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Editorial

China actively promotes CO_2 capture, utilization and storage research to achieve carbon peak and carbon neutrality

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Global climate change is a common challenge facing mankind, which has evolved from a scientific issue into a global economic and political issue of universal concern to the international community. Temperature increase, sea level rise, extreme weather and climate events caused by the climate change are becoming more and more prominent. The scientific understanding of climate change in the international community has been deepening. The Intergovernmental Panel on Climate Change (IPCC, 2014) further strengthened the scientific conclusion that human-induced climate change is more than 95% likely to be attributed to emissions of greenhouse gases from human activities.

The United Nations Climate Change Summit (held in September 2014) pointed out that climate change threatens the hard-won peace, prosperity and opportunities of all mankind, and that no one and no country is immune to its impact. Controlling global warming within 2°C is an urgent and severe challenge faced by mankind in dealing with climate change. The awareness of all countries on the issue of climate change is gradually increasing. The 26th Conference of the Parties (held in November 2021 in Glasgow, UK) urged all countries to achieve the net zero carbon emissions by around 2050, and step up efforts to reduce carbon emission before 2030. Therefore, taking active measures to cope with climate change becomes the common aspiration and urgent need of all countries.

Mitigating greenhouse gas emissions (represented by CO_2) has become the consensus of the world. In September 2020, Chinese President Xi Jinping pledged at the General Debate of the 75th Session of The United Nations General Assembly that China aims to peak its CO_2 emissions before 2030 and achieve carbon neutrality before 2060 (i.e., dual carbon goals), which demonstrates the responsibility of a major country.

CO_2 Capture, Utilization, and Storage (CCUS) is considered as an effective technology directly achieving carbon emissions mitigation, and has attracted widespread attention of the international community (Metz et al., 2005). The implementation of CCUS projects began in the 1970s, and was mainly carried out in the United States, Canada and some European countries. Those projects mainly focused on CO_2 enhanced oil recovery, whereas projects with the pure purpose of CO_2 sequestration are relatively rare due to their poor economy.

CCUS projects in China started relatively late, and most of them were gradually implemented after 2000 (Guo et al., 2014). The initial technical routes of these projects were similar to those of projects carried out in European and American countries, which began with the geological sequestration of CO_2 and enhanced oil recovery. In the past decade, CCUS projects in China began to develop in a diversified way, and there emerged a variety of carbon dioxide capture, storage and utilization technologies, including pre-combustion capture of power plants, CO_2 chemical and biological utilization, etc.

The realization of the dual carbon goals not only requires

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revolutionary changes in industrial technology, but also largely depends on the formulation of relevant policies and capital investment. The National Natural Science Foundation of China launched a special research program "Major Basic Science Issues and Countermeasures for National Carbon neutrality" in 2021 to meet the needs of basic science research for the national carbon neutrality strategy. Focusing on the two core issues of "carbon emission mitigation" and "carbon sink increase", the special program includes a total of 28 research projects, with an average funding of about 3 million RMB per project.

This special research program aims to reveal the oceans and terrestrial carbon sinks, the process mechanism, evolution trend and its mutual feedback mechanism with the climate system, delineate the geological process of carbon sequestration and the effectivity of fixing carbon. The program also has goals to increase the potential of CO_2 storage, to assess the technology risk and management mode, to analyze the economic transformation, the optimal pathway, climate control, international cooperation management and policy issues. Interdisciplinary integration research is needed to condense key basic science issues and solutions for serving the national carbon-neutral strategy.

It is foreseeable that China will further increase investment in realizing a carbon emission peak and its carbon-neutral strategy in the future. This is also a great opportunity for the development of CCUS-related technologies. The contribution of CCUS technology in carbon emission mitigation is generally low today. For instance, even in Norway, which has the highest proportion of carbon emissions treated by CCUS, the value is less than 5% (Cai et al., 2020). However, as the guaranteed technology of carbon peak strategy, the contribution ratio of CCUS in carbon emission mitigation is expected to significantly increase in the future.

Although the CCUS technology has been implemented for many years and many projects have been carried out, there are still many challenges to be solved, such as:

(i) CCUS related technology development and cost control

The CCUS technology includes capture, transportation, utilization and storage, all of which need to consume a lot of energy. At present, the cost of the CCUS projects is still high. It is estimated that the cost of the whole CCUS process will be 150-540 RMB per ton of CO_2 by 2025, of which CO_2 capture cost accounts for more than two thirds of the total cost, about 100-480 RMB/ton. In comparison, the cost of CO_2 sequestration is 50-60 RMB/ton, while the cost of CO_2 transportation is very low, less than 1 RMB/ton (Cai et al., 2021). Obviously, the wider promotion of CCUS projects in the future largely depends on the further development of CO_2 capture technology and the rapid reduction of cost.

(ii) Effect of long-term CO_2-water-rock interaction on rock structure and mechanical properties

In the process of CO_2 geological storage and utilization, the injected CO_2 will inevitably change the pH of formation water, breaking the original water-rock balance and inducing a new water-rock reaction. Thus, the rock structure and mechanical properties of the caprock are likely to be changed over time, which affects the safety of the storage reservoirs. The current studies mostly focus on the effect of CO_2-water-rock interaction on the leakage channels (porosity and permeability) of the caprock (Credoz et al., 2009; Liu et al., 2020). However, the study on the change of rock mechanical properties caused by chemical reactions requires further research attention. A few previous studies only simply correlated the evolution of rock mechanical properties with porosity, but without considering the influence of changes in mineral composition induced by CO_2-water-rock interaction on the rock mechanical properties (Agarwal, 2019). Therefore, it is necessary to further deepen the relevant investigation and build a comprehensive rock mechanical parameter evolution model considering the changes of porosity, mineral composition and content, and other factors (Tian et al., 2019).

(iii) CO_2 leakage monitoring and risk assessment methods

The leakage risk of CO_2 after injection has been one of the main concerns, which directly affects the safety and feasibility of CCUS technology (Bachu, 2008). At this point, the construction of a CO_2 leakage monitoring system is particularly important. However, the CO_2 leakage process is usually characterized by sudden occurrence and weak surface response. Therefore, a single monitoring method is difficult to ensure the reliability of monitoring. In the future, it is necessary to combine various monitoring methods with their respective advantages.

For a long-term (more than 100 years) CO_2 leakage risk assessment, the most commonly used method at present is to employ the reactive transport modelling. However, due to the large time scale, parameter uncertainty and the difficulty of validation, the predicted results have high uncertainty. Some natural CO_2 gas reservoirs have existed for more than thousands of years (Jonathan et al., 2018). Taking natural CO_2 gas reservoirs as a natural analogue of CO_2 geological sequestration can solve the problem that long-term simulated results are difficult to verify, thereby improving the reliability of long-term risk assessment (Xu et al., 2019).

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Conflict of interest

The authors declare no competing interest.

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