THE IMPACT OF HYDRAULIC FRACTURING ON THE ENVIRONMENT AND HUMAN HEALTH

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Abstract

In this paper we evaluate the greenhouse gas emissions based on a critical analysis of the existing literature and the calculations made by the authors in the USA and Europe. The study examines the European legislation applicable to hydraulic fracturing activities and provides recommendations for further work. It addresses potential gas resources and future availability of shale gas in relation to the current supply of conventional gas and the likely evolution.

Keywords: *hydraulic fracturing, gas resources, pollution, unconventional hydrocarbons, resources*

1. INTRODUCTION

Geological hydrocarbon formations, under certain conditions, are created from organic sediment marine compounds. Conventional oil and gas come from the thermo-chemical fracture of organic matters from sedimentary rocks, the so-called parent rock.

With successive dives under other rocks, these formations were heated by about 300 °C every 1 km of depth; once the temperature of about 600 °C was reached, the organic matter was decomposed into petroleum and then into the gases. The depth, temperature and duration of exposure have determined the degree of decomposition.

The temperature and duration of exposure allowed a more advanced fractionation of complex organic molecules, decomposing to the simplest component methane, consisting of a carbon atom and four hydrogen atoms.

Depending on the geological formation, the resulting liquid or gaseous hydrocarbons broke out of the mother rock and migrated, usually upward, to the porous and permeable layers. In order to engage in an accumulation of hydrocarbons, these layers must themselves be covered by an impermeable rock called "protective" rock.

These hydrocarbon accumulations form conventional oil and gas deposits. Their relatively high oil content, their location a few kilometers from surface and ease of access to the earth allow for easy extraction by drilling wells.

Some hydrocarbon accumulations are found in very porous and permeable reservoir-rocks. These accumulations are called oil or gas from compact formations. Normally, their permeability is 10-100 times less than that of conventional deposits.

Hydrocarbons can also be stored in large quantities in rocks that are not rosier in principle but shale and other very fine-grained rocks, where the storage volume is ensured by thin cracks and very small porous spaces. These rocks have extremely low permeability.

The hydrocarbons present here are called shale gas or shale oils. These do not contain mature hydrocarbons, but only a precursor called kerogen, which chemical plants can turn into synthetic oil.

A third type of unconventional gas is methane from coal deposits, which is isolated in the coal deposit pockets. Depending on the characteristics of the deposits, the gas contains various components in varying proportions, including methane, carbon dioxide, H_2S, radioactive radon etc.

Compared to conventional deposits, all unconventional deposits share low oil and gas in relation to rock volume.

They are also dispersed on a considerable area of tens of thousands of square kilometres and have a very low permeability.

Therefore, special methods are required to extract this type of oil or gas. In addition, given that parent rocks have low hydrocarbon content, the well extraction volume is well below conventional storage, making them less profitable.

Not the gas itself is unconventional, but the extraction methods. These methods require sophisticated technologies, large amounts of water, and injection of additives that can be harmful to the environment.

The distinction between conventional gas and compact gas is not always very clear, especially since the official statistics did not make a precise distinction between these two production methods in the past.

Hydraulic fracturing for the extraction of gas from compact formations normally requires several hundred thousand liters of water (plus supportive agents and other chemicals) of the well for each fracture process, while hydraulic fracturing in shale gas consumes several million liters of well water.

2. EVOLUTION OF UNCONVENTIONAL GAS EXTRACTION

In the United States, given the maturity of conventional gas deposits, companies have increasingly been forced to drill in less productive formations.

In the beginning, oil platforms have expanded to the vicinity of conventional formations, producing somewhat less permeable formations.

Gas wells in compact formations have not been treated separately from conventional statistics due to lack of clear criteria to differentiate them.

Fig 1. Exploitation of shale gas

Since the beginning of the debate on climate change, one of the goals has been to reduce methane emissions.

Even though the theoretical potential of methane in coal deposits is huge, its contribution has nevertheless seen a slow increase in the United States over the past two decades, reaching about 10% in 2010.

Ultimately, potential gas fields with the most problems are exploited. These are shale gas deposits that are almost impermeable, or in any case less permeable than other gasify structures. Their development was triggered by technological advances in the field of horizontal drilling and hydraulic fracturing with the use of chemical additives, on the one hand, but perhaps more importantly, by the exemption from hydrocarbon extraction activities by hydraulic fracturing in Safe Drinking Water Act (SDWA, 1974), provided for in the Energy Policy Act 2005 (EPA, 2005).

