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Gas Hydrates Production in the Arctic Zone: Ecological Aspects

Zyrin Viacheslav[1] and Ilinova Alina [2]

[1,2] Saint-Petersburg Mining University, 21 line, 2, Vasilievskiy Island, 199106, Saint-Petersburg, Russia

ORCIDs: [1]0000-0002-7961-451X, [2]0000-0001-5168-0518

Abstract

Arctic has considerable strategic importance to the world economy, and especially for the economies of the Arctic countries. We underline strategic importance of the Arctic as a wealth of petroleum and mineral resources. The Russian Arctic shelf in the future can become the main source of hydrocarbons for both Russia and the world market in the whole. And special role is assigned to extraction of nonconventional petroleum, up-to-date Arctic technologies and equipment, and no less important aspect of ecology safety development of the Arctic. One of the most potential nonconventional sources of natural gas is gas hydrates, which impressive resources are concentrated in the Arctic Zone. In this paper we would like to pay special attention to the technologies providing gas hydrates production in the Arctic and to the ecological aspect of this activity. The paper in general presents main characteristics of the Russian Arctic and oil and gas recourses. Then we present some economic issues of gas hydrates production in the Arctic. We paid special attention to environmental regulation of natural recourses production in the Arctic with presenting main regulatory documents and laws in Arctic countries.

Keywords: Arctic, gas hydrates, ecology, Russia, Arctic Zone, gas production, mineral recourses, environmental regulation

INTRODUCTION

Russia is one of the most important players in the Arctic Zone with wide range of economic, security and political interests in the region. Arctic is a wealth of petroleum, gas and other mineral resources. From being regarded almost like a restricted area, the Arctic has become a global economic, ecological and social concern [1].

In 2008, the United States Geological Survey (USGS) estimated that the Arctic might contain 13% of the world's undiscovered oil and 30 % of its undiscovered gas [2]. Of these hydrocarbon resources, 84% were believed to be offshore and most of them are not distributed: the highest concentrations are expected to be in north of Alaska and in the western part of Russia [1].

Oil and gas resources are vital to Russian national security and economy; oil and gas alone account for roughly 20-25% of Russian GDP [3].

Arctic has been proclaimed as the resource base of the twenty-first century [1]. The Russian Arctic shelf in the future can become the main source of hydrocarbons for both Russia and the world market in the whole. Its industrial development in some circumstances (oil and gas prices, new knowledge and technologies, legal framework, etc.) may compensate decrease in oil and gas production in the old deposits in Russia (Western Siberia). The special role is assigned to up-to-date extraction technologies and oil and gas recovery technologies, providing energy effectiveness and ecology safety [4,5,6,7] and also to extraction of nonconventional oil and gas resources. One of the most important nonconventional sources of natural gas is gas hydrates (GH).

Gas hydrates are crystalline gas and water compounds with a variable composition. According to various estimates, natural gas hydrates contain about 2,000-5,000 trillion cubic meters of natural gas. Most part of these gas resources is concentrated in the Arctic Zone [7]. According to Russian estimates, up to 1,000 trillion cubic meters of gas hydrates may be present in the Russian Arctic [7].

In this paper we would like to pay special attention to the technologies providing gas hydrates production in the Arctic Zone and to the ecological aspect of this activity.

REVIEW

Despite the wide range of existing papers devoted to different aspects of Arctic zone development ward [8,9,10] perspectives of oil and gas production in the Arctic [9,11,12,13,14], there are no publications devoted to prospects of gas hydrates production in the Arctic that take into account peculiarities of the Arctic territories and necessity of environmental safety and compliance on this territories. Previous studies have addressed policy interests of different countries in the Arctic [14,15,16], Arctic energy policy and energy security [17,18], Russian thinking, policies, and challenges in the Arctic [19] and others.

There are a several technologies of gas hydrates production, which are proposed in numerous publications and researches [20,21], which are based on dissociation process and include: depressurization (decompression), thermal treatment (injection), chemical treatment, CO2 (carbon dioxide) or other gas injection.

Despite the enough quantity of technologies there is no any which has a stable wide commercial implementation, only several days' field tests.

