



## Environmental risks of shale gas production from gas-bearing area of Ukraine

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### Abstract

The article reveals the problem of shortage of natural gas in Ukraine as one of the key factors of national energy security. The present states of the fuel and energy sectors, the reasons for shortages of natural gas of domestic production and the perspectives of alternative gas extraction from shale are analyzed. The problems, environmental threats and risks associated with the prospects of development of alternative shale gas sources on the basis of detailed analysis of its production technologies are described. The comparison with the experience of shale gas extraction in the United States, where the technology was used for the first time, and with the consequences of violations of environmental safety is performed.

**Keywords:** energy resources, shale gas, soil erosion, pollution of groundwater, hydraulic fracturing, horizontal drilling, fracturing zones, geological research

### Streszczenie

Zagrożenia dla środowiska od procesów wydobycia gazu łupkowego z gazonośnych obszarów Ukrainy

Artykuł ukazuje problem niedoboru gazu ziemnego na Ukrainie jako jeden z kluczowych czynników bezpieczeństwa energetycznego kraju. Analizowany jest obecny stan sektorów paliwa i energii oraz przyczyny niedoboru gazu ziemnego w produkcji krajowej i perspektywy wydobycia gazu z alternatywnych łupków. Opisane są problemy i zagrożenia środowiskowe, oraz zagrożenia związane z perspektywami rozwoju alternatywnych źródeł gazu łupkowego na podstawie szczegółowej analizy jego technologii produkcji. Przedstawiono porównanie z doświadczeniem wydobycia gazu łupkowego w Stanach Zjednoczonych, gdzie technologia została wykorzystana po raz pierwszy, oraz ze skutkami naruszenia bezpieczeństwa ekologicznego.

**Słowa kluczowe:** źródła energii, gaz łupkowy, erozja gleby, zanieczyszczenia wód gruntowych, szczelinowanie hydrauliczne, wiercenie poziome, strefy szczelinowania, badania geologiczne

### 1. Introduction

Lack of fuel and energy resources in Ukraine and its dependence on external supplies pose a potential threat to the economic security of the country as a whole, and energy security in particular. The country's energy security is usually defined as the state's ability to provide effective use of its own fuel and power base, to make optimal diversification of sources and routes of energy supply, and to realize energy saving potential, to balance the supply and demand for fuel and energy resources [1].

Analysis of the ratio of the production and consumption of energy in Ukraine shows the difficult situation in oil and gas industry. During the period of 1998-2012 the oil and condensate production in Ukraine was maintained at the level of 3,7-4,5 million tons per year, and the gas production – at the level of 18 billion m<sup>3</sup> per year. During the analyzed period, oil and condensate consumption was approximately 19 million tons per year, while the consumption of gas was 81 billion m<sup>3</sup> [2]. Thus, the supply of Ukraine with energy sources of its own production did not exceed 28 % for gas and 24,2 % – for the total oil needs. Energy dependence on imported energy, especially oil and gas, is a major threat for sustainable development of the national economy. The price of imported Russian gas (total volume of which is about 40 billion m<sup>3</sup>) is too high (\$ 436 in the second half of 2012) for the development of the industrial sector of Ukraine. Shortage and high cost of hydrocarbons necessitates the national development in the direction of increase in the volume of domestic gas production.

The investigation of the problem of energy resources shortage in Ukraine reveals the following situation: oil and gas deposits, which are now actively exploited, are almost exhausted and the investment in further intensification of production from them becomes unprofitable. The possible approach includes the development of alternative deposits of the so-called unconventional gas. One of the currently considered directions is the production of shale gas.

However, shale gas contains a number of contradictions: some countries, such as France, Belgium and Switzerland, imposed a ban on its production, while others - the United Kingdom, Romania - removed the ban [3]. Therefore, the unequivocal conclusion regarding the feasibility and economic benefits of shale gas in the world remains to be determined [4]. Technology of shale gas extraction was not applied before in Ukraine and is, thus, new for the country. In spite of this fact Ukraine and the Anglo-Dutch oil and gas company “Royal Dutch Shell” have signed an agreement at Davos 2013 concerning shale gas extraction in Yuzovskiy field in Kharkiv and Donetsk regions [5]. Also on 5th November 2013 another agreement was signed in Kiev between Ukraine and the U.S. oil company “Chevron” on the division of production of shale gas in the Oleska area with 30% share for Ukraine [6]. These events caused a flurry of articles and discussions on various levels regarding both economic efficiency (cost of production in Ukraine will be more than in the United States, for example) and environmental impacts [7].

