frontiers | Frontiers in Energy Research

OPINION
published: 08 April 2022
doi: 10.3389/fenrg.2022.859696

The Opinion of CO_2 Storage Potential of Heavy Oil Reservoirs in the Junggar Basin

Yuhui Zhou[1,2], Kaiwen Dong[1,2], Haiyan Zhao[3] and Qiang Guo[4]*

[1]School of Petroleum Engineering, Yangtze University, Wuhan, China, [2]Key Laboratory of Drilling and Production Engineering for Oil and Gas, Wuhan, China, [3]Design Branch of PetroChina (Xinjiang) Petroleum Engineering Co. Ltd., Karamay, China, [4]Shanshan Oil Production Plant, Tuha Oilfield Company, CNPC, Hami, China

Keywords: CO_2 storage, storage capacity, mechanism of CO_2 storage, heavy oil reservoirs, carboniferous reservoirs

OPEN ACCESS

Edited by:
Qi Zhang,
China University of Geosciences Wuhan, China

Reviewed by:
Shuyong Hu,
Southwest Petroleum University, China
Xiang Zuping,
Fisheries Research Institute of Zhao Qing, China

****Correspondence:***
Kaiwen Dong
603483769@qq.com

Specialty section:
This article was submitted to Carbon Capture, Utilization and Storage, a section of the journal Frontiers in Energy Research

Received: *21 January 2022*
Accepted: *15 February 2022*
Published: *08 April 2022*

Citation:
Zhou Y, Dong K, Zhao H and Guo Q (2022) The Opinion of CO_2 Storage Potential of Heavy Oil Reservoirs in the Junggar Basin. Front. Energy Res. 10:859696. doi: 10.3389/fenrg.2022.859696

INTRODUCTION

On May 2021, 131 countries with more than 65% of greenhouse gas emissions and 75% of gross national product have established the goal of carbon neutrality. As one of the largest emitters of carbon dioxide, with 103.57 million tons of CO_2 emissions every year, China should put more cocentration on carbon dioxide emissions (Lu, 2021).

Carbon capture utilization and storage (CCUS) technology is currently considered to be the most promising technology for reducing greenhouse gas emissions. Studies by international organizations such as IPCC, IEA, GCCSI, and others show that CCUS technology is indispensable to achieve the targets for greenhouse gas emission reduction (Yu, 2020).

CO_2 capture and storage (CCS) technology can not only drastically reduce the concentration of CO_2 but also inject captured CO_2 into special underground geological structures to achieve the purpose of permanent storage of CO_2. The geological structures that are used to store CO_2 include oil and gas reservoirs under development or abandoned, deep brine layers, and oil reservoirs without exploitation value (Wang et al., 2021). CO_2 injection into oil and gas reservoirs can not only achieve CO_2 storage but also increase oil and gas recovery (Duan et al., 2018; Liu et al., 2018), which is currently the main form of CO_2 storage and has good economic benefits.

In 2007, China designed the first domestic CO_2 storage project in the Jilin oil field and the Caoshe Oilfield of East China Branch of Sinopec and achieved industrialization of the CCUS–enhancement oil recovery (EOR) technology. The annual CO_2 storage amounted to 350,000 t. In 2012, the Yanchang Oil Company completed a 50,000 t/a CO_2 capture and utilization project. The project used CO_2 that was produced by the coal chemical industry, and purified and pressurized liquefied by low temperature methanol washing technology, which was then injected into the oil field permanently. The viscosity of the crude oil was reduced, the recovery rate of the crude oil was increased, and then the permanent storage of CO_2 realized. In 2015, the CCUS project of refinery tail gas in Sinopec Zhongyuan oil field was completed, and the project was close to abandoned oil fields. The recovery rate of the oil field was increased by 15% by CO_2 flooding. At present, millions of tons of CO_2 has been stored underground (Zhang X et al., 2021; Li, 2018) (**Figure 1**) reflects the mechanism of CO_2 storage and is intended to provide the reader with a better understanding of the storage process.