Because of the growing interest for gas hydrates as a future potential energy source the ecological aspects is taken the leading role. The researches [22,23] show that methane hydrate recovery is a process with several important ecological problems. Firstly, hydrate is 25 times more active greenhouse gas as a carbon dioxide and massive methane releasing can be shortly the source of intensive global climate change. This issue is especially significant for Arctic region, which sensitive for any climate changes. But some papers [23] shows that global temperature rising to 0.08◦Cper year may cause heating the Arctic gas hydrate permafrost formations at a depth 198 m less than 100 years without technological impact, for any final conclusions the more researches should be done.

The second important problem is concerned with seabed stability for marine formations. The methane gas hydrate plays a leading role in stability of seafloor. Massive methane release could impact on fragile marine ecolife and cause sediment slide under gravity force down the continental slope.

So, many papers present case descriptions related to the Arctic and discuss such issues as geopolitics, politics interests, energy security, and others. A lot of papers devoted to oil and gas projects also are narrative and many papers are op-ed articles. However, there are not enough research papers focusing specifically on perspectives of gas hydrates production in the Arctic and ecological aspects of this activity. In fact, activities such as gas hydrates production in the Arctic have different underlying issues that could be taken into account. This paper sets out to research this issue.

ECONOMIC ISSUES OF GAS HYDRATES PRODUCTION IN THE ARCTIC

Today, there is only one pilot project of gas hydrate production, storage and transportation in Japan. That’s why now it is impossible to estimate the costs of such projects due to the lack of field trials of this technology in Russia (The Arctic 2015).

In general the commercial attractiveness of many Arctic projects is questioned [19]; for instance, economic efficiency of offshore oil and gas projects in the current conditions is low. Research conducted by the authors of this paper in 2011-2012 proved that these projects can be marginally profitable. The detailed calculations obtained on the basis of data of the Gazprom Company present that in case of oil price about 80-90 dollars for barrel Internal Rate of Return (IRR) of main oil and gas shelf projects is around 6-10%. Considering the oil price nowadays (55-60 dollars for barrel) it is logical that IRR considerably decreased. Taking into account the fact that technologies of gas hydrate's production, storage and transportation are not developed and are not adopted to the Arctic conditions in Russia, it is possible to assume that gas hydrate projects are less profitable than shelf oil and gas projects.

One more crucial problem of gas hydrate's projects in the Arctic is environmental safety and compliance. The additional concerns raised by increased industrial activity in the Arctic, in particular connected with oil and gas production, are currently leading to calls for greater attention to environment and ecology. The importance of ecological aspect in the Arctic cannot be overestimated: it is the area of global ecological concern [24].

ENVIRONMENTAL REGULATION OF NATURAL RECOURSES PRODUCTION IN THE ARCTIC

From the point of view of government regulation, many state documents have considered strategies of different countries in the Arctic [25-29]

The development of the Arctic region in Russia is governed at the state level bya set of different legal documents. The main document is The Strategy of developing the Arctic zone of the Russian Federation and national security system for the period till 2020.Analyzing the main acts and documenting it are possible to conclude that most likely; it has a theoretical character than practical. Russia does not have a comprehensive strategy in the form of an integrated and coordinated policy in the Arctic [19], including environmental regulation in the region. Even though a document entitled Strategy for development of Russia’s Arctic zone was adopted in 2013, this observation still stands.

An important role in environmental policy in the Arctic plays such international environmental organizations and structures as International Independent University of Environmental and Political Sciences, International Arctic Scientific Committee, Arctic Monitoring and Assessment Program, World Meteorological Organization, Greenpeace, World Wildlife Fund and others. The most influential are such international organizations as the Arctic Council, Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) and Helsinki Commission (HELCOM). Russia is a permanent member of the Arctic Council.

From the point of view of government regulation, set of state documents in different countries regulates environmental policy in the Arctic. Legal framework of the Arctic countries is presented in Table 1.

In spite of the fact that nowadays in Russia there is a number of documents fully or partly devoted to environmental regulation in the Arctic Zone, the environmental opposition to Arctic oil and gas projects is minimal in Russia [1]. In the past, Russia has not given environmental problems as much attention as many Western countries have, but an energy policy has now been presented for the public discussion as a Project of Energy Strategy of Russian Federation for the period till 2035 (edition of February 1, 2017). The Strategy objectives include improved energy efficiency as well as limitation of the impact of the fuel and energy complex on the environment and climate.

