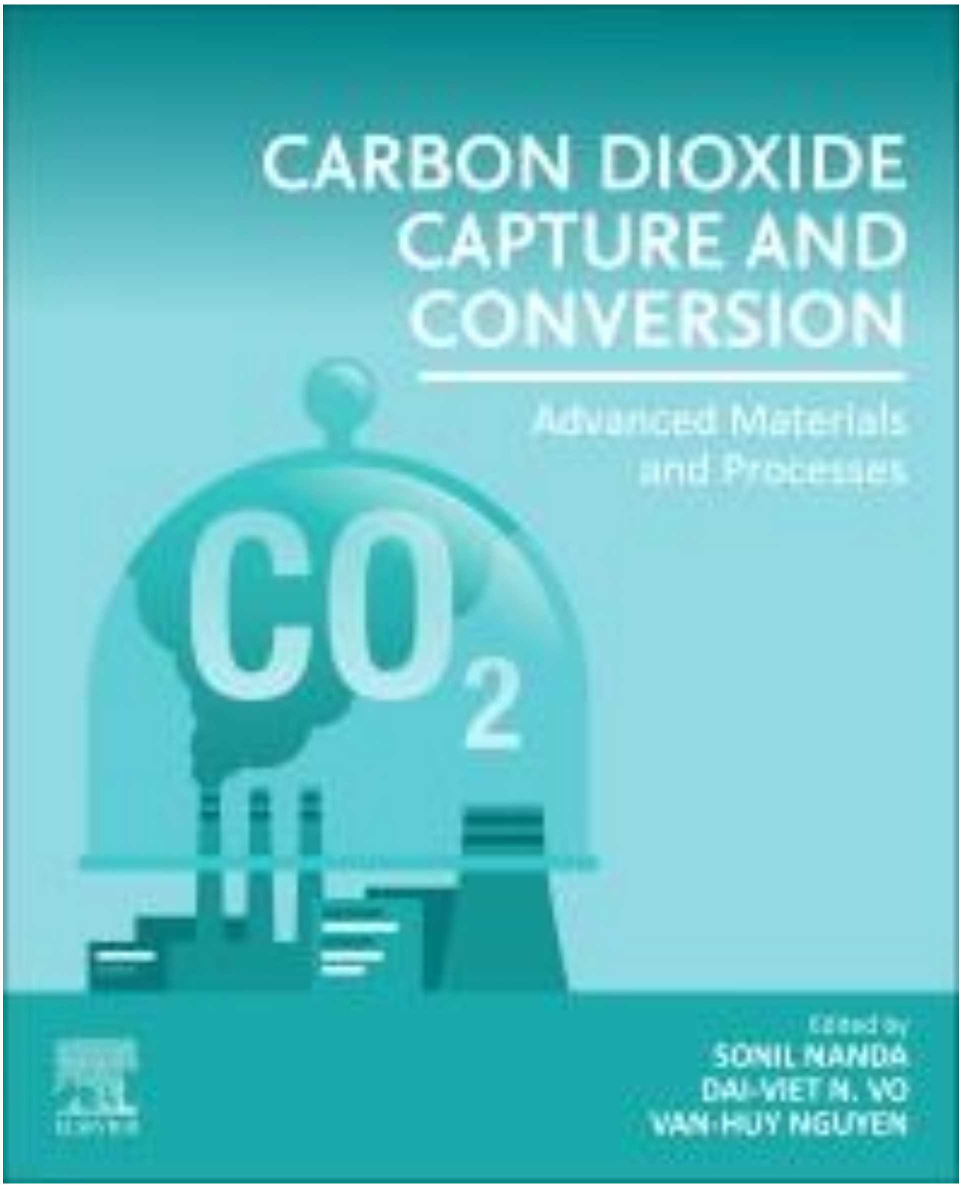

Carbon Dioxide Capture and Conversion

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Preface

Excessive utilization of fossil fuels and petrochemicals along with the increased industrial manufacturing processes, emissions from automobiles, and anthropogenic activities has resulted in a rise in the CO_2 levels in the atmosphere. A higher level of CO_2 in the atmosphere is a leading cause of global warming and climate change. Biofuels, biochemicals, and bioproducts have a lower carbon footprint because the CO_2 liberated from their end-use is utilized during photosynthesis to produce new plant biomass. Nevertheless, there is a growing interest in carbon capturing and sequestration techniques along with their utilization for manufacturing value-added industrial products. This book covers the current research and development of some leading technologies for capturing and utilizing CO_2 for high-value industrial processes and product manufacturing.