Increasing the oil recovery rate by CO_2 flooding is the most economical and effective means to achieve greenhouse gas emission reduction and deal with world environmental problems at this stage. At present, some oil reservoirs in China have carried out field tests of CO_2 flooding and achieved preliminary success. However, there are few studies on the development of heavy oil reservoirs by using CO_2 flooding to increase recovery and storage efficiency. Whether heavy oil

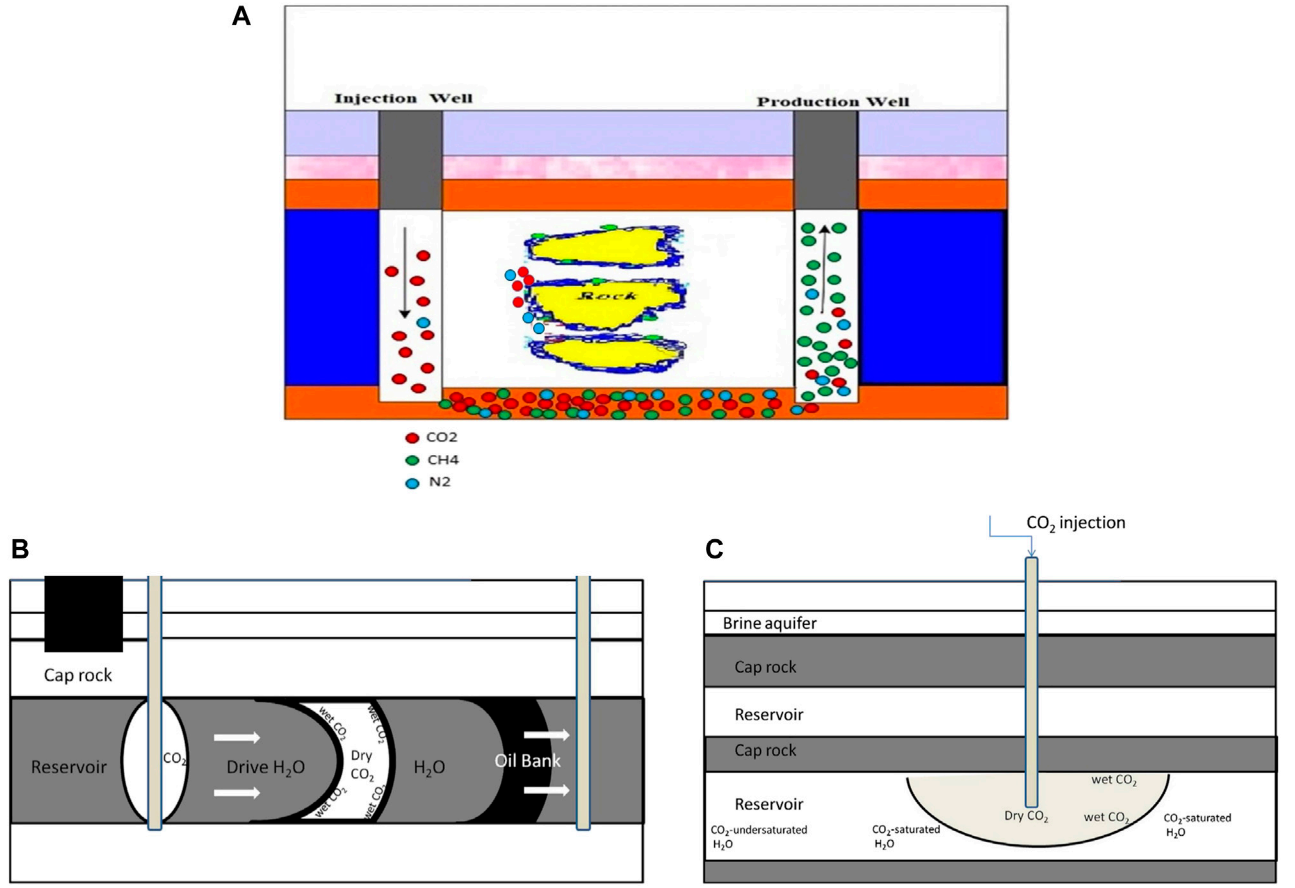

FIGURE 1 | Schematic diagram of CO_2 storage mechanism. Sources: Wang et al. (2013) and Syah et al. (2021). **(A)** The supercritical CO_2 injection into porous media. **(B)** Schematic diagram of CO_2 injection to enhance oil recovery. **(C)** Schematic diagram of CCS scenario in a saline aquifer.