Table 1. Environmental regulation in the Arctic countries

Country	Regulatory documents and laws
USA	Federal Environmental Law. 999 edition. West Group 1999, 42 U.S.C.A. § 4321 to 4370b (1999) Comprehensive Environmental Response, Compensation and Liability Act – CERCLA (1980) Outer Continental Shelf Lands (OCSLA) (1972) Marine Protection, Research and Sanctuaries Act (MPRSA)(1972) Energy Policy Act (2005)
Canada	Northwest Game Act (1906) Arctic Waters Pollution Prevention Act (1970 R.S.C. 1985) Gas Flaring and Venting in Alberta: Report and Recommendations for the Upstream Petroleum Industry by the Flaring/Venting Project Team. – Clean Air Strategic Alliance (2002) Canadian Environmental Protection Act (CEPA) (1999) Canadian Environmental Assessment Act (CEAA) (2012) Reclaimed Industrial Sites Act (2006)
Denmark	Consolidated Environmental Protection Act № 698 (1998) Act No. 292 of April 27, On Access to Information Relating to the Environment «Environmental Information Act» (1994) Act no. 420 of June 13, on Waste Deposits (1990) Greenland Bureau of Minerals and Petroleum Drilling Guidelines (2011)
Norway	Act relating to petroleum activities in 1997 (“1997 Petroleum Regulation”) Guidelines for offshore environmental monitoring (2011)
Russia	Federal Law on Environmental Protection (2002) Federal Law on the Continental Shelf of the Russian Federation (1995) Federal Law dated July 31, N 155 On Internal Sea Waters, Territorial Sea and Adjacent Zone of the Russian (1998) The Federal Law «On Specially Protected Natural Territories» dated March 14, № 33 (1995)

TECHNOLOGICAL AND ENVIRONMENTAL ISSUES OF GAS HYDRATES PRODUCTION IN THE ARCTIC

The gas hydrate recovery technologies are based on dissociation process, i.e. hydrate separation on gas and water and can be joined in the groups as following: depressurization, heat treatment, chemical treatment.

These methods include decreasing pressure inside the formation around the drilling well or water or free gas pressure on the hydrate after it removing.

Depressurization

Numerous theoretical and field researches reveal that the depressurization is the most effective method for GH recovery. The main idea of this method is decreasing pressure inside the formation around the well or water or free gas pressure on hydrate seam. Depressurization is effective for the deposits with depth more 700 m, especially for located near the free gas layer.

The technology firstly has been field tested within the framework of Japanese-Canadian joint research program at the Mallik site, Canada, and has provided sustained production during 6 days with use of submersible pumps [31,32]. Mallik site is located at Canada permafrost region, where hydrate formation locates on depth more than 900 m.

The second field test of the depressurization technology was provided by Japan MH-21 program at Atsumi deposit but for the deep water conditions (depth around 1300 m). After 6 days test the production rate was 13 000 m^3 of methane.

The main feature of the depressurization technology is that it highly depends on the deposit location, so for marine reservoir (such as Atsumi, Japan), where the complicated formation structure was the reason of experiment stop, because the rock parties which was held by hydrate became mobile after hydrate dissociation and have blocked the well. But this test results shows the real recovery problems, the main of which can be solved with using sand-control methods or similar technologies.

Heat treatment

Heat treatment technology includes steam injection, hot water or brine injection, cyclic stimulation technologies, electrical heating [33].

Scientific experiments conducted at the Mallik site in arctic Canada (2002) was based on the injection on heated up to 80°C water. But technology has shown low results – 470 m^3 for 5 days when, as it was mentioned above, with the depressurization the 13 000 m^3 of methane has been produced.

The efficiency of this technology depends on the formation depth. The main drawbacks of the heat treatment technologies are high energy consumption, problems with heating agent transporting to the hydrate zone without heat loss and prevention of upper layers heating, long time dissociation process.

Chemical treatment

Chemical treatment technologies require injection of chemical inhibitors (methanol, brain, glycol etc.) for faster and efficient hydrate dissociation. But the main limiting point for these technologies is high ecological risks of using inhibitors and proven low speed of process. Another way of chemical methods is CO_2 injection, but it efficient only for water-bearing gas hydrates reservoirs, physical and chemical reactions are very difficult and require a numerous researches.

