. In between there is an increase pattern observed.
4. Along PL-2 radon concentration first increases and then decreases up to the door 1.
5. In PL-3 a dip in the radon concentration has been observed at 0.61 meter.
6. In PL-4 it is clearly observable the high radon concentration in the corner opposite to the all doors and then a constant radon profile.
7. From PL-1 to PL-6 has been plotted at different time interval, the gap between the sequential line decreasing showings that the radon concentration is approaches to steady state.
8. When the velocity at door opening increases, it will affect the distribution profile of radon as shown in the following picture.

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