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# Possible Environmental Impacts of Shale Gas Production in Europe Based on The International Practices of Fracking Technology Utilization

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**The primary problem sets related to shale gas production have been detected – these are economic, geological and environmental ones. According to the information of the contemporary scientific research, a possibility of the shale gas production hydraulic fracturing technology impact on the environment has been considered. A potential threat of air contamination with the contaminants resulting from hydraulic fracturing has been detected. Facts of contaminating open and subsoil waters used at exploration, production and transportation of shale gas with mud have been established. A potential risk of radioactive contamination of open and subsoil waters, related to the flowback fluid at hydraulic fracturing, has been shown. Primary aspects of the shale gas production impact on the geological environment have been highlighted. It has been specified that the differences in the geological structures of North America and Europe are the key argument against practicing hydraulic fracturing in Europe. It has been emphasized that the proposed areas of shale gas production in Europe differ in the scope of production areas, water resources, structure, geological and other specifics that together with ambiguity, and often with inconsistency of the data on the impact of shale gas production on the environment in the USA, does not allow coming to some shared vision of the relevance of its production.**

**Key words:** Shale gas, Hydraulic fracturing, Environment, Environmental problems, Environmental risk.

In the current context, when various European countries are starting the discussion on the issue of shale gas exploration and extraction, the prospect of its extraction development should be considered, first of all, based on the available U.S. experience. The decade-plus long experience of well operation in the USA (Barnett Shale, Fayetteville Shale, Marcellus Shale, Haynesville Shale, etc.) has detected the following main problems:

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**Economic problems**

Extraction of shale gas at the amount of cost price and depreciation within the range of \$100-250/thousand $m^3$ is commercially viable only at demand availability and high gas sale price at the level of prices of \$350-500/thousand $m^3$; according to the Financial Group Prime Mark, the cost price of shale gas production is more than 3 times higher than that of gas from Gazprom traditional deposits (Fig. 1).

**Geological problems**

The operating life of shale gas wells is less than that of the usual natural gas wells; while average life of gas wells in the USA is 30-40 years, these numbers are much less for shale gas – average operating life of a shale well at Barnett Shale is 8-12 years, and about 15% of wells, drilled in 2003, exhausted their capacity in five years.

**Environmental problems**

Negative impact of shale gas production on the environment and human health, due to contamination of air, open and subsoil waters, raise of radiation background, negative effect on the geological environment (including increase of seismic activity), depletion of land, biological and water resources.

Environmental problems arise, first of all, due to the hydraulic impact, which occurs when water, sand and chemicals (Fig. 2) are introduced into claypans.

**Main Directions of Shale Gas Production Impact on Atmosphere**

The fact that hydraulic fracturing is accompanied by *air contamination* has been definitely confirmed in the USA, where a high level of benzene and other potentially toxic carbohydrates, including ethylbenzenes, toluene, xylene, associated with eye irritation, headaches,

