Transient Diffusion Modelling of Methane Plume and Source Localization

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Introduction: Methane detection and quantification is of great importance due to its natural abundance, potential to cause explosion and known greenhouse effect. Leak detection and concentration monitoring at source is highly challenging as CH_4 is odorless and colorless. This can be performed by deploying sensor network over a potentially affected zone. But it requires optimal positioning of the sensor nodes to localize the source and estimate concentration for early warning and forecasting. That needs comprehensive simulation and numerical analysis of the gas diffusion behavior.

Computational Methods: The transient behavior of gas diffusion profile based on Fick's law was simulated using *transport of diluted species interface* tool inside a cubical geometry of sides 0.5 m (shown in figure 1).

$$\frac{\partial c_i}{\partial t} + \nabla.(-D_i \nabla c_i) = R_i$$

$$N_i = -D_i \nabla c_i$$

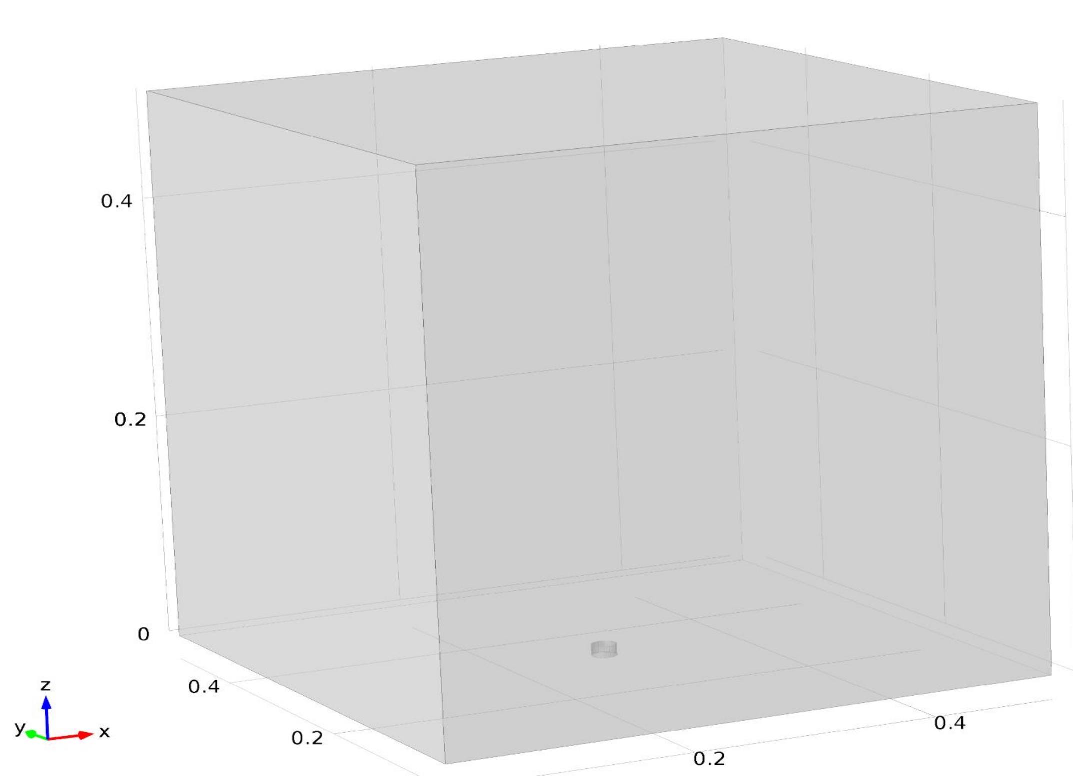

Figure 1. Geometry dimension

Results: The figure 2-3 illustrates the 3-D diffusion profile considering a point source. The profile follows upward hemispherical trajectory with a concentration gradient from the source. Whereas the figure 4 indicates the 2-D diffusion profile which follows Gaussian distribution whose amplitude decreases and variance increases with time.