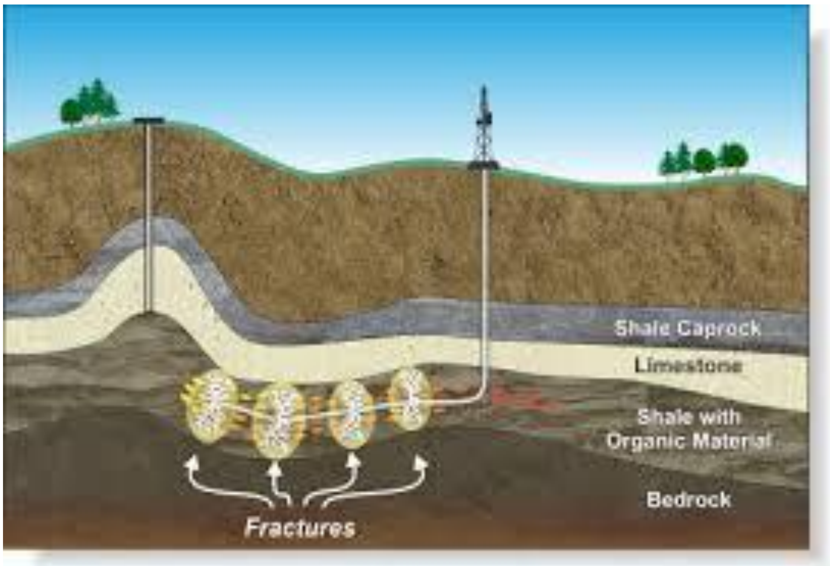

Fig 2. Method of hydraulic fracturing

The first activities began many decades ago, with the development of the Bossier Shale (Louisiana) in the 1970s and the Shale Antrim (Michigan) in the 1990s. Fast access to shale gas fields, however, began around 2005, with the Barnett shale development in Texas. During this period, side effects on the environment have become more and more obvious to citizens and regional policymakers.

Mainly, the development of Shark Marcellus has been the subject of discussion because this deposit covers much of the state of New York. Some believe that its development could have a negative impact on New York City's protected water supply areas.

The US Environmental Protection Agency is conducting a study on the risks associated with hydraulic fracturing, the technology chosen for the development of unconventional gas fields.

In Europe, these developments are a delay of several decades compared to the US. In Germany, gas deposits from compact formations are exploited by hydraulic fracturing for almost 15 years (at Söhlingen), although on a very small scale.

The total volume of European unconventional gas production is in the order of some millions of m^3 per year, compared to several hundred billion m^3 per year in the United States (Kern, 2010).

Most exploration concessions are granted in Poland but similar activities started in Austria (Vienna Basin), France (Basin and South East Basin), Germany and the Netherlands (North Sea Basin - Basin), Sweden (Scandinavian region) and the United Kingdom (Northern and Southern oil systems).

The public's opposition to these projects, based on information from the United States, has intensified rapidly. For example, in France, the National Assembly imposed a moratorium on such drilling activities and prohibited hydraulic fracturing. The French Minister of Industry proposes a different project that would allow hydraulic fracturing exclusively for scientific purposes under the strict control of a committee made up of MPs, representatives of the government, NGOs and local people. This amended law was approved by the Senate in June 2011.