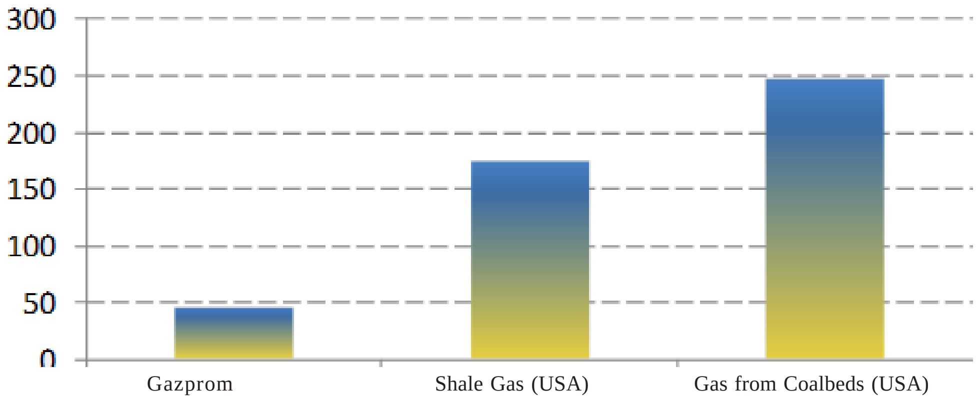


**Fig. 1.** Cost price of gas extraction from various sources, $1000/ m3

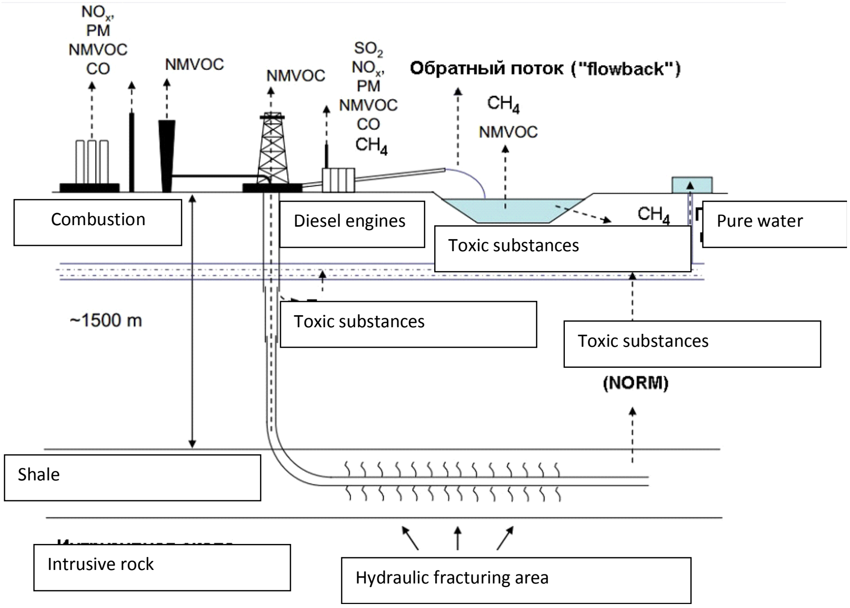


**Fig. 2.** Possible negative impact on the environment at production of natural gas from shale formations [1]

sore throat, respiratory difficulties and excess cancer risk has been detected. According to the estimates of T.Colborn and co-authors [2], 37% of volatile chemicals used at hydraulic fracturing could be a threat for the public health.

Toxic gas emission at hydraulic fracturing is classified as follows:

a) Emission from reservoirs for exhausted mud and flowback after hydraulic fracturing;

b) Emission from trucks and drilling equipment (dust particles, $SO_X$, $NO_X$, NMVOC and CO);

c) Emission from processing and transportation (dust particles, $SO_X$, $NO_X$, NMVOC and CO);

d) Emission from operating the drilling equipment (dust particles, $SO_X$, $NO_X$, NMVOC and CO);

Emission of the shale gas itself materially affects the environment too, as it is a greenhouse