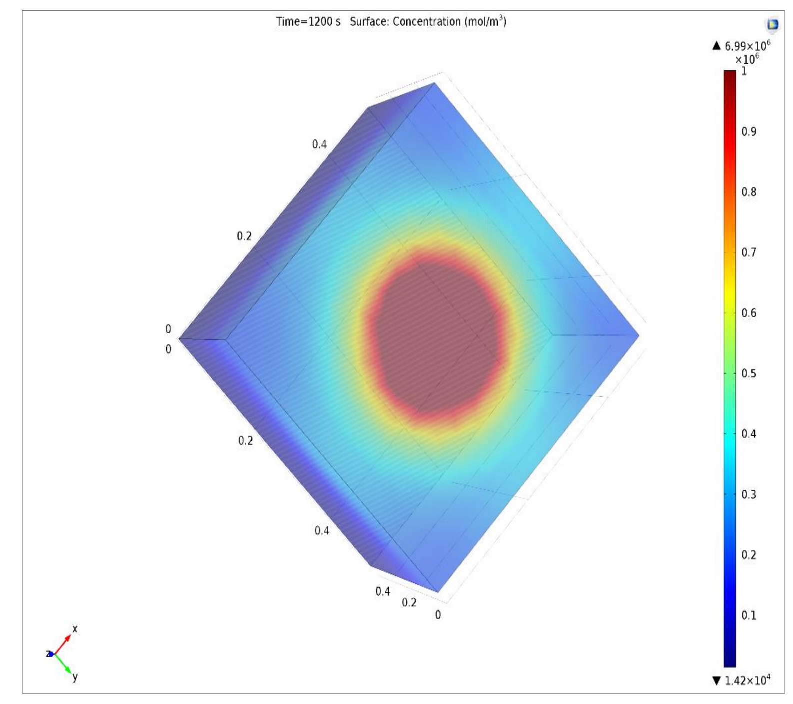

Figure 2. Surface conc. diffusion profile

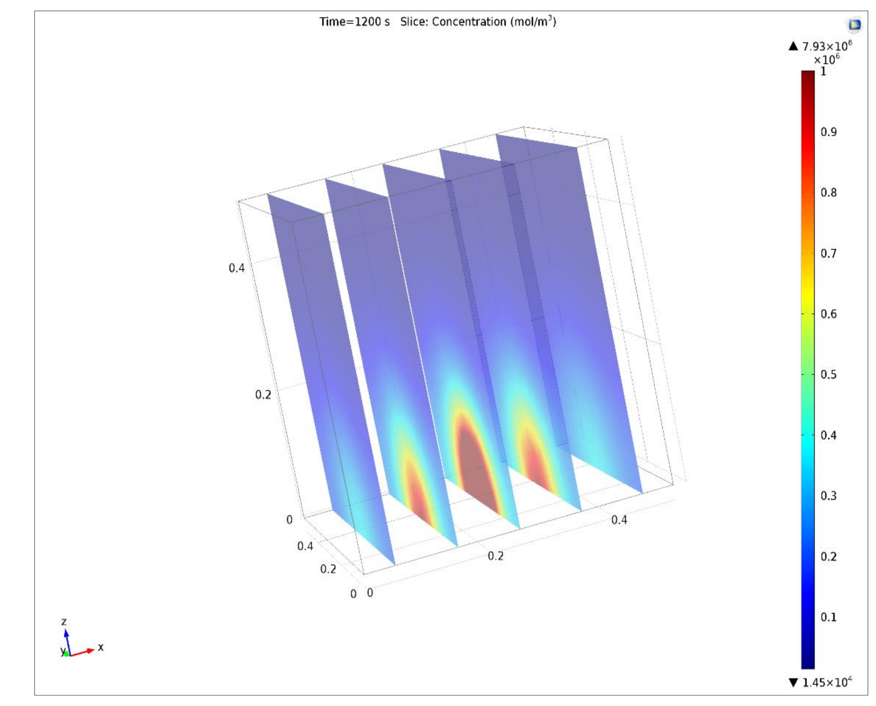

Figure 3. Slice conc. diffusion profile

Variable	Value	Units
Geometry dimension	50	cm
Mass source	20	mol/s
Diffusion Coefficient	0.21	cm2/s
Time	1200	sec

Table 1. Parameters of simulation

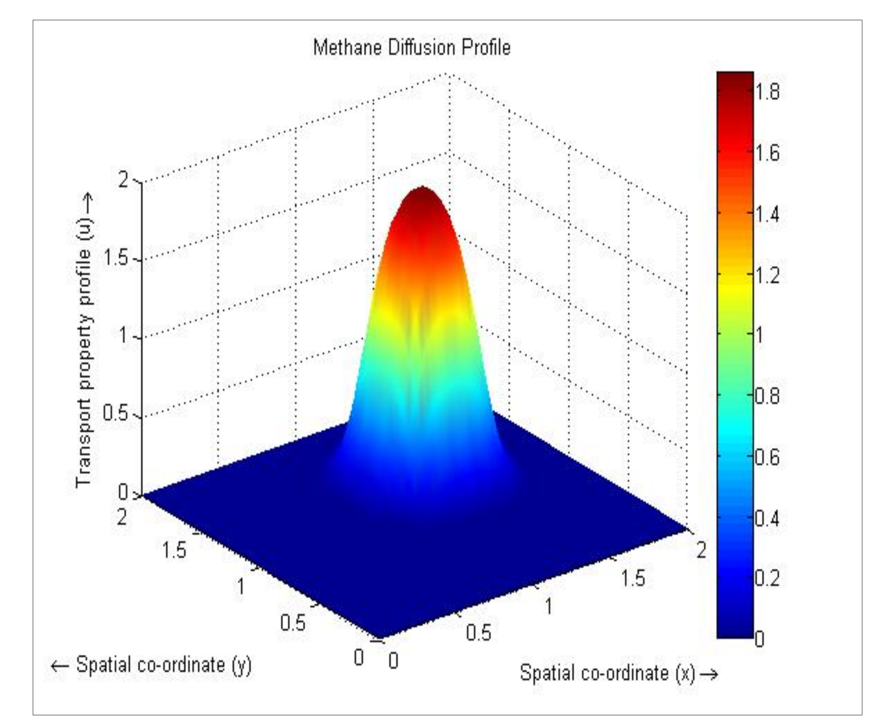

Figure 4. PDF of methane diffusion

Conclusions: Transient concentration diffusion profile of methane in isotropic medium for a point mass source follows hemispherical trajectory. Optimal sensor network positioning can be achieved by Lagrangian particle dispersion modelling in non-isotropic medium under the influence of external force mathematically.

References:

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