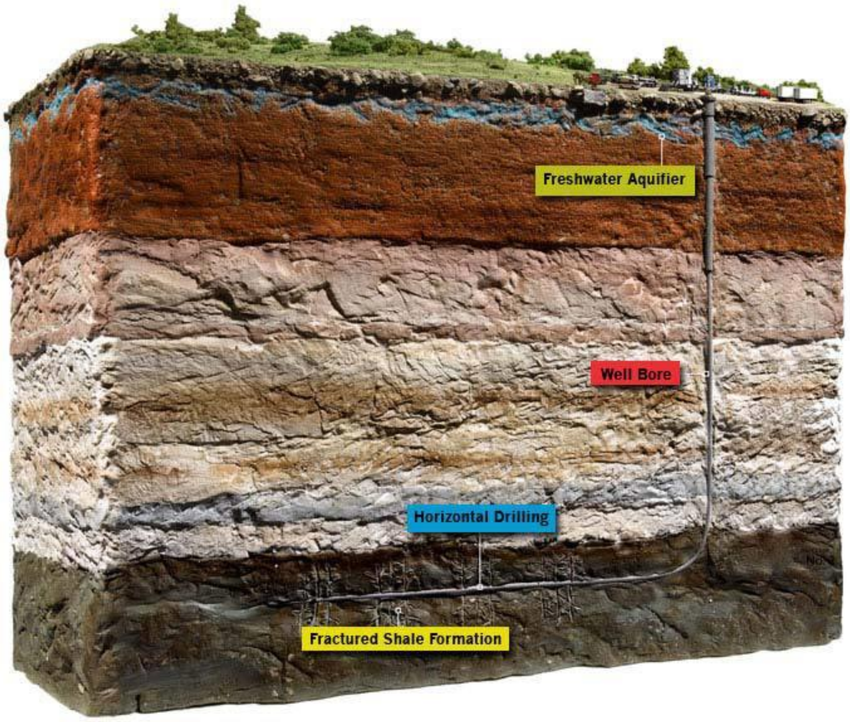

Fig 3. Hydraulic fracturing diagram

In the German Land of North Rhine-Westphalia, residents, local politicians from most parties, and representatives of water management authorities and mineral water companies have voiced concerns about hydraulic fracturing.

A first step was to place water protection on the same level as mining legislation and to ensure that no permit can be issued without the permission of the water authorities.

Also, the most heavily involved company, ExxonMobil, has launched an open dialogue to discuss citizens' concerns and assess the possible impact.

The Scottish government has banned hydraulic fracturing in this country. Until recently, the chemical composition of fracturing fluids has been considered secret and has not been published, but this position has changed due to the growing public insistence. It should be noted that the lists of chemical additives used are very different from one formation to another, as well as the composition of the water used in the injection.

In Romania, the curse of hydraulic fracturing slowly spreads slowly to 70% of the territory due to complicity between companies and politicians. We know the perimeters for which there are signed agreements for the exploration and exploitation of shale gas by using hydraulic fracturing.

They represent almost 20% of the territory of our country: Vama Veche, Costineşti, Eforie, Bârlad, Vaslui, Băile Felix, Buziaş, Măcin etc. In addition, in Romania OMV-Petrom, Rompetrol, RomGaz hold old, historical licenses for conventional gas and oil exploration. Companies are no longer bothered to obtain authorizations and have gone through a few perimeters to drilling at the depth of the shale layer and it is not excluded that the hydraulic fracturing has begun.

To date, in Romania, they were illegally licensed on the basis of the Oil Law no. 238/2004, ten perimeters for the exploration or exploitation and exploitation of hydrocarbons. Out of the 10 agreements concluded, the only agreements declassified at the request of civil society are the three oil agreements owned by Chevron in Dobrogea. The rest are secretive. The reason is the commercial secret invocation.

Fig 4. The governor of the Danube Delta Biosphere Reserve draws attention to the dangers of shale gas exploitation

In June 2012, the Ponta government decided to apply a moratorium on exploitation until the completion of European studies on the impact of hydraulic fracturing on the environment and postponed any discussion until after the parliamentary elections. Although the opposition opposed shale gas and was in favour of consulting the directly affected communities, the USL alliance introduced in the Energy Program 2013-2016 that it is considering "exploring exploration actions to identify exploitable bituminous shale ".

In October 2013, in contradiction with the demands made in the street protests that began in August, the Prime Minister said the government would support explorations, as energy independence and economic development are national strategic objectives as long as all environmental standards are respected.

In Romania, but also in the European Union, there is no specific legislation regulating the exploration and exploitation of shale gas, but only the concession of conventional oil and gas reserves. Consequently, exploration and exploitation of unconventional deposits is at the discretion of mining companies.

3. WORK METHODS

Like shale gas, shale oil consists of hydrocarbons blocked in rocky pores. This oil is in an intermediate form, called kerogen.

To convert kerogen into oil, it must be heated to 4500 ° C. Therefore, shale oil production is related to conventional shale mining practices followed by heat treatment. Its first uses date back more than 100 years.

At present, Estonia is the only country whose energy balance contains an important share of shale oil (~ 50%). Very often, kerogen is mixed with the already mature oil layers of the structures located between the low-permeability parental rocks. This oil is called "petroleum from compact formations", although very often the distinction is unclear and there is a gradual transition between the different maturity levels.

