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Review of the scientific evidence to support environmental risk assessment of shale gas development in the UK

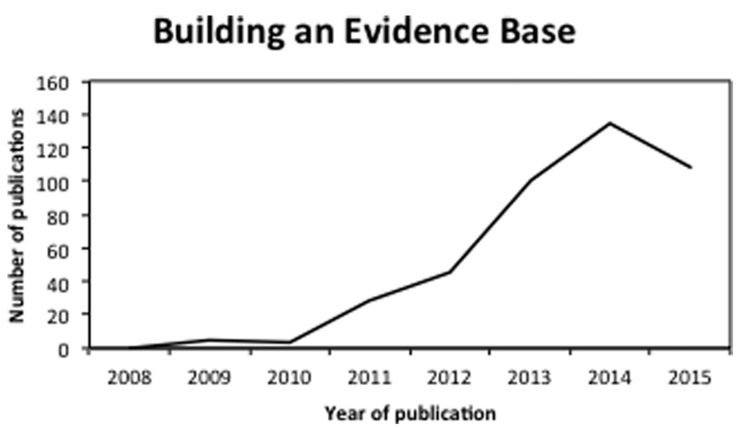
George Prpich *, Frédéric Coulon, Edward J. Anthony

School of Energy, Environment and Agrifood, Cranfield University, College Road, Cranfield MK43 0AL, UK

HIGHLIGHTS

- Shale gas operations involve environmental risks.
- Scientific evidence to support risk assessments about shale gas is amassing.
- We describe how environmental risk assessment is used to gather and organise evidence.
- Evidence generated in the US might not be transferable to other regions.

GRAPHICAL ABSTRACT



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ABSTRACT

Interest in the development of shale gas resources using hydraulic fracturing techniques is increasing worldwide despite concerns about the environmental risks associated with this activity. In the United Kingdom (UK), early attempts to hydraulically fracture a shale gas well resulted in a seismic event that led to the suspension of all hydraulic fracturing operations. In response to this occurrence, UK regulators have requested that future shale gas operations that use hydraulic fracturing should be accompanied by a high-level environmental risk assessment (ERA). Completion of an ERA can demonstrate competency, communicate understanding, and ultimately build trust that environmental risks are being managed properly, however, this assessment requires a scientific evidence base. In this paper we discuss how the ERA became a preferred assessment technique to understand the risks related to shale gas development in the UK, and how it can be used to communicate information between stakeholders. We also provide a review of the evidence base that describes the environmental risks related to shale gas operations, which could be used to support an ERA. Finally, we conclude with an update of the current environmental risks associated with shale gas development in the UK and present recommendations for further research.

1. Introduction

Development of unconventional natural gas reserves is on the rise, driven largely by immense, yet unconfirmed, recoverable reserves and

* Corresponding author at: Cranfield University, College Road, Cranfield MK43 0AL, UK.
E-mail address: g.prpich@cranfield.ac.uk (G. Prpich).

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the 'shale gas' revolution in the US (European Commission, 2014). Shale gas is the most common unconventional natural gas resource and is trapped within fine-grained sedimentary rocks deep within shale formations (e.g. 2000–4000 m) (Wang et al., 2014). This resource cannot be economically recovered using conventional technologies, however, recent advances in drilling technology (horizontal drilling), and the use of hydraulic fracturing (high pressure injection of water and sand into the formation to open up channels for gas to flow) have led to a surge in the development of this resource.

Estimates of technically recoverable reserves of shale gas resources vary among agencies worldwide. For example, US estimates from the EIA's Annual Energy Outlook reports in 2011 and 2013 estimate that the technically recoverable shale gas resources range between 187.5 Tcm and 206.7 Tcm respectively (EIA, 2015a). Similar reports estimate the technically recoverable shale gas resources in the UK at 19.8 Tcm, while the British Geological Survey estimate these same UK resources to range between 23.3 and 64.6 Tcm (Andrews, 2013). Despite the presence of shale gas, most regions have yet to exploit these resources and therefore lack the necessary knowledge to make an informed estimate of the recovery potential. To date, only three countries commercially exploit this resource, Canada 120 MMcm/d, China 4.89 MMcm/d, and the US 960 MMcm/d (EIA, 2015b). Shale gas has transformed the US into the world's largest producer of natural gas, and shale gas constitutes over one third of the US's total natural gas production (Lund et al., 2013; Rivard et al., 2014).

Shale gas development has been a controversial subject that has polarised the debate among industry, scientists, governments, and the public (Theodori et al., 2014). Those opposed argue that the costs to the environment and the public will be too high, while those in favour contend that shale gas is vital for meeting demand and achieving climate change targets (Engelder et al., 2011). Though the shale gas revolution has been linked to a significant reduction in US carbon emissions (Jenner and Lamadrid, 2013), the global impact of shale gas is more uncertain. For example, the carbon footprint of shale gas production compares favourably to onshore natural gas (Weber and Clavin, 2012), but both systems are susceptible to the release of methane. Methane is a more powerful greenhouse gas compared to carbon dioxide and its release could negate the carbon benefits of using natural gas in the first place (Howarth, 2014). Efforts to characterise the source and quantity of methane emitted from shale gas operations is on-going (Karion et al., 2015; Lan et al., 2015; Zavala-Araiza et al., 2015).