Thus, the feasibility of development of shale gas production in Ukraine, as in many other countries, is not clear and requires thorough study and consideration of both economic benefits and side effects [7].

## 2. Analysis of recent studies and publications, which discuss the problem

According to the U.S. Energy Information Administration (EIA), the amount of the studied and estimated reserves of shale gas in Ukraine is 7 trillion m<sup>3</sup>, which puts the country on the third place in Europe, after Poland and Norway [8].

There are two major shale gas deposits in Ukraine: Yuzivska, located in Eastern Ukraine (Donetsk and Kharkiv regions) in the Dnipro-Donbas petroleum basin, and Oleska in Western Ukraine (Lviv and Ivano-Frankivsk regions), a part of the Poland's Lublin gas basin. Yuzivska deposit is estimated to contain around 2 trillion cubic meters of gas, while Oleska's deposit is considered to have about 1,5 trillion cubic meters. Given the fact that after the start of industrial production (may occur in 2017) the total annual volume of gas in the two areas will be an average of 10-15 billion cubic meters, the Ukraine will get 3,0-4,5 billion cubic meters of gas per year. This is almost 20% of the total production of natural gas in Ukraine and 15% of that purchased from Russia (in the current year it is expected to reach 27 billion cubic meters).

It is yet unknown to which extent these deposits are technically recoverable. Shale gas, in fact, is an analogue of natural gas produced in Ukraine and imported from Russia, with the only difference that it is found not in huge natural underground reservoirs, but in small traps in the shale [9]. Considering the fact that its production technology is completely different, the innovative technologies should be applied, since it is not enough just to drill vertical wells. Technology of exploitation of shale deposits includes the use of the so-called hydraulic fracturing (HF) [10]. Initially, during drilling of the well, the method of horizontal directional drilling (HDD) is utilized. It is the controlled trenchless method of laying of underground utilities, based on the use of special drilling systems (installations). Length of laying of tracts can be from a few meters to several kilometers, while the diameter – more than 1200 mm. Subsequently, the HF is conducted in the drilled well in order to form cracks in the shale rock. Then the mixture containing 98,0-99,5 % of water and sand and 0,5-2,0 % of chemicals is

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injected into the well under high pressure. A mixture breaks the "pores" in shale rock, through which the gas is released from the many small traps [11].

The experience of shale gas extraction shows that the application of the methods for intensification of the flow of gas, especially HF combined with horizontal drilling is almost always a necessary element for extracting gas from gas shale [12]. Another essential element is the detailed evaluation of filtration-capacitive properties of gas shale. Before 1998 in the majority of gas wells that were drilled in gas shale in the basin of Fort Worth (USA), the methods of the so-called massive hydraulic fracturing were utilized. They include the use of 40 to 400 tons of special material with granules that is pumped into reservoir to prevent the closure of cracks in the borehole. This method is quite expensive and often ineffective due to detected problems with the "pollution" of the gel with propane. In 1998 a new methodology of facilitated HF was introduced. It involves the use of significant amounts of water instead of gel. For example, in a typical horizontal well drilled in gas shale, the hydraulic fracturing requires utilization of 11 000 to 15 000 m<sup>3</sup> of water. Water treatment of layer cracks costs less than gel treatment, and most importantly, it is more effective. It is necessary to mention that it is not always easy to provide so much water to the well. During the facilitated HF, the total content of water in the pumping fluid is 99,5 %, and it is mixed with the following components: surfactants, solution of KCl (potassium chloride), gel, corrosion inhibitor, acidity regulator, the regulator of iron, lubricants, hydrochloric acid, etc.