reservoirs are suitable for using CO_2 flooding to increase recovery and storage technology still lacks in-depth studying (Wang, 2010; Wang et al., 2013).

The Junggar Basin has rich heavy oil reservoirs, which are distributed in 29 layers of six oil fields in the northwestern margin and two eastern oil zones. According to the 2020 data, Xinjiang Oilfield has developed more than 1 billion tons of heavy oil resources and a cumulative proven oil area of 348.9 km^2 and geological reserves of 596 million tons. Currently, water flooding and steam stimulation are mainly used as the main development technologies. Through the exploitation experiences for heavy oil reservoirs in the Junggar Basin, the results show that the development of heavy oil reservoirs is faced with many problems, such as low overall production, large production decline, high injection–production ratio of heavy oil, serious formation deficit, significant drop in stratigraphic pressure, and poor development effect.

After years of research and a large number of CO_2 storage tests, the geological storage of CO_2 is technically feasible, but people have been worried and in doubt about whether the stored CO_2 will leak (the safety of store CO_2) (Ren et al., 2017), which is one of the important factors restricting the development of CO_2 geological storage technology. In addition, with the development of more and more CCUS projects, the screening and evaluation of stratigraphy will be essential (Geng et al., 2009). Reservoir screening studies have also been developed over many years with the implementation of the EOR program (Luo et al., 2013; Tan et al., 2015), and there are many existing methods and screening criteria. The methods to screen and evaluate the existing research criteria have far-reaching significance for the studies of increased oil recovery and storage efficiency with CCUS technology.

Mechanism of Carbon Dioxide Storage in Reservoirs

1) Oil and water in the reservoir occupy a certain space, and CO_2 is injected into the exploited oil layer by CO_2 flooding for increasing oil recovery. Under a high pressure condition, crude oil is driven by CO_2 to flow to production wells, and oil recovery is increased accordingly. A part of CO_2 is stored in formation pores or dissolved in crude oil that cannot be exploited; and a part of CO_2 is discharged from the production wells and injected circularly with crude oil, water, and natural gas.

2) CO_2 can be dissolved in residual oil and residual water. Because the oil–water with dissolved CO_2 is heavier than that without CO_2, the oil–water with dissolved CO_2 can be deposited for a long time.
3) CO_2 is weakly acidic after encountering with groundwater, and it can react with minerals around rocks to form new minerals, and thus CO_2 is permanently stored. But the trap is small and the reaction is slow.
4) If there is edge and bottom water in the reservoir, CO_2 can be injected into this part of the water layer and be dissolved in water. After a long time, the water that is saturated with CO_2 becomes more and more viscous, and it is easy to store in the formation for a long time no longer upward migration to increase the storage capacity (Zhang and Lv, 2021).

CO_2 Storage in the Reservoir Has the Following Main Advantages

1) Professional technical experience of CO_2 flooding has been accumulated in the process of reservoir development.
2) CO_2 injection for increasing oil recovery has been tested and the economic benefits of this have been achieved.
3) The storage state of natural CO_2 gas reservoir reveals that favorable geological structure conditions can store CO_2 for a long time. The cost of CO_2 storage in depleted reservoirs is lower, and the economic and environmental benefits are remarkable.

Main Factors Affecting CO_2 Storage

Rock Properties

A certain amount of CO_2 can be stored through the reaction of CO_2 with mineral rocks, but not all mineral rocks can react with CO_2. Only those mineral rocks containing Fe/Ca/Mg can react with CO_2 to form siderite, calcite, and dolomite. But the reaction of mineral rocks with CO_2 can also bring some adverse effects, such as reducing formation permeability and CO_2 injection capacity.