Shale gas development has also been linked to a range of environmental concerns (e.g. water, air, health) (Council of Canadian Academies, 2014; Jacquet, 2014; Kravchenko et al., 2014; Rivard et al., 2014; Small et al., 2014; Vengosh et al., 2014). Despite these concerns, there is cause for cautious optimism that shale gas can be extracted with acceptable environmental impacts, particularly if appropriate lessons can be learned from the US experience about regulation and environmental management (European Parliament, 2012).

Compared to the US, progress on shale development in the EU has been slow, which could be attributed to the EU's precautionary approach to new technological developments (Jasanoff, 1990; Majone, 2002). Differences in governance structures between the US and other countries might also contribute to delays in development (Lozano Maya, 2013). Other contributing factors include population density, more stringent environmental regulations, and the need to respond to public concerns (McGowan, 2014). Research has also shown that there is an increased tendency for the public to view energy policy from an environmental perspective (Davis and Fisk, 2014), which can slow the progress of shale gas developments as Governments seek to develop environmental regulation to manage the impact that energy projects will have on the environment. Currently, only the UK, Denmark, the Netherlands, Poland, and Romania have granted, or plan to grant the authorisation of hydraulic fracturing (European Commission, 2014).

Although the EU (as a whole) has assumed a precautionary approach towards shale gas development, the UK has been supportive with Government declaring their interest in the resource. Despite the Government's interest to develop shale gas, drilling and hydraulic fracturing has yet to begin as policy makers, regulators, industry, and the public struggle to understand the risks and benefits associated with this activity. Steps to have been taken to promote shale gas development, the most notable being: establishment of the Office of Unconventional Gas and Oil (OUGO) in 2012, change to the UK petroleum licensing process, and the requirement that operators complete an environmental risk assessment before conducting hydraulic fracturing activities.

In this paper, we review the status of shale gas development in the UK. In particular, we describe the elements of shale gas development that led to the UK's Department of Energy and Climate Change (DECC) requirement that all shale gas operators complete an environmental risk assessment (ERA) in advance of permission to explore for the resource. We discuss how operators and regulators can use an ERA to inform stakeholders about complex and uncertain processes like shale gas development. We also critically review the evidence base pertaining to environmental risks, in particular the primary, peer-reviewed evidence that is often used to support ERA's. Overall, we provide an update of the current environmental risks associated with shale gas development in the UK from the perspective of a structured ERA.

2. The UK experience

Taking a step back, the UK Government ordered a review of shale gas operations in 2011. The inquiry reported that hydraulic fracturing did not pose a significant risk to underground aquifers as long as the drilling wells were constructed properly (Byles et al., 2011). Further to this, induced seismicity was not thought to pose a significant risk in the UK and therefore the inquiry recommended that a moratorium should not be placed on the use of hydraulic fracturing in the exploitation of the UK's hydrocarbon resources.

During the release of this report, Cuadrilla Resources Ltd. hydraulically fractured the UK's first shale gas wells at Preese Hall in April and May 2011. Two seismic events followed this activity, the largest of which had a magnitude of $2.3M_L$. Investigations carried out concluded that the seismicity was linked to the direct injection of fluids into an adjacent fault zone (Green et al., 2012). Given this event, the UK Government suspended all further hydraulic fracturing activities.

The events in Blackpool triggered two responses: first, it raised concerns about the risks associated with hydraulic fracturing and shale gas exploitation; and second, it highlighted the uncertainty (i.e. lack of information) about this activity. As a result, a number of reports were commissioned to understand the risks associated with this activity.

Notably, the Royal Society and Royal Academy of Engineers (RS/RAE) prepared an influential review of the hydraulic fracturing evidence (Mair et al., 2012). Recommendations from the report suggested that there was need for: (1) baseline monitoring of seismicity and groundwater; (2) assurance of the integrity of wells; (3) co-ordinated leadership of shale gas activities; (4) a programme of research; and (5) implementation of improved environmental risk assessment and management. In response, the UK Government, led by the Department of Energy and Climate Change (DECC), accepted all recommendations, in particular the requirement that an Environmental Risk Assessment (ERA) be completed in advance of granting a licence to explore for shale gas resources (DECC, 2012).

During this period of investigation, additional reports were commissioned by the EU (Bloomfield, 2012; Forster and Perks, 2012) and the UK (Healy, 2012; Kibble et al., 2013) to investigate the environmental and public health risks that shale gas and hydraulic fracturing might pose. In general, findings revealed considerable uncertainties due to a lack of baseline data and insufficient evidence to support risk-based assessments, thus necessitating the use of expert judgement.

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