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Shelter models for consequence analysis and risk assessment of CO_2 pipelines

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ABSTRACT

Pipelines are acknowledged as one of the most efficient and cost-effective methods for transporting large volumes of various fluids over long distances and therefore the majority of proposed schemes for Carbon Capture and Storage (CCS) involve high pressure pipelines transporting carbon dioxide (CO_2).

In order to be able to design and route pipelines safely, it is a code requirement that a separation distance, or safety zone, is defined between the pipeline and any habitable dwellings along the route. Safety zones are generally defined on the basis of a Quantitative Risk Assessment (QRA). The purpose of a QRA is to assess the risks posed by a pipeline failure to people in the vicinity and to ensure that consistent levels of risk are applied along the pipeline route. The risk levels are normally calculated along a transect drawn perpendicular to the pipeline. These levels are then compared with defined acceptance criteria to determine the safety zone i.e. the distance from the pipeline within which the risk to the public from a pipeline failure is considered to be unacceptable.

The calculation of the risk level requires the determination of both the probability of a failure occurring in the pipeline and the consequences of that failure to the population. For natural gas pipelines, existing and accepted QRA techniques can be implemented to define the consequences of failure based on the thermal hazards. However for CO_2 pipelines, the consequences of failure need to be considered differently, as they relate to a toxic hazard rather than a thermal hazard. Therefore in order to conduct a consequence analysis, what is required is a determination of the concentration of CO_2 to which an individual may be exposed during a release event. This type of data can be generated either using dispersion models. These models will produce a profile of the change in CO_2 concentration with time at various distances from the release, see for example [1, 2], that can then be used in the QRA to determine the toxic dose and therefore the level of harm experienced by an individual. However, none of these approaches consider the effect of shelter on the dose experienced by an individual who is within a building at the time of the release or is outside and enters a building to seek shelter.

The work described in this paper seeks to address this gap and describes the application of two models–an analytical and a Computational Fluid Dynamics (CFD) model–that can be used to determine the effects of shelter on the toxic dose received by an individual during a pipeline release event. The motivation behind this work was:

i) to develop a validated and computationally efficient shelter model, which had been tested against experimental data and CFD models,

ii) to use both CFD and analytical models to demonstrate how shelter should be considered as part of the QRA procedure for a CO_2 pipeline.

A description of the analytical model has been published previously [3]. Therefore, the current paper concentrates on an explanation of the development and application of the CFD model. Using a case study scenario for a single roomed building, engulfed by a transient cloud of CO_2, comparisons are made between the output of the analytical models and the CFD models for the same scenario. A sensitivity analysis indicates the input parameters that most affect the resultant toxic effects within the building.

The paper further demonstrates how both models can be extended to investigate the effects of partial coverage of the building with the cloud of CO_2 and the impact of partitions within the building. Predictions of toxic dose are made for both models and it is demonstrated how these results can be used in a QRA analysis.

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