Environmental problems of shale gas production

V. Mykhailov, O. Hrinchenko *(Taras Shevchenko National University of Kiev)*

SUMMARY

This paper discusses the main environmental problems arised at prospection, exploration and exploitation of unconventional hydrocarbons, in particular shale gas production in Ukraine. It is based both on reviewed world publications and authors' data on sources of unconventional hydrocarbons in Ukraine. As a result, it was established that the main environmental threats that can arise at the prospection, exploration and exploitation of shale gas fields are associated with application of hydraulic fracturing (fracking) as well as drilling of a large number of exploration and operating boreholes. Among the main environmental impacts are ground water pollution by chemicals commonly used as components of hydraulic fluids and disruption of tectonic stability of rock massif at hydraulic break-down that can cause technogenic microearthquakes. However, the results of investigations carried out have shown that concerns of ecologists are exaggerated in many respects and shale gas can be produced without any environmental pollution, even if it will occur within densely populated areas of Ukraine. Certainly, all issues of prospection, exploration and production of unconventional hydrocarbons in Ukraine demand detailed studying by complex scientific researches that should cover all range of problems – geological, economic-geological, ecological and socio-political.

Introduction

Environmental impact of shale gas production is the most important problem under debate, especially in densely populated regions of Europe. The main environmental threats of shale gas production are associated with application of hydraulic fracturing (fracking) that means us-age of large volumes of water. It can result in contamination of water-bearing horizons through application of high-toxicity chemicals, possible air pollution and technogenic microearthquakes. Moreover, need for drilling of a large number of boreholes raises concern about possible alteration of natural landscapes in the densely populated area. All the above mentioned have led to the formation of public antipathy to shale gas production in Europe and European governments (France, Romania, Austria, England) have imposed the moratorium on shale gas production by fracking methods.

In Ukraine, issues of exploration and development of unconventional hydrocarbons (including shale gas production) have been discussed since 2010 and, as a result, reviewed in numerous publications (*Vyzva and Mykhailov, 2013; Mykhailov et al., 2014a,b; Mykhailov, 2016a,b*). Corresponding lecture course was developed (*Mykhailov et al., 2016*) and taught at Taras Shevchenko National University of Kyiv since 2016. Problems of prospection and exploration of shale gas fields and other unconventional hydrocarbons of Ukraine, possible hazardous geological processes which can accompany exploration and production of oil and gas as well as environmental problems of gas field development are thoroughly discussed and reviewed by these publications.

Methods and Theory

The hydraulic fracturing is used not only for shale gas production, but also «intensification» of oil and gas production in the fields In Ukraine characterized by low fluid inflow. The hydraulic fracturing can create system of highly-permeable cracks which will enhance inflow of gas and oil from hydrocarbon-rich horizon. Boring fluids used for hydraulic fracturing commonly includes water-sandy mixture (98%) and different chemicals (2%). Ecologists consider fracking as a very hazardous technology due to the presence of high-toxic chemicals that could release into groundwater and atmosphere.

By expert estimations, one cluster that includes 6 boreholes consumes about 54-174 thousand m^3 of water (depending on length of vertical section of borehole) and 1,0-3,5 thousand m^3 of chemicals. According to the practice operating in the USA, only 1,3-23 thousand m3 of fluid might be pumped out from borehole after formation of hydraulic fracturing. At the same time, large portion of fluid (about 80%) remains in borehole that creates real threat of its entering into water-bearing horizons with subsequent pollution of underground water reservoirs. To prevent these undesirable phenomena the technology of concrete casting of vertical section of borehole is applied for its complete isolation from subsoil waters. Portion of hydraulic fluid which is pumped out from a borehole should be stored in technical tank for some time with subsequent removal and utilization. Hydraulic fluid mishandling can create real threats of its entry into the environment. The main environmental problems include *(Aksyutin et al., 2019*):

- emission of pollutants into the atmosphere and evaluation of possible climate change due to emission of greenhouse gases;
- surface and ground water contamination by high-toxic substances and drain waters as well as consumption of considerable water resources for industrial requirements;
- withdrawal of land resources for location of payable areas and, as a result, alteration of landscapes within the territories adjacent to mining sites;
- fluctuations in seismic activity and radiation background level due to the changes in geological nature of mining sites.

