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A risk assessment tool applied to the study of shale gas resources

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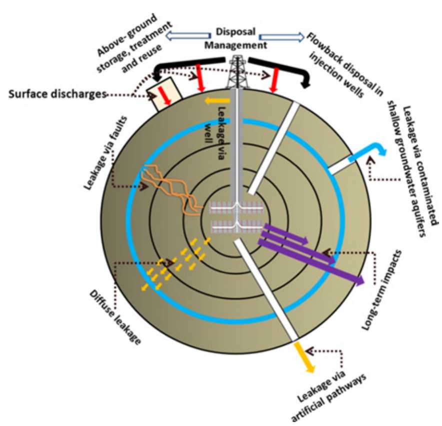
HIGHLIGHTS

- The proposed methodology is a risk assessment useful tool for shale gas projects.
- The tool is addressed to the early stages of decision making processes.
- The risk assessment of a site is made through a qualitative estimation.
- Different weights are assigned to each specific natural and technological property.
- The uncertainty associated to the current knowledge is considered.

GRAPHICAL ABSTRACT



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ABSTRACT

The implementation of a risk assessment tool with the capacity to evaluate the risks for health, safety and the environment (HSE) from extraction of non-conventional fossil fuel resources by the hydraulic fracturing (fracking) technique can be a useful tool to boost development and progress of the technology and winning public trust and acceptance of this. At the early project stages, the lack of data related the selection of non-conventional gas deposits makes it difficult the use of existing approaches to risk assessment of fluids injected into geologic formations. The qualitative risk assessment tool developed in this work is based on the approach that shale gas exploitation risk is dependent on both the geologic site and the technological aspects. It follows from the Oldenburg's 'Screening and Ranking Framework (SRF)' developed to evaluate potential geologic carbon dioxide (CO_2) storage sites. These two global characteristics: (1) characteristics centered on the natural aspects of the site and (2) characteristics centered on the technological aspects of the Project, have been evaluated through user input of Property values, which define Attributes, which define the Characteristics. In order to carry out an individual evaluation of each of the characteristics and the elements of the model, the tool has been implemented in a spreadsheet. The proposed model has been applied to a site with potential for the exploitation of shale gas in Asturias (northwestern Spain) with tree different technological options to test the approach.

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1. Introduction

The most recent technological innovations in hydraulic fracturing (fracking) and horizontal drilling have led to an increase in non-conventional fossil fuels extraction on a commercial scale in different regions of the world, particularly in the USA. Although commercial drilling operations do not exist at present in the member states of the EU there are exploration wells and permits in several European countries as Poland, Romania, UK or Spain (Jaspal and Nerlich, 2014; Johnson and Boersma, 2013; Brown et al., 2014; Cienfuegos and Loredo, 2010). These operations must manage adequately the concerns about public health and environmental effects as the EU Commission advocates for ensure that risks that may arise from these are managed adequately in Member States that wish to explore or exploit such resources. This will require the undertaking of preliminary risk assessments as a precautionary action. These preliminary risk assessments must be carried out by considering a model that incorporates the experience gained in other countries, such as the USA. Furthermore, these studies must define the most critical characteristics that a priori must be taken into consideration to ensure the environmentally safe extraction of fossil fuels from non-conventional resources. In addition, the carrying out a risk assessment in the early stages of a shale gas extraction project could be used to compare risk impact between different technological options available. So, during the decision-making processes, it can balance the environmental risk levels associated with the deployment of a particular concept with other risk variables as costs associated or the framework directives on the regulation of extraction activities.

Implementation of the risk management systems together with the existence of an appropriate legislative framework and independent technical bodies constitute the main safety measures to consider in the development of extraction projects for non-conventional fossil fuel deposits with respect to the environment. A generally accepted procedure to assess extraction procedures would focus on the identification of risks and their evaluation and control. This particular focus is due to the influence that the project has on acceptable environmental development and its relation with safety and public health aspects. The most general potential risks that are associated with the extraction of non-conventional fossil fuel resources are as follows: water use (Broderick et al., 2011; EPA, 2012); additives and waste (toxic and radioactive natural materials); emissions to the atmosphere and surface and groundwater pollution (by leakage due to failure of the drill integrity (EPA, 2012), spillages on the surface or migration through the geological formations) and induced seismicity as a result of hydraulic fracturing operations (Green et al., 2012; The Royal Society and The Royal Academy of Engineering, 2012; Bunger et al., 2013). Other potential effects on the environment as marks on the land, motorized traffic, noise and light contamination cannot be considered in this approximation as they are general aspects of risk assessment of any large engineering projects and there is a wide and proven experience in their management. The significance of each specific risk, which is function of its probability and the consequences, will be mainly dependent of the location and on the technological operations applied.