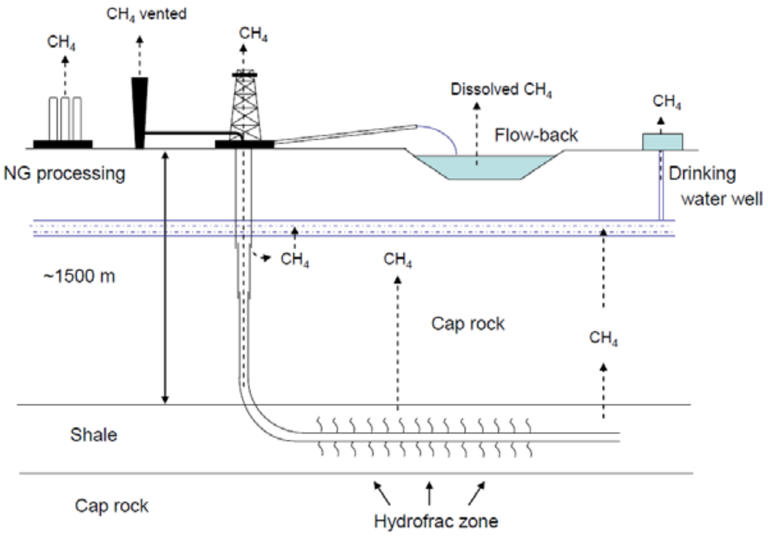


**Fig. 3.** CH4 emission ways at shale gas exploration, extraction and transportation [1]

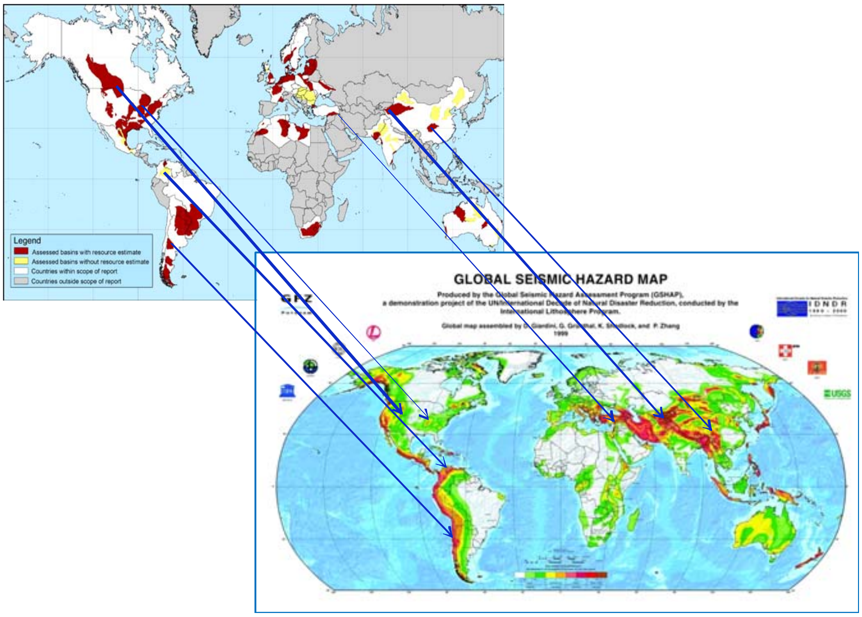


**Fig. 4.** Comparison of global seismic hazard map and shale gas deposit map

gas. According to the expert examination, about 3% of one well total production volume is discharged into the atmosphere, according to the information provided by R.W. Howarth [3], the total volume of methane loss at gas production equals to 3.6-7.9%. Possible ways of $CH_4$ emission in the process of shale gas exploration, extraction and transportation are shown in Fig. 3.

Investigation of the European Commission (DG CLIMA)[4] confirmed that though in comparison to coal shale gas production allows reducing greenhouse gas emission up to 49%, emission at production, if compared to traditional gas, increases up to 60% due to the emission of a significant amount of greenhouse gasses.

**Shale Gas Production Impact on Open Water and Subsoil Water**

One of the most negative environmental factors of shale gas production is ***the contamination of open and subsoil water*** by the mud used for the shale gas exploration, extraction (including at hydraulic fracturing) and transportation.

The primary contamination scenarios are the following:

a) Breakdowns at reservoirs and tailing dumps located on the surface;
b) Mud ingress from the drilling area into the water-bearing layers;
c) drilling mud spillage at drilling;
d) Leakage or incidents as a result of surface works, for example, leakage from waste lines, non-qualified handling of machinery, out-of-date equipment, etc.;
e) Leakage because of the poor concrete well coating;
f) Spillage as a result of a backflow leakage of the drilling mud after hydraulic fracturing (so-called "flowback");
g) Leakage through geological structures into natural or artificial fractures or the ways of filtration.

In Europe, the depth of gas-bearing shale beds is not homogenous and depends on the geological and hydrogeological characteristics of the area. The research published by the British Institute of Geological Survey and the UK Environment Agency[5] showed that when fracturing the bed, separating water from gas, oil and gas production companies allow large volumes of methane to mix with water. Methane ingress into the water in large amounts may result in overshooting of its permissible concentration in the pure water and a negative effect on the human health.