Another environmental aspect associated with shale gas production is the utilization of waste rocks extracted at drilling. In comparison with a traditional gas borehole, that is drilled up to 2 km depth and can produce about 85 m^3 of drilling chips, the similar cluster drilled up to the depth of 2 km with vertical section borehole of 1,2 km can produce 10 times large amount of waste rocks, about 840 m^3 (140 m^3 by one borehole). In Ukraine, possible occurrence depths of gas bearing horizon are supposed to be about 1,5-4,0 km and, therefore, the yield of drilling chips would make 1350 m^3 per one cluster (6 boreholes).

By the estimation of specialists, indexes of carbon dioxide emission at operation of shale gas boreholes are substantially different from those of conventional gas production.

Results

As a result of researches carried out it is established that the main ecological threats associated with shale gas production are following:

- chemicals mishandling and irregularities in drilling technology that can lead to the entry of toxic agents in natural reservoirs of drinking, subsoil and surface waters within the areas around the sites of oil and gas field development;
- accumulation of heavy metals, organic chemicals and naturally occurring radioactive material in subsoil waters;
- increase in consumption of technical water within the areas of gas field development and lack of infrastructure for utilization of considerable volumes of technical fluids (5-10 million m^3 by 3000 boreholes) which will be pumped out from boreholes before their operation;
- need for utilization of considerable volumes of waste rocks in the areas of shale gas production (about 700 thousand m^3);
- the development of about 3000 boreholes at preparatory stage, that are designed for production of 10 billion m^3 of gas in Ukraine aggregate emissions of carbon dioxide into the atmosphere will make not less than 600 million tons;
- migration and uncontrolled emission of shale gas after hydraulic fracturing of rocks; gas entry into water-intake facilities of municipal water supply of the adjacent areas.

As it might be seen, environmental implications can be rather essential and their elimination will demand considerable financial expenses and arrangements at all levels of central and local government, wide involvement and information of public. Among other environmental concerns associated with shale gas production are (*Aksyutin et al., 2019: Support to…, 2013*):

- higher level of water and chemicals consumption in comparison with conventional gas production.
- lower capacity of shale gas boreholes in comparison with capacities of conventional gas wells.
- maintaining the integrity of boreholes and other equipments at all stages of exploitation to prevent risk of pollution of surface and subsoil waters
- prevention of spills of chemicals and drain waters
- potential uncertainties associated with long-lasting presence of hydraulic breakdown fluid in underground space
- potential toxicity of chemical additives in fluids used for hydraulic breakdown
- development of more wide areas of mining in comparison with conventional gas production.

Microearthquakes (less than 3 by magnitude) are also the integral component of hydraulic fracturing. But they pose very small risk and all registered microseismic events show magnitudes that are less than 0,5. For example, all the seismic transients registered during 2009-2011 within the basin of river Horn, British Columbia were caused by hydraulic fluid flooding near fault zones, but only one seismic even was registered as sensible on the Earth surface without any harmful consequences. During 2008-2009 numerous low-magnitude earthquakes (up to 3,3 magnitude) were registered in Kleburn, Texas State. Even though these earthquakes were originally treated to be associated with development of Barnett shale gas field, subsequent studies carried out by seismologists of Texas University did not confirm any relations between these events (*Shcherba, 2013*).

The most earthquakes during a hydraulic fracturing are associated with injection of discharged (waste) water into borehole deeply underground that can disrupt fluid balance in rocks and crustal stress level near the fault zone. For example, in 2011 two low-magnitude (3,2 and 2,4) earthquakes were registered in Lancashire (Great Britain) as a result of hydraulic breakdown occurred in boreholes. But risk of these events is treated to be rather insignificant.