During the HF work it is necessary to strictly follow the technology protocol, so that chemical reagents that are pumped into reservoir with water do not appear in the groundwater and pressure fresh water of artesian pools. Otherwise, it can cause a great damage not only to the health of people living near areas of exploration, but also to the entire ecosystem [13]. In the U.S., for example, there was a scandal involving violations of the rules of conducting hydraulic fracturing by the largest service companies [14]. In particular in 2003, the Agency for the Environment Protection revealed initiative for voluntary memorandum with three major service companies involved in hydraulic fracturing (Halliburton, BJ Services, Schlumberger) in order to stop using diesel fuel as a carbon agent for HF mixtures. It is interesting that in 2005 the U.S. Congress removed hydraulic fracturing from practices of the current Safe Drinking Water Act (SDWA), and service companies can use any type of fluids for hydraulic fracturing, except diesel fuel. However, major service companies systematically violated that agreement: for example, the company Halliburton has admitted that in 2005 and 2007 it used 807 000 gallons of fluid containing diesel in varying combinations. Given the fact that shale gas production requires much more wells than the conventional one, the American public is seriously concerned about the possible extent of groundwater contamination.

### **3. The aim of research**

The aim is to study the impact of unconventional methods of gas production on the state of agro-ecosystems and the ways to neutralize these effects; to establish links between the characteristics of shale gas technology and environmental condition of the surrounding areas based on the experience of leading foreign extracting companies.

### **4. Experimental procedures**

The results are based on data from the evaluation of gas reserves in certain areas of Ukraine, conducted by the State Service of Geology and Mineral Resources of Ukraine [15], as well as the analysis of the application of conventional described by both Ukrainian and foreign scientists. Methods of graphical analysis of State Geological Maps of Ukraine [2], and analytical and synthetic approach to the study of environmental effects of the use of natural gas fields based on the experience of international companies were used.

### **5. Results**

It is well known that the regional geological research is a prerequisite for the functioning of civilized countries. The study of maps of geological content presented in [2, 15, 16] shows that not all regions of Ukraine are covered by modern maps, especially in the scale smaller than 1: 200 000, and therefore data on deposits of unconventional gas have been studied insufficiently. The most complete studies include those on the prospects of shale gas extraction conducted in Western Ukraine [15]. The main shale characteristics in Western Ukraine

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compared with that in countries, where an active shale gas extraction is going on (USA) and the results of the pilot drill (Poland) are shown in Table 1.

Table 5.1 The main characteristics of shale gas in the indicated countries

Characteristics	USA	Poland	Western Ukraine
Content of organic matter in shales	35 %	3 %	0.5 %
Depth of shale deposits	180 – 500 m	2000 m	2000 – 4000 m
A share of each country in world stocks	90 %	< 1 %	< 1 %

As a result of analysis of the data presented in Table 1, it can be concluded that shale gas in Ukraine has the lowest industrial indicators in terms of organic matter content, depth of deposits, the power of layers, etc. Due to the potential environmental risks the feasibility of its production should be further investigated.

In order to analyze the impact of shale gas on the environment, we considered the Oleska gas-bearing area as an example. The presence of regional discontinuous disturbances of north-western and north-eastern directions at the site, and fracturing of rocks in all sedimentary strata associated with that, is naturally a negative factor of a real threat to drinking fresh and mineral underground waters. Impermeable in their natural state strata with the power of 1 km between the Silurian and chalk, stops being impermeable during HF because of the presence of fracturing zones [17]. Drinking water in the course of HF work is likely to become contaminated with chemical reagents, which are pumped in the reservoir with water and through the fracturing zones enter the aquifer in the Upper Cretaceous sediments (the main aquifer of drinking water supply in the Oleska area and territory adjacent to it) and other aquifers. The greatest danger exists for water located in the Volyn-Podolsk Artesian Basin. There not only water in available intakes of drinking groundwater and mineral water that is bottled in factories could get contaminated, but also water in wells of human settlements, because the fracturing zones penetrate the entire thickness of sedimentary rocks - from Silurian to Quaternary sediments [17]. Drinking water, located in the Carpathian Artesian Basin to the west of Oleska area (mainly the aquifer system in the Quaternary sediments), is protected vertically and laterally by a thick impermeable clay material (Sarmatian clay), in which fracturing zones are almost absent.

The environmentalists are concerned because the production of unconventional gas is accompanied by exclusion of a large number of lands and intensification of human activities, including the protected areas (The territory of Oleska area has a regional landscape park "Stilsko Hill Ridge", national park "Northern Podillya" and others). The difference of unconventional gas extraction compared to traditional is that for a fuller exploration of deposit potential, the wells should cover the largest possible underground part of the gas-containing horizon. Therefore, it is necessary to drill a lot of wells. For example, in the Barnett Shale, USA, at the end of 2010 there were nearly 15 000 wells drilled in the area of 13 000 km<sup>2</sup>. The average density, thus, is about 1,15 wells per 1 km<sup>2</sup> (100 ha), but locally the frequency of wells can be up to 6 wells per 1 km<sup>2</sup> [18]. On average, the development of one square mile (259 hectares) of shale gas deposits usually requires 16 vertical wells, each with its own drilling platform, access roads and industrial pipelines [19].