Chemical agents make up about .5% of the liquid used for hydraulic fracturing. Concentration of part of chemicals, included in its composition, exceeds the maximum permissible concentration. Thus, since 2000 solutions with

**Fig. 5.** Impact of exploration and production of shale gas on the landscape
A view from the airplane to Jonah deposit, Wayoming, May, 2006. Photo: SkyTruth

dopants, having hazardous properties (among other things – very poisonous, cancerogenic, mutagenic and (or) toxic) have been applied in the fracturing fluids in Germany. According to the estimates of German scientists, the fracturing fluids used in Europe are very hazardous for humans (table 1)[6].

The UK Environment Agency analyzed the composition of the return water from the exploration well of Cuadrilla Resources Ltd[5]. As a result, high levels of sodium, chlorides, bromides and iron, as well as an increased value of lead, magnesium, zinc, chrome and arsenic in comparison to the water injected into the rock for hydraulic fracturing, have been detected.

According to the United States Environmental Protection Agency (EPA), every year 70 to 140 billion gallons of water are used at drilling of 35,000 wells. Apart from the direct use of significant quantity of *water resources*, hydraulic fracturing causes a negative indirect effect on the environment of the nearby territories.

According to WWF, use of greater volumes of water for injecting into the beds may lead to the disturbances of stream conditions in the territory that threatens to reduction of open water resources[7]. This factor is essential for the territories with a lack of water reserves and intensive agriculture, for example, for France.

A potential risk, associated with the ***radioactive contamination*** of open and subsoil waters, is related, first of all, to natural radioactive materials, particularly uranium, thorium, radium , which are taken out to the surface by the flowback, that leads to the formation of a high level of gamma-radiation.

German scientists have proven that the rise of deep underground waters, containing natural radioactive substances, with return water, leads to the presence of these substances in surface subsoil water[6].

Analysis of the return water from the exploration well (Cuadrilla Resources Ltd), performed by the Environment Agency of Great Britain, showed the content of a number of radionuclides of natural origin, including $^{40}$K, $^{212}$Pb, $^{214}$Pb, $^{214}$Bi, $^{228}$Ac and $^{226}$Ra[5]. They present information about the radiation intensity from the contaminated equipment from .3 up to .6 mcSv/h$^{-1}$ that equals to the quintuple radiation dose of the

**Table 1.** Assessment of the dopant concentration applied in fracturing fluid Damme 3 and further developments, in accordance with the toxicological and eco-toxicological risk coefficient

| | Purpose of application | Dopant | Soluble concentration | Risk coefficient Toxicological for humans | Eco- toxicological assessment Not enough data (>2600000) |
|---|---|---|---|---|---|
| 1* | Clay stabilizer | Tetramethylammonium chloride | 520 mg/l | 1733000 | |
| 2 | | *Choline chloride* | *750 mg/l* | *< 43* | *210* |
| 1 | Adhesion reduction | Hydrogenated oil stock | 220 mg/l | 2200 | 55000 |
| 2 | | *Butyl diglycol* | *350 mg/l* | *40* | *6600* |
| 1 | Surface active agent | Ethoxylated octylphenol ether | 36 mg/l | 120000 | 20000 |
| 2 | | *1-hexanol ehoxylated* | *130 mg/l* | *743* | *760* |
| 1 | Biocide | Isothiazolinone derivatives (Kathon®) | 4 mg/l | 7520 | 72000 |
| 2 | | *Ethylene glycol(bis) hydroxymethyl ether* | *1000 mg/l* | *10000000* | *Not enough data (139000)* |

* 1 - Damme 3 fracturing fluid; 2 – further developments.

natural background[8]. Radon and radium are soluble in water, thus there is a risk that they could get into the body orally from the water supply system through subsoil water, at leakage of the return drilling mud.

**Slate Gas Production Impact on Geological Environment and Seismic Activity**

The primary *impact on the geological environment* at shale gas production lies in subsurface resources integrity disturbance that causes slides and technogenic earthquakes. The US Geological Survey Institute has proven that the number and frequency of earthquakes in the continental USA in comparison to the 20th century increased sixfold in 2011 because of hydraulic fracturing, while earthquake magnitude related to hydraulic fracturing was equal to 2.4 points and higher on the Richter scale[9]. According to the comparison of the global shale gas play location map and the global seismic hazard map (Fig.4) a number of potential shale gas production regions coincides with the regions of material seismic activity.

