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A risk assessment methodology for high pressure CO_2 pipelines using integral consequence modelling

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ABSTRACT

This paper presents a risk assessment methodology for high pressure CO_2 pipelines developed at the Health and Safety Laboratory (HSL) as part of the EU FP7 CO2Pipehaz project. Until recently, risk assessment of dense phase and supercritical CO_2 pipelines has been problematic because of the lack of suitable source term and integral consequence models that handle the complex behaviour of CO_2 appropriately. The risk assessment presented uses Phast, a commercially available source term and dispersion model that has been recently updated to handle the effects of solid CO_2. A test case pipeline was input to Phast and dispersion footprints to different levels of harm (dangerous toxic load and probit values) were obtained for a set of pipeline specific scenarios. HSL's risk assessment tool QuickRisk was then used to calculate the individual and societal risk surrounding the pipeline. Knowledge gaps that were encountered such as: harm criteria, failure rates and release scenarios were identified and are discussed.

Keywords: CCS; Carbon dioxide; Pipelines; Phast; Risk assessment; CO2Pipehaz

1. Introduction

Current opinion suggests that carbon capture and storage (CCS) is an important part of the strategy to help reduce CO_2 emissions and prevent global warming. It involves a three-step-process: capture and compression, transport (onshore and possibly offshore) by pressurised pipeline and injection to a geological storage site offshore (DNV, 2008). CCS implies the transportation of large quantities of CO_2, which if released could cause significant harm.

There are a number of projects relating to CCS currently ongoing such as CO2Pipehaz, a project partially funded by the UK's Health and Safety Executive (HSE) and the European Commission (EC). The overall purpose of this project is to address what occurs following an accidental release of CO_2 from high-pressure pipelines, such as:

- Accurate predictions of fluid phase;
- Discharge rate;
- Emergency isolation; and
- Atmospheric dispersion.

The results will feed into emergency response planning and will be used to determine minimum safe distances to populated areas. Part of the project includes the development of multi-phase heterogeneous discharge and dispersion models that are able to accurately model the formation of solid CO_2 which, up until now, has not been investigated in detail.

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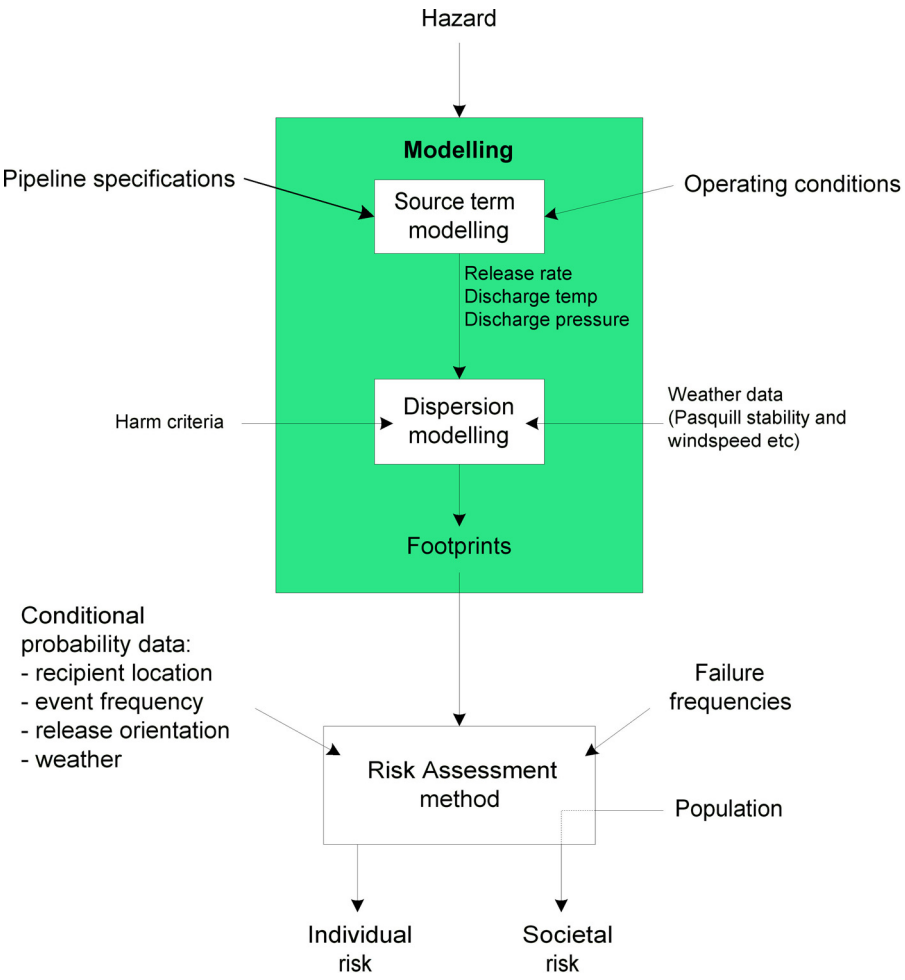

Fig. 1 – CO_2 risk assessment methodology.

Large scale and small-scale experiments are also part of the project and will help validate the dispersion results from the developed model. This paper focuses on the development of a risk assessment methodology using integral consequence modelling, the outline of which is shown in Fig. 1.

The risk assessment method requires the combination of the probability of a hazardous event occurring and the consequence of that event causing a fatality. A typical procedure, which is applicable to substances other than CO_2, comprises the following processes:

- Establish the failure modes and the type of release that results (catastrophic rupture, continuous leak, etc.);
- Establish the source terms (release rate, mass, momentum, energy, phase, etc.);
- Estimate the consequences resulting from the release using appropriate integral dispersion models and harm criteria;
- Choose a failure position within the length of the pipeline being considered and determine suitable weather conditions local to the release site; and
- Carry out the risk assessment for:
  - Individual risk (hypothetical individual) and/or
  - Societal risk (all surrounding population).

Currently there is no official EU position on the methodology for estimating risks for pipelines. Mendes et al. (2011) carried out a comprehensive review of the risk criteria and associated risk assessment methodologies of different countries and concluded that a range of assumptions is in use worldwide. As part of the CO2Pipehaz project Dupuis (2013) examined current risk assessment approaches used for CO_2 pipelines and concluded that the methodologies were developed for dangerous goods other than CO_2. The report also concludes that the specific properties of CO_2 lead to specific risks and that these should be considered in the methodology. The method presented here is applicable for the example CO_2 pipeline used in the CO2Pipehaz project and may not be applicable for other types of CO_2 release such as vessel failure. It is also not applicable for pipeline failures of other substances, unless solid formation is considered likely. However, the assumptions and the derived event tree could be adjusted where appropriate to allow application for other risk assessment purposes.

The purpose of this paper is to present a generic methodology applicable to CO_2 pipelines so that users can apply assumptions specific to their region. This paper does not intend to recommend specific input values for use in CO_2 risk assessments because some countries may have very specific and/or different guidance, and as such, these values should be used in preference. Generic assumptions should not be treated as standard practice without further examination.

2. Carbon dioxide harm criteria

Although CO_2 is not classified as toxic, it still has major accident potential, particularly in relation to CCS (McGillivray and Wilday, 2009). Exposure for several hours to a concentration of 3% CO_2 affects the human respiratory system while the

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