Chapter 1 by Patra et al. gives an overview of several sources of CO_2 generation along with some recent developments in CO_2 capturing and storage technologies. The chapter also discusses the utilization of CO_2 for producing value-added materials using various sustainable technologies. Chapter 2 by Ayodele et al. describes the prospects, challenges, and opportunities for sustainable utilization of CO_2 towards a circular economy. Processes such as reforming hydrocarbons and biomass, as well as hydrogenation, are reported for the utilization of CO_2 in producing renewable fuels and value-added products. Chapter 3 by Farooqi et al. comprehensively reviews the current progress and advancements of CO_2 conversion into valuable fuels, including methane, dimethyl ether, methanol, and gasoline. Chapter 4 by Leong et al. discusses the opportunity and challenges in the bioconversion of carbon sources, which could provide promising and closed-loop solutions for food security, energy, resource scarcity, and reduction of CO_2 emissions. Chapter 5 by Truong and Mishra gives a broad outline on the utility of homogeneous organic bases for the direct and smooth conversion of CO_2 into urea, carbamates, carbonates, polymers, carboxylic acid derivatives, methanol, and heterocyclic compounds. Chapter 6 by Berahim and Zabidi highlights the progress made by the ongoing research and development in the catalytic conversion of CO_2 into methanol with a focus on developing Cu/ZnO-based catalysts, catalyst activity, and the impact of process variables on the formation of products. Chapter 7 by Mahinpey et al. reviews the current progress made in the application of CaO-based sorbents in the calcium-looping process applied in post- and precombustion technologies. Chapter 8 by Alipour et al. describes the evaluation of various heterogeneous catalysts for the dry reforming process by utilizing CO_2. The chapter discusses the effects of catalyst components, catalyst preparation methods, and the impact of reforming process conditions on the catalytic activity and coke deposition. Chapter 9 by Okolie et al. provides an overview of the unique properties of supercritical CO_2 and its applications in industrial processes such as hydrotreating of biofuels, extraction of bioactive compounds, including cannabinoids, biomass pretreatment, sterilization of medical equipment, and conversion of waste heat into power. Chapter 10 by Yong et al. elucidates the fundamentals of gas transport through polymeric and inorganic membranes followed by membrane preparation strategies, modifications methods in polymeric and inorganic membranes as well as prospects of membrane separation for CO_2 capture. Chapter 11 by Monir et al. presents a detailed study of the effectiveness of the application of enhanced oil and gas technology in an unconventional petroleum reservoir. This chapter evaluates the prospects and challenges of CO_2 sequestration in oil and gas reservoirs for their enhanced recovery.

We are grateful to all the authors for contributing their high-quality chapters toward the development of this book. We also express our sincere thanks to the staff and associates at Elsevier for their enthusiastic assistance and support in the preparation of this book. Our special thanks go to Susan Dennis (Publisher), Emerald Li (Editorial Project Manager), R. Vijay Bharath (Production Project Manager), Sujatha Thirugnana Sambandam (Publishing Services Manager) and Christian J. Bilbow (Cover Designer).

Sonil Nanda
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CHAPTER 11

Sequestration of carbon dioxide into petroleum reservoir for enhanced oil and gas recovery

Minhaj Uddin Monir[1], Azrina Abd Aziz[2], Fatema Khatun[2], Mostafa Tarek[3] and Dai-Viet N. Vo[4]

[1]Department of Petroleum and Mining Engineering, Jashore University of Science and Technology, Jashore, Bangladesh
[2]Faculty of Civil Engineering Technology, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia
[3]Faculty of Chemical and Natural Resources Engineering, Universiti Malaysia Pahang, Kuantan, Pahang, Malaysia
[4]Center of Excellence for Green Energy and Environmental Nanomaterials, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam

