Investigation on Water Resource Risk of Shale Gas Exploration and Development

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Abstract. For the Sichuan basin of China, water resources are scattered in various regions, limiting the development of shale gas. Exploitation of shale gas has undoubtedly aggravated the contradiction between supply and demand of water resources. For this problem, from the enterprise level, use technological innovation, control the source, and use technological progress to make up for the shortcomings of energy development and water resource health. Strengthen the whole process supervision, set up monitoring points in an all-round way before mining, during mining and after mining, and regularly monitor the water quality and water body in the mining area. For the government, scientific and technological innovation should be encouraged, relevant laws and regulations and industry regulatory system should be improved, resource allocation should be optimized by various means, and regional shale gas development strategy should be scientifically and systematically planned.

Keywords: Shale gas, exploration and development, water resources, risk

1 Introduction

In recent decades, shale gas, as a new clean energy, has become a new trend in the energy field [1]. The United States is the world's leading power in developing the shale gas economy, with profound capital and technology accumulation. For the past two decades, the shale gas production in the United States has increased by about 20 times [2,3]. The vigorous development of the United States in the field of shale gas made the world pay attention to shale gas, and China has also increased its research in this area [4,5]. After decades of research, China has successfully exploited shale gas in Sichuan Basin and its surrounding key areas, and based on it, the total amount of shale gas in China will eventually reach 200×10^8m3 by 2020, now China is paying more attention to it and will increase the exploitation of shale gas in Sichuan Basin [6].

Shale gas is bound to be an important part of national energy, so its exploitation is very critical. However, unlike conventional natural gas, shale gas and its development

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characteristics determine that it cannot be effectively developed under conventional exploitation mode, and must rely on hydraulic fracturing technology. In addition, this technology has the characteristics of high water consumption and a large amount of polluted wastewater will be produced. It is necessary to conduct research to establish relevant measures to solve economic, environmental and energy problems, which is conducive to the long-term development of energy in China.

2 Water resource consumption for shale gas exploration and development

The consumption of water resources for shale gas exploitation is mainly due to the use of horizontal drilling and hydraulic fracturing technology, which is unavoidable. A lot of water is required in various shale gas development links (see Figure 1), but hydraulic fracturing costs the most. According to statistics, there will be more than 1000 shale gas wells in South Sichuan in 2021. Considering the exploration and development process of shale gas, the water consumption cannot be underestimated.

2.1 Drilling, cementing and well washing

The first step of rock gas exploitation is drilling, through which the formation can be drilled into a borehole, and drilling equipment and drilling fluid are required. The drilling fluid is mainly composed of clean water and mud, which is the circulating fluid during drilling. Shale gas drilling is not very different from conventional oil and gas drilling, but with the increase of shale gas well length, its water consumption is far more than that of conventional oil and gas wells. At present, the water consumption of shale gas in Sichuan Basin is 600-700 m^3 for each well.

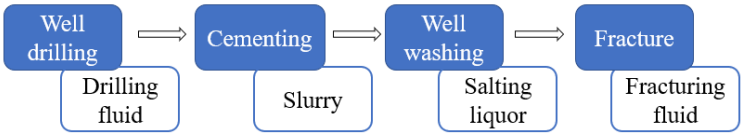

Fig. 1. Water use in shale gas development (original figure)

The main job of cementing is to run casing into the well, and then inject cement between the wellbore and casing to protect and support the casing in oil and gas wells. A small amount of cement is required in the cementing process, which creates a demand for water resources. At present, the cementing cement demand in Sichuan Basin is not large, and only 80 m3 of water is needed for wells 3000 to 4000 meters deep, which is much less than that in the United States.

Well flushing is conducted after the completion of cementing operation. The prepared well flushing medium is injected through the wellbore or drill pipe with pumping equipment, which can bring the gas, liquid and solid impurities out of the ground, so the nature of the medium in the wellbore can be changed and the purpose of well flushing can be completed. The well flushing medium used in the well flushing process also

uses water. Taking the shale gas well in Sichuan Basin as an example, a conventional well flushing with a depth of 3000 to 4000 m requires 90-120 m^3 of water.