Oil Field Water Character

The solubility of CO_2 in formation water is mainly affected by the salinity of formation water; in general, the solubility of CO_2 decreases with the increase of formation water salinity.

Crude Oil Properties

The solubility of CO_2 in crude oil is mainly affected by the properties of the crude oil. Generally, CO_2 solubility in light oil is higher than it is in heavy oil.

Reservoir Temperature and Pressure

The phase state of CO_2 is significantly affected by temperature and pressure. When CO_2 is in the supercritical state under reservoir temperature and pressure, it is the most suitable for geological storage. Low reservoir pressure or high reservoir temperature are not suitable for CO_2 storage.

CO_2 Storage Capacity of Jiuqu Carboniferous Reservoirs in Junggar Basin

Jiuqu Carboniferous reservoir is located 40 km northeast of Karamay and is located in the upper plate of Baijiantan South Fault in the northwestern margin of the Junggar Basin alluvial zone. The top surface of Jiuqu Carboniferous bedrock is a fault nose with northwest–southeast tilt controlled by the Xibaibaibai fault, the central fault of Jiuqu and the fault of Well Jian 229 in the upward direction. Jiuqu and Jiuqian 25 well areas are located in the upper part of fault nose structure and monoclinic fault blocks controlled by Xibaibaibai fault, central Jiuqu fault, Jiuqian 25 well fault, and Jian 229 well fault. The high point of storage depth for Carboniferous reservoir in this area is 220 m, which shows the pattern of low in the southeast and high in the northwest. The slope of the erosion surface at the top of the Carboniferous is 3°–10°, and the slope of paleogeomorphology gradually becomes steeper along the dip direction of the structure, and the storage depth is gradually deepened. The reservoir data and formation conditions of the Carboniferous in the ninth area are as follows: geological reserves is 1344.88×10^4 t, formation temperature is 26°C, formation pressure is 7.16 MPa, crude oil volume coefficient is 1.09, and CO_2 storage stock is 140×10^4 t.

Based on the numerical simulation model of carboniferous reservoir in nine districts and the optimization of numerical simulation parameters, the development effect of CO_2 flooding in the target area is predicted. The working system is as follows: daily gas injection rate is 2.5×104 m^3, water is injected once every 4 months to reduce gas channeling pressure, daily water injection rate is 40 m^3; define continuous work for 2 years as a cycle, a total of three gas injection cycles, each cycle continuous gas and water alternate four times, its time-exhausted production; the predicted time was 15 years from May 1, 2012, and compared with the failure plan. The simulation results show that the recovery rate is 12.08% in the depletion stage and 18.08% in the CO_2 flooding stage. The recovery rate of CO_2 flooding is 6.0 percentage points higher than that in the depletion stage, and 4.07×10^4 t of CO_2 is stored in the gas injection production process.

CONCLUSION

After the description on the sequestration status for natural CO_2 gas reservoirs (Guo et al., 2016), it shows that favorable geological structures are capable of storing CO_2 for long periods of time, in which the cost is low and the economic and environmental benefits are significant. The main factors that affect CO_2 storage include: rock properties, formation water properties, crude oil properties, and reservoir temperature and pressure.

In the coming decades, CO_2 storage technology is one of the most promising ways to solve the problem of carbon emission. In the long run, the cost of CO_2 storage technology will be lower. Hence, in the field of carbon emission reduction technology in China, CO_2 geological storage technology is a potential breakthrough.

At present, many CCUS projects prefer oil and gas fields as storage sites. In the process of oil and gas exploration and development, the oil and gas industry has accumulated rich geological data and has a natural advantage in carrying out carbon dioxide storage (Wang et al., 2013). CCUS technology that combines CO_2 storage with EOR, which integrates the utilization and storage of carbon dioxide, has received great attention in recent years with the continuous expansion of unconventional oil and gas development.