Furthermore, the variability in the nature of the risk must be taken in consideration. In any industrial project it is possible to establish risks that encompass geopolitical, regulatory, environmental, economic, technological and social types. This paper includes a review of the potential environmental risks and their relation with the technological aspects. From these, a methodology has been designed for the initial assessment of health, safety and environmental risks (HSE) associated with hydraulic fracturing operations for the recovery of non-conventional fossil. Despite several approaches to risk assessment of fluids injected into geologic formations, as the features, events, and processes (FEP) scenario approach (Savage et al., 2004; Wildenborg et al., 2005) or Probabilistic Risk Assessment (PRA) (Rish, 2005), these involve a level of detail beyond what is likely going to be available at the initial stage of a shale gas project. Instead, the developed methodology uses available qualitative information (such as expert knowledge, studies, reports and publications) as approaches for potential probabilities and consequences combined. Many of the properties and the values for the attributes considered in these early phases of the risk assessment involve estimations that can be measured or modeled with some additional effort. Since at the earliest stages of the Project the lack of data will be very common it is therefore important to maintain the uncertainty as an entrance and exit value in the methodology, separate from the scores for the characteristics. Uncertainty in this paper, broadly defined, includes parameter uncertainty and variability. The conceptual model for the approach developed here is based on a model designed to evaluate the HSE risk during the initial selection of candidate locations for geological CO2 storage (Oldenburg, 2008). In the work presented here Oldenburg's model was adapted to the specific requirements of non-conventional fossil fuel resources and hydraulic fracturing technology.

The methodology allows the assessment of different non-conventional fossil fuel deposits and different scenarios in a given location, thus enabling modifications to be made as new data on the site become available. This process allows different options to be compared, which in turn facilitates the decision making process. This approach also represents a powerful communication tool to inform stakeholders through the sharing of knowledge and in particular on assessed risks associated with a shale gas project.

2. Methodology and tools

The HSE impacts of shale gas that are of concern are caused by high concentrations in the near-surface environment of both, natural contaminants (NORM, organic elements, heavy metals and others) that are present in the geological formation and chemicals that are introduced by hydraulic fracturing fluid. The potential pathways for leakage from shale gas formations to the near surface environment can be associated with geological and not geological elements already present in the operations area (e.g., faults, high permeable zones, existing wells) or associated to the operations performed to extract shale gas (e.g., new wells drilling, flowback and production water management, methane management) (Healy, 2012). Even though these two kinds of characteristics are not fully independent, the qualitative methodology developed to estimate the HSE risks evaluates the goodness of both characteristics types separately. This division is of course approximate but allows, in the early stages, maintaining a simplicity of approach, with a focus on a characteristic that is determined by the area where the resources are present and on another one that can be modified by design engineering.

The main characteristics and processes related with the risk associated to the production of non-conventional fossil fuels are shown in Fig. 1. The Table 1 shows the attributes and properties in which the characteristics can be decomposed to enable that their risk performance can be inferred, along with the proxy for the risk element to which it is associated. It should be noted that the undesired negative impacts that could arise due to technological aspects in the project are related to deficiencies in the process rather than to the technology itself (Krupnick, 2013; Krupnick et al., 2013). Additionally, the potential HSE impact due to leakage of fluids from the target geological formation can be attenuated by the potential for secondary trapping of the upper levels of the system, i.e., the leakage pathways do not necessarily lead to the leakage of fluids into the environment. Furthermore, depending on the site characteristics on the surface, there is a potential for dispersion or attenuation in the nearby surroundings that potential pollutants may disperse and mix with water and/or air. This situation is described by the concept of the 'multi barrier system', which is widely applied to guarantee the safety of systems that involve the geologic media as geologic storage of CO_2 or geologic storage of radioactive wastes (Toth, 2011).