2.2 Fracturing

Fracturing is a common method in shale gas development. Injecting water containing chemical agents into the rock stratum can break the rock through hydraulic application to release shale gas. The principle of this is to change the permeability of shale through the injection of chemical agents, thus speeding up the exploitation of shale gas. Due to the special way of shale gas storage, most of the current exploitation is through hydraulic fracturing. Although its efficiency is high, it also increases the water consumption. Compared with the 900-1200 m^3 natural gas straight wells in Sichuan Basin, the fracturing water consumption of shale gas horizontal wells is 20 times more than that of conventional natural gas straight wells. As the shale gas level will be re fractured later, this will cause additional water demand.

3 Water pollution in shale gas exploration and development

Water pollution during shale gas development is closely related to its development technology. The most critical technologies for shale gas reservoir development are horizontal well and horizontal multi-stage fracturing technology. After decades of development, this technology has become indispensable in the field of shale gas exploitation and is still developing in practice. Compared with conventional natural gas, this technology will use a large amount of drilling fluid and fracturing fluid and increase the discharge of production wastewater, causing surface water pollution and groundwater pollution to a large extent.

3.1 Drilling fluid

In recent years, with the rapid development of science and technology, the development of the oil and gas industry is also changing with each passing day. Therefore, with the updating and iteration of drilling fluid, the composition is becoming more and more complex, including more than 200 kinds of chemical reagents such as grease, weighting agent, organic colloidal polymer, etc. The specific pollutants are closely related to the type of drilling fluid.

Compared with the exploitation of conventional natural gas resources, the exploitation of shale gas involves long distance horizontal drilling in addition to vertical wells. The selection of drilling fluid for these two drilling methods is also different. For vertical wells, the drilling fluid is similar to that for conventional wells, while for horizontal wells, the drilling fluid should be selected according to the rock stratum. The drilling fluid will pollute the environment. During drilling, the drilling fluid may leak. If the drilling fluid leaks too much and enters the formation, it may also pollute the groundwater. Most of the chemicals in the drilling fluid enter the specially designed waste

storage pit with the drilling fluid, and cannot be discharged at will. However, the treatment of these drilling fluid wastewater is also a big problem. Some of them will be discharged into the nearby environment, which will cause huge pollution to the surrounding soil, water source and air.

3.2 Fracturing fluid

The situation of shale formation, the technology used and the time required for drilling determine the demand for fracturing fluid. Most fracturing fluid is composed of water, and proppant accounts for less than 10%. One fracturing requires 8000-19000 m^3 of water, and the rest is composed of chemical agents with different compositions. These additives consist of different chemicals. Its components are shown in Table 1, and each has specific functions. However, similar chemicals may seep into the ground, which has always been a concern and should be paid attention to.

Table 1. Composition and proportion of fracturing fluid in hydraulic fracturing [7]

Component	Common substances	Volume ratio	Function
Water and sand	Sand suspension	99.510	Fracture opening, dissolved mineral
Dilute acid	Hydrochloric acid or chloride acid	0.123	Crack
Inhibitor	Polyacrylamide, mineral oil	0.088	Reduce the resistance between fracturing fluid and pipeline and reduce pressure loss
Surface active agent	Isopropyl alcohol	0.085	Increase the viscosity of fracturing fluid to ensure that the proppant is suspended in the fracturing fluid
Salt	Potassium chloride	0.060	Maintain the viscosity of fracturing fluid when the temperature rises
Gelatin	Aluminum phosphate	0.056	Improve the high temperature resistance of fracturing fluid
Scale remover	Glycol	0.043	Prevent pipeline scaling
PH regulator	Sodium carbonate, potassium carbonate	0.011	Ensure the effectiveness of chemical additives
Decomposing agent	Sulfate	0.010	Promote fracturing fluid gel breaking flowback
Crosslinking agent	Sodium borate, zirconium trichloride	0.007	Promote crosslinking and thickening
Iron control agent	Citric acid	0.004	Prevent metal oxide precipitation
Corrosion inhibitor	N. N-dimethylamide	0.002	Prevent pipeline corrosion
Bactericide	Glutaraldehyde	0.001	Inhibition of bacterial growth

3.3 Production wastewater

In terms of production wastewater, because drilling fluid and fracturing fluid contain many chemical components, part of the chemical substances in production wastewater are from drilling fluid and fracturing fluid, and about 10% - 40% of the injected fracturing fluid returns to the surface during hydraulic fracturing.

Halides, strontium, barium and some radioactive substances, organic and inorganic substances will be adsorbed by the formation during fracturing. In addition, if the production wastewater cannot be properly disposed, which will lead to leakage, it will cause incalculable losses to the environment [8]. Treating the wastewater from shale gas development is a difficult and important task.