In pure state, petroleum from compact formations is mature oil blocked in layers of impermeable rock with low porosity. Therefore, its extraction generally requires hydraulic fracturing techniques.

One of the common features of dense geological formations containing hydrocarbons is their low permeability. For this reason, the methods used for the extraction of shale gas, gas from compact formations and even methane from coal deposits are very similar.

Since shale gas formations are by far the most waterproof structures, the greatest effort is needed to access gas bags. The exploitation of these formations therefore presents the highest environmental risks. However, there is a continuous transition from the exploitation of conventional gas permeable structures to the exploitation of nearly impermeable gaseous shale by the extraction of gas from compact formations.

Their common feature is that artificial contact between drilled wells and gas bags must be artificially improved. This contact is achieved by so-called hydraulic fracturing, also called "simulation" or "fracking".

Pressurized water opens cracks and allows access to as many pockets as possible. Once the pressure is reduced, wastewater mixed with heavy or radioactive metals from the rock formation is pushed to the surface simultaneously with the gas.

Supporting agents, generally sand particles, are mixed with water. They contribute to the maintenance of cracks and allow further gas extraction.

Chemicals are added to this mixture to provide a homogeneous distribution of the support agents by forming a gel to reduce friction and finally to dissolve the gelatinous structure at the end of the fracturing process and thereby allow fluid reflux.

Water may be contaminated with chemicals from the fracturing process, but also with the wastewater contained in the deposit containing heavy metals (example: arsenic or mercury) or radioactive particles.

Pollutants could migrate to surface and underground waters from various causes such as trucking, leakage in the collection network, wastewater basins, compressors, etc., accidental leakage (explosions with fracturing fluid or wastewater), damages to the cement wall and casing column, or simply uncontrolled underground flows along natural or artificial cracks present in the formations.

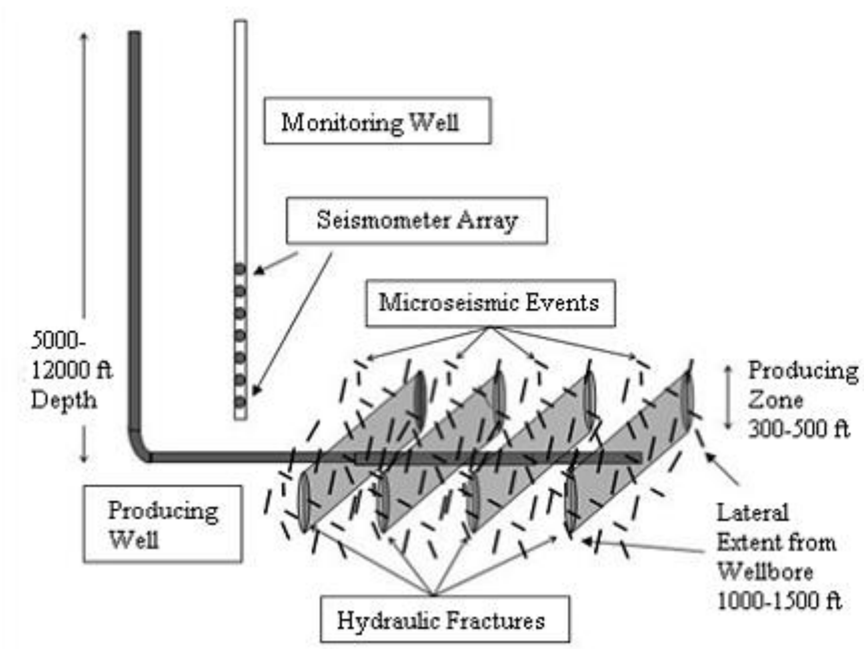

Fig 5. Schematic diagram of the development of hydraulic fractures and micro-quakes in a succession of fractal wells

Earthquakes are caused by fracturing or waste water injection.

Other possible impacts are air and noise pollution as the machinery is based on combustion engines: fluids (including wastewater) can emit harmful substances into the atmosphere, and trucks carrying frequent transport can emit volatile organic compounds, other air pollutants, and noise.

We also note the use of space in the landscape because drilling facilities require space for technical equipment, fluid storage and access paths for delivery.