In Poland, as a result of fracking procedures carried out along horizontal section of boreholes the increased levels of noise were constantly registered during 2010-2011. But any environmental impacts on quality of surface and ground waters, atmospheric contaminations as well as signs of ground vibrations or earthquakes which can pose danger to buildings or infrastructure were not registered. The hydraulic fracturing did not cause any changes in composition of soil gases, namely any increased concentrations of radioactive radon or methane did not established. Methane was also absent within aeration zone of drilled borehole. Hydraulic breakdown did not cause opening of paths for gases migration from Earth depth neither within the whole area of drilling site nor near-borehole zone.

At the same time, as a result of development of shale gas fields of Marcellus basin in the USA and based on the analysis of 141 wells drilled for drinking water. which are located at the distances of up to 1 km from boreholes drilled for shale gas, the raised contents of methane (82% of samples), ethane and propane (10 water supply wells) are established (*Jakson et al., 2013; Shcherba, 2013*). Another environmental threat that might be associated with shale gas development is associated a negative impact on land resources (*Aksyutin, et al., 2019; U.S.EPA, 2015*) that can result in:

- degradation soil (due to the deprivation of top soil)
- soil compaction (as a result of permanent load)
- soil contamination (in case of accident caused by spill of fluids or combustive and lubricating materials).

Thus, the environmental safety is one of the most urgent problem of shale gas field development. The major threat is posed by disruption of tectonic stability of rock massif at hydraulic breakdown that can result in earthquakes and contamination of water-bearing horizons used for water supply of human settlements.

At the same time there is question left that should be defined. Is this threat widespread or has local development and occurs at certain geological conditions? As a rule, gas bearing shale formations occur at considerable depths (2-4 km) within tectonically stable regions and are overlain by thick stratas of impermeable rocks. It considerably reduces risks of both earthquakes and pollution of water-bearing horizons which are mostly confined for upper sections of the Earth crust (first tens or hundreds meters). Hazardous processes can be manifested within zones of disjunctive dislocations which crosscut rock massifs. Here hydraulic breakdown can cause both local earthquakes and, in case of presence of hydraulic connection between deep and surfacial levels, pollution of underground water by chemicals of hydraulic fluids. Preliminary prospection and forecasting of such zones is necessary condition for reduction of environmental risks.

By composition, fluids which is used at hydraulic can include such chemical components as dimethyl formamide, citric acid, borates, sodium chloride, sodium, ethylene glycol, guar gum, potassium chloride, isopropanol, hydrocarbon distillate and various acids. Most of these chemicals and compounds (with ethylene glycol as an exception) are included as common components of household goods (soap powders, soap, cosmetics, plastics, hair-dyes, pool cleaning goof of basins, etc.), sometimes foodstuff (citric acid, guar gum) or pharmaceutical drugs (hydrocarbon distillate) which are used in everyday life.

Thus, concerns of environmentalists are exaggerated for the most part and based on information lack. Therefore, among the key tasks are broad-scale public informing, public awareness campaigns with local communities, especially in the areas of possible unconventional hydrocarbons development, control (supervision) by public, especially scientific communities (Universities, Scientific institutions of NAS of Ukraine) for the process of exploration and mining operations at all stages of work. While development of gas field mining the gas producing companies have to provide set of actions aimed at prevention of hazard effects and elimination of possible negative impacts on the environment. The major actions should include:

- carrying out of outrunning geological studies in the are of gas field development for the purpose of discovery of disjunctive dislocation zone, zones of decompaction and other geological structures that disrupt stability of rock massifs; studying of hydrogeological and engineering-geological parameters of rocks, seismic events, etc.;
- independent environmental (geological and ecological) expertize for exploration and production project with all necessary approvals;
- strict observance of technology of borehole drilling and hydraulic fracturing;

- compliance of fluid (mixture) composition used for hydraulic fracturing to requirements of Public sanitary and epidemiologic service of Ukraine and project parameters;
- maintaining of complete impermeability of prospecting and operational boreholes in order to prevent contamination of water-bearing horizons by chemicals;
- continuous monitoring of drinking ground water composition within the area of gas field development with involvement of independent experts;
- sustainable use of the available water resources which will be used for carrying out a hydraulic fracturing;
- utilization of discharged liquids according to requirements of legislation and international standards;
- constant control of atmospheric emissions;
- recultivation of areas which will be used for location of drilling sites.