The content of water resources plays an indispensable role in the exploitation of shale gas. At present, China's shale gas is mainly exploited in Sichuan Basin, and will continue to be exploited on this basis in the future. Sichuan Water Resources Bulletin shows that the average annual total amount of water resources in Sichuan Province is 2564.7×10^8 m^3, ranking the second in China. Although there are many water resources, many problems remain unsolved. It has the following characteristics: (1) the total water resources is in the hinterland of the basin, which accounts for 80% of the total population and economy. (2) The uneven distribution of water resources between and within years has caused frequent droughts in Sichuan Province. (3) Extensive utilization of water resources makes the utilization rate of water resources in Sichuan Province only 30-40%. (4) There are a lot of high energy consumption and high pollution industries in the province, leading to water unavailability and aggravating the contradiction.

4 Risk Solutions

With the consumption of conventional energy, the global energy structure has begun to change, gradually turning to the situation of paying equal attention to both conventional and unconventional energy. The particularity of shale gas exploitation determines that it has a certain impact on water resources. Water resources are closely related to people's production and life, so how to minimize the impact on water resources while exploiting shale gas is a problem that needs to be closely concerned by relevant subjects of shale gas exploitation.

4.1 Enterprise measures for risk prevention

Shale gas exploration enterprises make use of technological innovation to make up for the weakness of energy development and water resource health. Firstly, the selection of shale gas development area, water resource environmental carrying capacity and gas well design is optimized. Use effective tools to comprehensively consider the economic benefits and water resources benefits of shale gas enterprises. Secondly, in the process of shale gas exploitation, water consumption and pollution are largely determined by the construction quality of construction enterprises. The enterprise's construction technology innovation aims to effectively control water consumption and flowback, ensure

the rational use of chemical components of drilling fluid and fracturing fluid, and minimize the impact on the water environment. In addition, the composition of waste water from shale gas exploitation is complex, and the requirements for treatment technology are high. Optimizing the combination of various single technologies is conducive to efficient treatment of flowback liquid, and even if wastewater leaks, the pollution to water resources can be minimized.

Shale gas exploitation enterprises should control the impact on water environment during exploitation by means of management. Before exploitation, the local water resources and water quality shall be strictly evaluated, and the HSE work in the early stage shall be well done to ensure the coordinated development of social economy and water environment carrying capacity. During the drilling process, the water-based, oil-based and other solid wastes and flowback fluids shall be properly treated to form a set of systematic pollutant treatment standards, which shall be strictly followed. The enterprise shall set up water environment monitoring points during the whole mining process to regularly monitor the water quality and water body near the mining area. Enterprises should also conscientiously implement the production management specifications and relevant laws and regulations on water environment protection, improve their awareness of water environment protection, and earnestly assume the responsibility of protecting water resources.

4.2 Government measures for risk prevention

For the government, shale gas development strategies and implement effective water resources optimization management plans are important. Through the assessment of water environment carrying capacity, scientific shale gas exploitation planning is formulated, shale gas exploitation and water resources protection measures are formulated, and sustainable development is achieved by optimizing resource allocation. The idea of water resources protection that gives priority to scientific planning, focuses on technical treatment and covers the bottom of end treatment should be formed. Formulate relevant measures to ensure the normal and safe exploitation of shale gas. On the basis of ensuring no damage to the environment, set incentive policies to encourage rational exploitation of shale gas energy, comply with the national energy plan, and promote the national energy development. Improve relevant laws and regulations, and mine under the premise of laws; Putting people first and ensuring people's safety.

Improving government regulatory policies and establishing laws and regulations to improve water resources' strange ability can also constrain the generation of water resources risks from the outside [9]. Improve the construction quality standard of storage facilities, reduce the risk of spillage or leakage, and build and improve the monitoring system. As long as relevant enterprises can meet the standards in the document, they can control water resources, improve the protection level of water resources, and reduce the pollution and loss of water resources. Now, the environment has more and more influence on people's life, and people's environmental awareness has been improved. The proper treatment of drilling fluid has become a problem that the entire industry has to pay attention to.

5 Conclusions

In this paper, water resource risk of shale gas exploration and development is studied. Water resource consumption for shale gas exploration and development includes: drilling, cementing and well washing, and fracturing. Water pollution of shale gas exploration and development is presented, including drilling fluid, fracturing fluid, and production wastewater. Based on the conditions, risk solutions are given, including enterprise measures for risk prevention and government measures for risk prevention.

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