Finally, the enormous consumption of natural and technical resources in relation to recoverable gas or oil should be analyzed through a cost-benefit analysis of these operations. There is a risk of impact on biodiversity, although so far it has not been able to prove.

A major feature distinguishing between shale gas production and conventional gas production is the rapid decline in well production. It is possible to simulate the hypothetical development of a field by comparing several identical production profiles.

Figure 6 shows the result of a scenario of this kind, totalizing the production profiles of shale with the addition of a new probe each month.

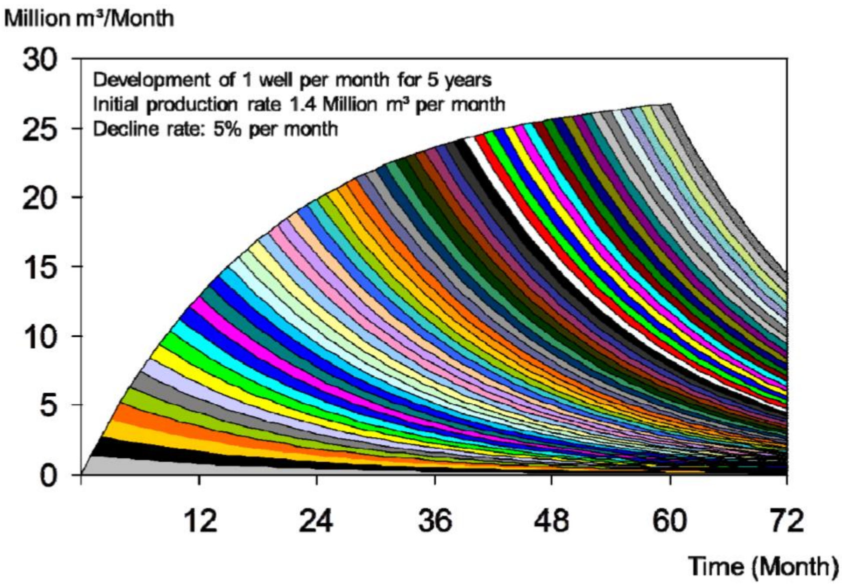

Fig 6. Developing the typical shale deposit holding by adding new probes at a steady pace development of a probe per month

The data used are similar to those for Barnett, with a typical production of 1.4 million m³ in the first month and a decline of 5% per month. After 5 years, there are 60 wells producing around 27 million m³ / month or 325 million m³ / year. Given the rapid decline in production wells, the production rate per well drops to 5 million m³ per well per year after 5 years.

This scenario of development is used to estimate the impact of shale gas production on the European gas market.

4. RESULTS AND CONCLUSIONS

An unavoidable impact is the high level of land occupancy required for drilling facilities, parking and parking spaces for trucks, equipment, gas processing and transport infrastructures, as well as access ways.

Among the major possible consequences, we can mention pollutant emissions, groundwater contamination due to uncontrolled gas or fluid flows due to eruptions or spills, fracturing fluid leaks and uncontrolled wastewater discharges.

The American experience shows that accidents are numerous, which can harm the environment and human health. At 1-2% of all drilling permits, violations of legal requirements were reported. Many of these accidents are due to incorrect handling or equipment with drain holes.

The fracturing fluids contain dangerous substances and the rejected liquids additionally contain heavy metals and radioactive substances from the deposits.

In the proximity of gas wells, there are reports of groundwater contamination with methane, which in extreme conditions causes the explosion of residential buildings, as well as contamination with potassium chloride, which causes salinisation of drinking water.

These consequences accumulate with the density of shafts that exploit shale formations (up to six platforms per km^2).

The current European framework for hydraulic fracturing - the central element of shale gas and oil extraction from compact formations - has a number of gaps. The most important deficiency is that the threshold set for environmental impact assessments in hydraulic fracturing activities for hydrocarbon extraction is too high for any potential industrial activity of this type, which is why it should be lowered substantially.

In a lifecycle analysis, a thorough cost / benefit analysis could be a tool for assessing global benefits for society and its citizens.

A possible general ban on the use of toxic chemicals should be considered. At the very least, all chemicals used should be made public, the number of authorized products should be limited and their use should be controlled.

Given the complexity of the possible consequences and risks of hydraulic fracturing for the environment and human health, consideration should be given to the development of a new directive at European level to regulate in an exhaustive manner all aspects of the field.

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