Analyzing above mentioned technologies, depressurization shows the highest potential, but combination of methods could provide more effective gas production.

The potential technologies for methane producing from GH are energy effective complexes, which could combine several recovery methods and guarantee the ecological safety. For instance, the electrothermal complex, created in Saint-Petersburg Mining University, which can be used for depressurization and combination of heat and chemical treatment [34].

Despite of complex gas hydrate formation recovery the much more important problem need to be taken into account – the ecological risks, especially for Arctic region.

Ecological impact

Today's research about gas hydrate impact on climate change is numerous, but only several make some predictions for Arctic region. But most of them are about the risks of massive methane release after uncontrolled hydrate dissociation, which has no connection to technological treatment.

Gas from hydrate is powerful greenhouse gas and this fact is very important and need to be considered for the Arctic regions. The East Siberian Arctic Shelf at Svalbard formation [35,36] reveals the release of methane from the Arctic zone to the ocean, but the source of gas is not clear. That is why releasing the methane due to technological treatment need to be researched carefully. After that the potential risks and limitation of used methods for Arctic can be evaluated. Proved fact is that for GH formation with low depth drilling process is the reason for gas releasing and occurrence of accidents.

Another ecological issue is impact of possible hydrate production from marine deposits to stability of seabed. Strict bonds of hydrate with the near formation provide the seafloor stability and it methane extraction could rise seafloor slumps. Nevertheless, the research of the large slide in the Cape Fear shows low impact of hydrate on this process detailed study of the largest slide feature (the Cape Fear slide), has shown little evidence of a significant role for gas hydrates in that. To prevent seabed deformation can be used technologies proposed the replacement of hydrate-forming gases by pumping seawater with the dissolved natural hydrogen sulphide [37].

DISCUSSION

The aim of this paper has been to go a bit beyond general sweeping statements about gas hydrates production, when it comes to dealing with the new challenges, not only technological, but also ecological as well.

On the basis of the conducted research we would like to infer following results.

First, it is necessary to improve the legal component in the sphere of oil and gas production in the Arctic, in particular of gas hydrates. Special attention should be paid to environmental issues as the ecosystem of the Arctic represents quite fragile system. The monitoring of ecological situation must be hold regularly. And all available technologies for gas hydrates production must be tested out with respect to environmental safety.

Assignment responsibility on oil and gas operators for keeping ecological standards in the area of environmental management should be associated, on the one hand, with various benefits and tax incentives to stimulate the introduction of new environmental friendly knowledge and technologies, and, on the other hand, with increasing of fines and the introduction of different sanctions for failure to comply with environmental obligations.

As it is shown from above the only technologies which was field tested at the Arctic region is depressurization, and it shows impressive results. Other technologies has a lot of limitations for implementing for the regions with fragile ecosystem, heating technologies is very energy demanding, but Arctic deposits mostly locates at the far from developed energy systems and heating process require careful control. Further way for technologies development is teting of complex methods for GH treatment, evolution of heating technologies with low energy consumption, preventing near layers damage.

CONCLUSION

In the whole, at this stage the Russian Federation largely keeps up from the European countries and USA in the sphere of environmental issues, that is why close cooperation with international ecological organizations can have a positive effect both on the development of the national science and in this area, and on the improvement of new ecologically friendly technologies. Active ecological policy in respect of distinguishing technologies for oil and gas production in the Arctic will help to save ecosystems of the most important strategic region of the Russian Federation and the whole world for the further effective and sustainable development of the territories.

Gas hydrates are one of promising nonconventional sources of gas in the long term period. In this regard issues of development of ecologically safe technologies which will allow to get gas hydrates is especially relevant. The ecological risks are the main point for future gas hydrate production, and technological progress should be based on the ecological safety, and could be provided in the following ways:

1) Government and public control for any implemented Arctic hydrate recovery technologies
2) Complex research of drilling process for GH formation
3) Proved by numerical researches and simulation, field test efficiency and safeness of implemented technologies for Arctic deposits
4) Careful technology control – control for formation condition, gas production rates prevention of creating so called gas-hydrate bomb
5) Control on hydrate decomposition and gas releasing through evaporation
6) Exclude aggressive inhibitors based technologies for Arctic zone
7) Careful control for heating methods, preventing heating of near layers.

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