A hydraulic fracture at one of the first wells in the EU, which is located in Great Britain (Blackpool, Cuadrilla Ressources), conducted in 2011, caused an earthquake of magnitude 2.3 on the Richter scale. An independent research, conducted upon the order of the British government, confirmed that the earthquake was caused by the direct injection of fluid during hydraulic fracturing, and acknowledged that probability of repetition of new earthquakes at hydraulic fracturing cannot be excluded at all.

**Differences in the geological structure of the North America and Europe are a key argument against practicing hydraulic fracturing in Europe**

Thus, for example, in the Czech Republic, production is mainly proposed in tectonically active areas or areas with tectonic defects that poses significant risk[10].

There are two types of seismic activity related to hydraulic fracturing[11]. The process of hydraulic fracturing itself may lead to earth shocks measuring about 3 on the Richter scale. The second type of seismic activity is a result of injection of waste water, reaching available fault lines that may result in more material earth shocks. Such shocks do not occur directly on the shale gas production sites, i.e. they pose a threat to the territories located at a larger distance.

**Shale Gas Production Impact on Landscapes, Land and Biological Resources**

Non-traditional gas production *influences biological diversity* and, as a result of construction of infrastructure objects and drilling sites, may lead to degradation or full extinction of the natural environment because of excessive water withdrawal, split of wild animals and plants distribution, soil degradation, etc. Thus, a negative impact of flares at gas combustion, spreads over the territory 3-4 times exceeding the allocation area, forest stand is destroyed; soil becomes contaminated with oil and becomes fritted.

The primary types of the impact *of shale gas production* on land reserves are as follows:

a) Soil degradation (damage due to elimination of the upper layer of soil);
b) Soil consolidation as a result of constant load (recovery of the primary state is sophisticated and long-lasting);
c) Contamination in case of breakdown with the spilled fluids, fuel, oils and lubricants.

According to the expert estimates, apart from withdrawal of lands for wells and equipment allocation, additional land, required during repeated hydraulic fracturing operations, can be compared to 4% of land in Europe used today for housing, industrial facilities and transport. Thus, this potentially restricts shale gas production, especially in the densely populated regions of Europe.

The necessity of material compensation for the loss of harvest and probable decrease of field area to the owners of agricultural lands is one more problem at development of gas production from non-traditional sources on an industrial scale.

The necessity of establishing a dense network of drilling sites and construction of a network of roads, leading to them (Fig.5) provide a more significant ***impact on the landscape*** than in the case of carbohydrates production from traditional deposits.

Fig. 5 represents a view from the airplane to Jonah deposit – Wyoming, May 12, 2006. A shoot from the plane that represents a site of 3-5 acres, relevant for gas production by hydraulic fracturing with the border-line distance of 40 acres. The image shows access communications, pipe corridors and other infrastructure at Jonah deposit of the mountainous western state Wyoming – Green river valley. The production plants were erected within 7 years.

**European Law and Public Opinion in European Countries in the Context of Possible Shale Gas Production**

The proposed areas for shale gas production in Europe differ in size of production territory, water resources, structure, geological and other peculiarities that alongside with the ambiguity and often with inconsistency of the data on the impact of shale gas production in the USA on the environment, does not allow coming to the shared vision of the relevance of its production.

Imperfectness of legal norms detected by the analysis of the European Union legislation is another important problem. Particularly, the issues of impact assessment on the environment, implementation of Directives on industrial emissions, water environment, etc. in relation to hydraulic fracturing, are defined not full enough, both in the EU legislation and national acts of the European countries.

Nature protection requirements of the states, planning shale gas production, should also be considered. In a number of countries, particularly in Poland, a significant part of the territories most favorable for shale gas exploration and production is located in sparsely populated areas within specially protected natural areas. When the areas of planned shale gas production coincide with the conservation areas, conflict situations would arise.