Abbreviations

IEA	International Energy Administration
EOR	Enhanced oil recovery
EGR	Enhanced gas recovery
GHGs	Greenhouse gases
OOIP	Overall on-site initial oil
IFT	Interfacial tension
ppm	Parts per million

11.1 Introduction

Global energy demand has increased by 28% due to the ever-growing population, and the basic energy needs are being met by fossil fuels. Approximately 80% of the global energy consumption is met by natural sources, although these sources are nonrenewable (Asif and Muneer, 2007). They also reported that the world's electricity demand has been met by nonrenewable fossil-based fuels for thousands of years and are called primary energy sources. In contrast, the International Energy Administration (IEA) reported in their analyses that fossil fuels will be the primary source of energy supply for another half-century. It is high time to develop oil/gas recovery (EOR/EGR) techniques. EOR/EGR is a tertiary recovery method that has been extended to existing oil/gas fields to obtain existing oil/gas that is trapped or may not be recovered by

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11.3 Advanced oil and gas recovery mechanism

Primary recovery typically uses only reservoir pressure to stimulate production. Around 30% of the oil in the reservoir is normally derived via traditional pressure extraction techniques. Secondary recovery requires water, or sometimes steam, to be pumped in to maintain the pressure in the petroleum reservoir. The water is pumped back into the tank after it is flooded, to sustain the pressure of the reservoir (also known as the vacuum substitute) and sweep or displace the oil from the reservoir to drive it into the well. The concentration restored (known as the recovery factor) is increased by water injection and the reservoir production rate is sustained for a longer period. A term used by a wide variety of approaches to increase the volume of crude oil extracted from the oil field is tertiary or increased EOR. It is often connected to and followed by the formation of an area by water injection or by water flooding.

Thermal recovery methods are usually applied to viscous, hard crude oil, which involve the use of heat or thermal energy in the tank to raise the temperature of the oil, which, in turn, decreases its viscosity. To improve the recovery of oil, chemical methods are mainly used. It is a displacement process in which various kinds of chemical additives are used. The purpose of applying methods of chemical flooding is to control volatility by adding polymers to mitigate pumped water volatility and by using surfactants and/or alkalis to mitigate interfacial tension (IFT). Due to a shortage of high-temperature compatible chemical products and high salinity, chemical EOR is currently faced with major challenges, especially in light oil reservoirs (Hashemi et al., 2014). A schematic diagram of the oil well and gas well used for the extraction of oil and gas, respectively, from the reservoir is shown in Fig. 11.2.

Three processes are successfully preserved by chemical EOR technology: polymer, surfactant-polymer, and alkaline processes. The most useful and oldest EOR procedure is gas injection or flooding. Two key classes of miscible and immiscible gas injections are involved in gas injection techniques. Gas is not miscible in the shape of immiscible reservoir fluid. The mechanism of miscibility is for solvent extraction to obtain miscibility. The most popular gas injection techniques include injection of nitrogen and flue gas, hydrocarbon injection, and CO_2 flooding. A set of screening criteria for each EOR method was suggested by Taber et al. (1997).

Propitious requirements such as gravity, temperature, and crude oil content must be met for miscible displacement to be used. When the oil in the