So the question arises, especially in populated areas, about the allocation of land for drilling and access roads, as well as construction of supporting infrastructure (gas and water treatment companies, network of gas pipelines, etc.). Such infrastructure and construction projects, realized at the same time, create environmental risks of accelerated soil erosion. The report of the U.S. Environmental Protection Agency (EPA) indicates that the area of one hectare (2,47 acres) is a typical area for the allocation of land for drilling, access roads and pipelines. Increased traffic to deliver equipment and materials necessary for the drilling and hydraulic fracturing (for drilling of one well in previous years up to 1000 truck trips were needed) leads to disruption of existing roads, culverts and bridges, which accelerates soil erosion and increases road dust deposition in water reservoirs adversely affecting the biodiversity of the aquatic environment. Construction of all-weather (paved) roads, in addition to the soil erosion, can also lead to fragmentation of forests and fields that have a negative impact on individual living organisms [12].

The above mentioned demonstrates the need for comprehensive preliminary hydrogeological research [20], especially for the study of fracturing as a way of chemicals migration into the upper aquifers.

In addition to high environmental risks, the shale gas deposits have a number of disadvantages associated with high rock strength (which makes drilling difficult) and low capacitive-filtration properties, which negatively affect both the size of the deposit, and the mode of its exploitation.

Extractive companies often argue about the 30-40-year period of the production life of shale gas wells, but it turned out [21] that the average term of commercial life of horizontal wells is about 7,5 years.

The inevitable impact of shale gas production (as well as of other minerals) is evident in the use of large areas of land for drilling platforms, maneuvering areas for trucks, equipment, facilities for processing of oil sludge and drilling solutions, discharge barns and access roads. The main possible negative factors include the emissions of pollutants into the air, groundwater contamination by uncontrollable gas and liquid flows, caused by leakage, and uncontrolled discharge of stratal water in the discharge barns. Extractive liquids contain dangerous substances and stratal water, in addition, also has heavy metals and radioactive materials from the deposits.

The U.S. experience shows: the use of powerful hydraulic fracturing in the shale gas production is associated with high number of accidents that cause harm to the environment and human health. Documented violations of legal requirements vary in the range of 1-2 % of subjects who received permits to conduct drilling operations. A large number of these accidents happen due to improper handling of equipment and leakages. Moreover, in the case of scientifically groundless application of strong HF on large areas of industrially developed lands, the shale gas production is known to lead to groundwater contamination by methane, which sometimes leads to explosion of residential buildings, and by potassium chloride, which causes salinization of drinking water. The extent of influence increases as shale gas deposits are being developed with high density, up to six wells per square kilometer. Special dangers are caused by the greenhouse gas emissions.

Process of volatile methane leakages after hydraulic fracturing can have a huge impact on the balance of greenhouse gases. Existing assessments indicate a range of 18 to 23 grams of CO<sub>2</sub>, equivalent to 1 MJ resulting from extraction of unconventional natural gas. Emissions of methane entering the aquifers are still not assessed, but it is known that at some sites they may vary (depending on the productivity of wells and other factors) tenfold [21].

## 6. Conclusions

The results of study of methods imperfections and negative effect of shale gas production on agroecosystems should encourage the decision makers for moderation in making decisions on the use of the above technologies.

Technologies of shale gas production using horizontal drilling are associated with major hazards at every stage: poisoning of drinking groundwater and surface water, the danger of air poisoning, the risk of earthquakes and destruction of industrial and civil buildings as well as the danger of destruction of land resources and national parks.

The experience of countries that have been already developing shale gas production (e.g. USA, Poland) should be accurately examined: technology and related mechanisms of production, their initial and subsequent impact on the agro-ecosystem. The increase in hydrocarbon amount of own production, meeting the needs and financial interests of the international gas corporations should not lead to environmental disasters and impossibility of residence of the population in areas of gas production and territories surrounding them.

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