Conclusions

All problems associated with possible production of shale gas in Ukraine need carrying out detailed scientific researches for the purpose of practical substantiations of administrative decisions as to the development of unconventional sources of hydrocarbons. Such researches have to cover all the range of issues – geological, economic-geological, ecological, socio-political. Such researches, with few exceptions were not carried out in Ukraine.

The public should be informed in the proper way that it is not impossible to avoid completely possible negative impact on environment at the course of development of any minerals (e.g. coal mines in Donbass, sulfur deposits in Near Carpathians, iron ore deposits in Krivy Rih area, etc.). But the elimination of possible environmental impacts should be vital and obligatory task.

References

Aksyutin, O.E., Ishkov, A.G. and Grachyov, V.A. [2019]. Prospects and problems of shale gas production in Europe. *Forecasting problems*, 5, 141-148. [in Russian]

Jackson, R.B., Vengosh, A., Darrah, T.H. et al. [2013]. Increased stray gas abundance in a subset of drinking water wells near Marcellus shale gas extraction. *PNAS*. 28(110), 11250-11255.

Mykhailov, V., Karpenko O. and Karpenko, I. [2014b]. Geological features of Ukrainian shale formations promising for the presence of industrial unconventional hydrocarbon accumulations in connection with hydraulic fracturing of layer. *Proceedings of XLII Summer School-Conference APM*, 352-357.

Mykhailov, V.A. [2016a]. Unconventional hydrocarbon deposits of Ukraine. Cooperation of science and industry in hydrocarbon exploration and production. *Prace Naukowe Instytutu Nafty i Gazu Panstwowego Instytutu Badawczego. Krakow*, 55-66.

Mykhailov, V.A. [2016b]. Prospecting and evaluation of unconventional deposits of hydrocarbons in Ukraine. *Visnyk Taras Shevchenko national university of Kyiv. Geology*, 2(73), 38-45. [in Ukrainian]

Mykhailov, V.A., Karpenko, O.N. and Ogar, V.V. [2016]. Oil and gas of shale rocks, tight collectors, methane of coal basins. Textbook. M.: LLC «Enterprise VNA», 238. [in Ukrainian]

Mykhailov, V.A., Vakarchuk, S.V., Zeykan, A.Yu. et al. [2014a]. Unconventional sources of hydrocarbons of Ukraine. Book VIII. Theoretical substantiation of resources of unconventional hydrocarbons in sedementary basins of Ukraine. K.: «Nika-center». [in Ukrainian]

Scherba, V.A. [2013]. Environmental problems of «Shale revolution». *Socio-ecological technologies*, 120-125. [in Russian]

Support to the Identification of Potential Risks for the Environment and Human Health Arising from Hydrocarbons Operations Involving Hydraulic Fracturing in Europe. [n.d.]. *Ref: AEA/ED57281/Issue Number 17/ Dr Mark Broomfield, AEA Technology*, 11 February 2013, 292.

U.S. EPA. Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft). *U.S. Environmental Protection Agency, Washington*, DC, EPA/600/R15/047, 2015, 998.

Vyzva, S.A. and Mikhailov, V.A. [2013]. Implications for unconvential hydrocarbons exploration and production in Ukraine. *75th European Assotiation of Geoscientists and Engeneers Conference and Exhibition 2013 Incorporating SPE EUROPEC 2013: Changing Frontiers*, 4927-4931.