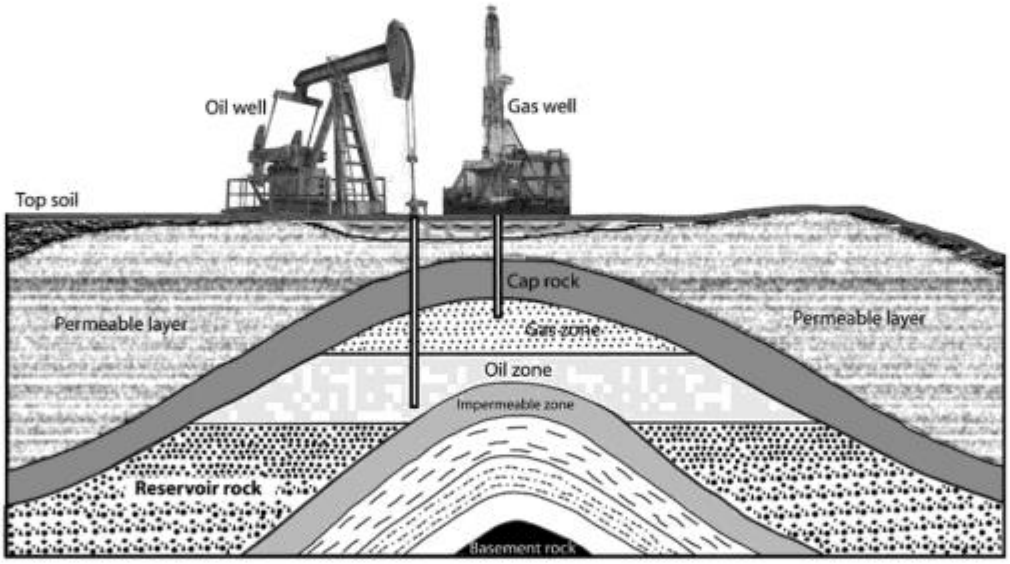

Figure 11.2 Schematic diagram of an oil well and gas well used for the extraction of oil and gas, respectively, from the reservoir.

reservoir combines with the pumped CO_2, a single liquid phase emerges. Their activity results in the swelling and lack of viscosity of crude oil, while, on the other hand, the effect of surface tension decreases. As a result, the oil must flow to the output wells. For low-pressure or heavy-duty oil fields, the immiscible displacement system is used. In this process, CO_2 is injected at a slow speed into the crest of the reservoir, simulating the gas cap and pushing the oil into the output wells. In crude oil, CO_2 dissolves slowly, which causes swelling. The immiscible displacement process can be compared with the flooding water system, because when the flooding water system is used, CO_2 plays a similar role to that of water.

11.3.1 Enhanced oil recovery

EOR is an approach to improve oil recovery during primary rehabilitation (rehabilitation by the key moving mechanism) and secondary water recovery. EOR is also called tertiary oil recovery. EOR could increase oil production by 60%−65% as compared to increase in production volume by 20%−30% via primary drive mechanisms and 40% via secondary drive mechanisms (Tunio et al., 2011). The weight resistance in the reservoir may be due to water-weight, oil-weight, or moderate-weight structures, based on the fluid distribution around mineral particles (Zhou et al., 2020).

Shiran and Skauge (2013) reported that low salinity brine injection was granted considerable attention as a waterflooding technique for EOR.

The use of low-salinity water in conjunction with other proven EOR processes (e.g., surfactant flooding, polymer flooding) has attracted considerable attention. They found that the final recovery factor for original oil in place (OOIP) improved to around 90%. Setting the rock/oil reservoir to create optimal conditions for the recovery of waste oil includes the following:

1. Reduction of interface tension (IFT) between fluid and oil displacement.
2. Modification of the wettability of the rock repository.
3. Raising the viscosity of the drive water.
4. Increasing the number of the capillary.
5. Minimizing capillary power.
6. Overseeing mobility.
7. Eliminating oil viscosity.
8. Swelling of the oil.

11.3.2 Enhanced gas recovery

Primary and secondary recovery methods contribute to maximum gas extraction from the reservoir. EGR can be done using CO_2 since it is thicker than natural gas. CO_2 is injected into the depleted gas tank base and continues to accumulate, causing excess natural gas to settle over it, which then drives natural gas into output wells (Khatun et al., 2016). However, a high concentration of natural gas can be recovered from several gas fields without the use of enhanced recovery technologies.

11.3.3 Challenges and strategy for increased oil/gas recovery

The main challenges facing EOR/EGR are as follows:

1. Capturing CO_2 from different sources.
2. Storing CO_2 in the tank for injection into the well reservoir.
3. Capturing CO_2 from petrochemical process sources and flares, which have been identified as one of the methods to limit greenhouse gas pollution in the environment (Ravanchi and Sahebdelfar, 2014).

11.4 Fundamentals of CO_2 gas injection

CO_2 is injected through a high-pressure oil-bearing stratum as part of the CO_2-EOR process. CO_2 injection oil displacement is focused on the phase behavior of gas and petroleum mixtures, which relies heavily on reservoir temperature, pressure, and oil composition. Two primary forms of CO_2-EOR

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