All these reasons would lead to distrust of the European population to hydraulic fracturing procedure resulting into large-scale protests and rejection of shale gas production in the European countries:

**Germany**

German authorities tend to restrict shale gas production. The stance of the Advisory Council on the Environment (SRU) is as follows:

a) From the point of view of energy policy, hydraulic fracturing is irrelevant and may not make a significant contribution into the energy revolution;

b) Presently, hydraulic fracturing cannot be allowed on an industrial scale due to serious gaps in the knowledge;

c) Application of hydraulic fracturing may be justified only in accordance with the positive conclusions, resulting from systematically developed pilot projects.

**Great Britain**

Shale gas development in Great Britain has been discontinued because of earthquakes in Lancashire. Corrected data on the shale gas reserves volume in Great Britain turned out to be more modest than it was claimed before, and now its production may become not profitable. In July 2014, British authorities raised a ban on shale gas production, and now almost half of the British territory, including several large cities and event national parks, is open.

**Austria**

Oil and gas company OMV was planning exploration of shale gas reserves in Lower Austria in summer 2012, but was forced to suspend their plans under the pressure of environmental protection protest actions of the local population and organizations. In September 2012, the Austrian energy concern OMV refused from the plans on shale gas production in the country, because environmental restrictions made this project not profitable.

**Bulgaria**

In January 2012, after large-scale protest movement Bulgaria prohibited exploration of shale oil and gas by means of hydraulic fracturing.

**Czech Republic**

Any geological exploration works related to the shale gas production are prohibited.

**France**

The Senate of France approved the prohibition of hydraulic fracturing; in 2012 a 5-year long prohibition was effected.

**The Netherlands**

Moratorium on shale gas production is in force.

**Sweden**

28 municipal governments appealed to the state politicians with the requirement of the municipal veto power for the exploration of shale gas and uranium.

**Poland**

Dependence on gas supply from Russia, as well as a growing demand for additional power sources, made Poland one of the most active protagonists of shale gas among European countries. Nevertheless, the issue of hydraulic fracturing prohibition is always raised by public and environmental organizations.

**Romania**

The Romanian government considers shale gas as a tool of national power safety improvement, and reducing the dependence on the imported Russian gas. However, large protest movements against the hydraulic fracturing technology have been held in a number of urban communities in Romania. In April 2012, the Prime-minister of Romania reported that shale gas production in Romania might be started not earlier than after 5 years. It is necessary to establish an appropriate legal basis, first of all, in the sphere of environmental protection, which would regulate the production within this time period.

**Ukraine**

Ukraine is considered to be the fourth country in Europe (after France, Norway and Poland) in terms of the shale gas reserves. In May 2012, the Ukrainian government signed two agreements on the allocation of shale gas deposit exploration products. This caused a number of protest campaigns held by the public and environmental movements. At present, due to the situation in the country, works on shale gas exploration and production have been suspended in most parts of the Ukraine.

## CONCLUSION

All population's and specialists' concerns could be confirmed or disproved by the results of research studies conducted by respectable international organizations, as well as by the US EPA.

However, nowadays there is no certain official opinion of EPA, the issue of the final report that is supposed to cover the problem of impact of shale gas on the environment in full, has been constantly postponed.

A lack of raw hydrocarbons and striving for energy safety will, by all means, force the countries in various regions of the world to develop their own reserves of shale gas. However, one should hope that environmental risks of high importance, relevant to the use of the modern hydraulic fracturing basic technology, would be taken into consideration when making a decision on developing of the reserves, especially in the densely populated European countries. The situation might become better in the future, when the shale gas production technology is improved that would help reduce environmental risks to a more acceptable level.

Thus, the fact of a negative impact of the hydraulic fracturing process on the environment and human health does not cause any doubts, and the main problem lies in a possibility to restrict and control possible negative effects. In comparison to the traditional natural gas, a negative environmental impact of the shale gas production which is related, first of all, to a negative impact on the environment, atmosphere, water and land resources, has been proven by the studies conducted that together with the analysis of environmental and geological consequences makes the shale gas production not profitable for the time being.

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