China's Junggar Basin is rich in heavy oil resources and has the conditions for studying CO_2 flooding to increase recovery and storage technology. Therefore, it is of great theoretical value and strategic significance to carry out the feasibility study of CO_2 flooding development and storage technology in heavy oil reservoirs in the Junggar Basin.

AUTHOR CONTRIBUTIONS

YZ, KD, HZ, and QG contributed equally to this work.

REFERENCES

Duan, Y., and Luo, H. (2018). On the Experience of CCUS Demonstration Projects at home and Abroad. *Shandong Chem. Industry* 2018, 47.

Geng, X., and Wang, H. (2009). *Discussion on the Storage Site Selection of Waste Oil and Gas Reservoirs*, 11.

Guo, P., and Xu, Q. (2016). Research Progress on CO2 Flooding and Geostationary Storage Technology of Natural Gas. *Lithologic Reservoirs* 2016, 28.

Li, Y. (2018). *Key Utilization of CCUS, PetroChina Petrochemical*, 1.23

Liu, H., Zhao, D., and Gu, J. (2018). Research Dynamics and Storage Potential Evaluation of CO2 Flooding Technology. *Chem. Management* 2018 (13), 1.

Lu, X. (2021). Progress in CCUS Applications in the Oil and Gas Industry. *Oil Gas Geology.* 42 (04), 1.

Luo, E., Hu, Y., and Li, Z. (2013). *Geostationary Storage and Application of CO2 Xinjiang Oil and Gas*, 9. doi:10.1155/2013/414193

Ren, S., and Han, B. (2017). *Analysis of CO2 Leakage Mechanism and Fault Tree in Oil Reservoirs, Journal of China University of Petroleum (Natural Science Edition)*, 1.01

Syah, R., Alizadeh, S. M., and Nurgalieva, K. S. (2021). A Laboratory Approach to Measure Enhanced Gas Recovery from a Tight Gas Reservoir during Supercritical Carbon Dioxide Injection. *Sustainability* 13 (21), 1. doi:10.3390/su132111606

Tan, Y., and Ruan, H. (2015). *Research on the Chemical Storage Mechanism of CO2 in Waste Low Permeability Sandstone Gas Reservoirs Journal of Chongqing University of Science and Technology (Natural Science Edition)*, 17.

Wang, H., and Liao, X. (2013). *CO2 Flooding in Xinjiang Oilfield Increases Oil Recovery and Geological Storage Potential Evaluation, Journal of Shaanxi University of Science and Technology (Natural Science Edition)*, 1.02

Wang, R., Li, Y., and Lv, C. (2021). The Deep Brackish Water Layer of the Ordos Basin CO2 Research on Methods for Evaluating Water Repellent and Storage Potential. *unconventional oil and gas* 8 (5), 50–55.

Wang, T. (2010). Analysis of CO2 Storage Potential and Influencing Factors in Brine Layer. *Lithologic Reservoirs* 22 (S1), 85–88.

Wang, X., Alvarado, V., Swoboda-Colberg, N., and Kaszuba, J. P. (2013). Reactivity of Dolomite in Water-Saturated Supercritical Carbon Dioxide: Significance for Carbon Capture and Storage and for Enhanced Oil and Gas Recovery. *Energ. Convers. Management* 65, 564–573. doi:10.1016/j.enconman.2012.07.024

Yu, Z. (2020). *CCUS under the Carbon Neutrality Target, Energy*, 1.12

Zhang, X., Li, Y., and Ma, Q. (2021). Research on the Development of Carbon Capture Utilization and Storage Technology in China. *China Eng. Sci.* 2021, 23.

Zhang, Z., and Lv, G. (2021). *CCUS Technology and Application of Shengli Oilfield, Reservoir Evaluation and Development*, 11.

Conflict of Interest: Author HZ is employed by the Petroleum Engineering Co. Ltd. Author QG is employed by the Tuha Oilfield Company, CNPC.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.