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Mini Review

Enhanced Oil Recovery: Methods and Applications Review

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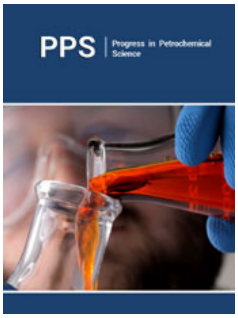
ISSN: 2637-8035



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Submission: September 10, 2021

Published: October 14, 2021

Volume 4 - Issue 2

How to cite this article: Mansour EM* and Ragab A. Enhanced Oil Recovery: Methods and Applications Review. Progress Petrochem Sci. 4(2). PPS. 000585. 2021. DOI: 10.31031/PPS.2021.04.000585

Abstract

Recently, the Enhanced Oil Recovery (EOR) research and implemented projects (pilots/full field) show massive interest from all major E&P companies, especially CO2 injection or flooding in oil reservoirs, to improve the oil recovery of the target reservoirs. Enhanced Oil Recovery (EOR) projects are usually applied after the secondary recovery phase. The Enhanced Oil Recovery (EOR) application is to recover the remaining oil, after the primary and secondary recovery phases, via enhancing the oil displacement and sweep efficiencies. The oil displacement efficiency could be improved by reducing the oil viscosity or lowering the interfacial tension. In contrast, the sweep efficiency could be improved by developing a favorable mobility ratio between the displacing fluid and the remaining oil.

Keywords: Enhanced oil recovery; EOR; Reservoir lithology; CO2; Steam injection; Air injection; Chemical flooding

Abbreviations: EOR: Enhanced Oil Recovery (EOR); HPAI: High-Pressure Air Injection; CHOP: Cold Heavy Oil Production

EOR Overview

The world will encounter a new challenge in the energy field called Enhanced Oil Recovery (EOR) technologies, where discovering hydrocarbon reservoirs will decrease, and nonrenewable energy will play a key role [1]. Therefore, increasing the recovery factors after primary and secondary production in mature reservoirs will be critical in the growing energy demand in the coming years. Many tertiary recoveries (EOR) methods are chemical flooding, gas injection, and thermal flooding [2]. Choosing the best way to increase oil recovery factors by enhanced oil recovery methods depends on recovery parameters screening, such as rock characteristics, availability of injection material, the reservoir fluid type, available equipment, oil properties, and other items [3].

EOR Status

All projects of EOR are strongly influenced by economics and crude oil prices. From the 1980s to 2005, thermal and chemical flooding EOR projects have been in constant decline [4]. Only two projects in 2008 were done in chemical EOR flooding projects. While as a result of increasing High-Pressure Air Injection (HPAI) projects in volatile oil reservoirs, thermal EOR flooding projects have presented a slight increase in 2004. Gas injection flooding projects have remained constant since 1908's and more development since the year 2000 due to extensive cheap sources of CO_2 from natural resources, as (Figure 1) [5]. Different EOR technologies have been evaluated successfully in Karazhanbas (Kazakhstan), Carmópolis (Brazil), and Buracica fields. Buracica field is an onshore volatile oil reservoir with 35 °API. Some flooding projects are reported as air injection from 1978 to 1980, immiscible CO_2 flooding injection in 1991, and polymer flooding injection in 1997. On the other hand, Carmópolis field is a heavy onshore crude oil with °API=22. The reservoir was mainly injected by waterflooding and *in situ*-combustion from 1978 to 1989, steam injection in 1978, polymer flooding from 1969 to 1972, and microbial EOR in 2002 pilot projects.

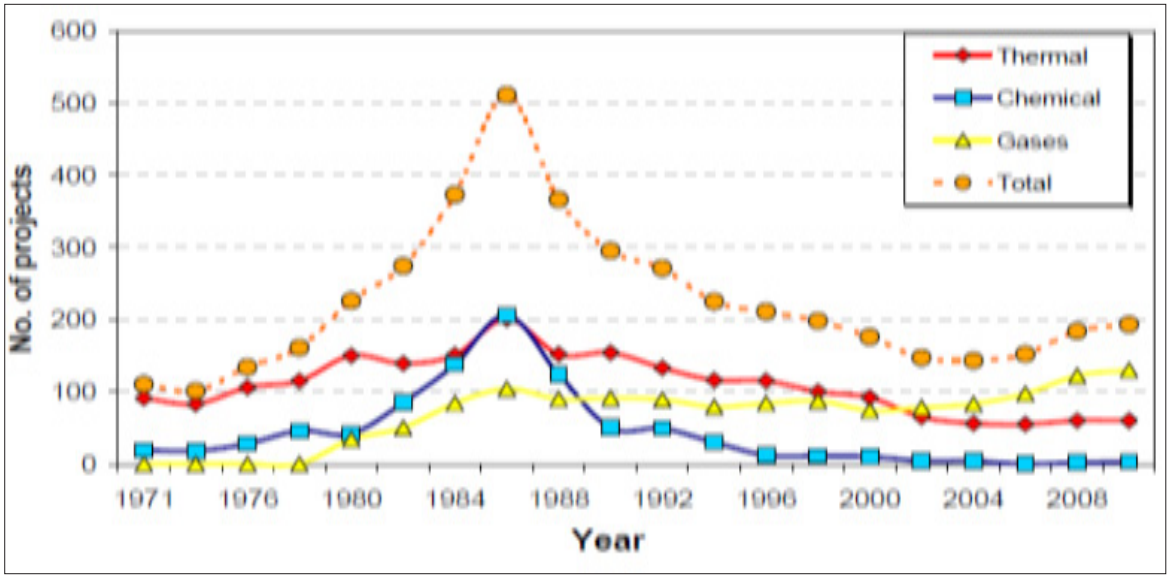

Figure 1: Evolution of EOR projects in the United States (From Oil & Gas Journal 1976-2008).

Karazhanbas field is a heavy onshore oil with °API=19. The reservoir is reported by steam injection, polymer flooding, *in-situ* combustion with foam injection. Karazhanbas field was also developed by waterflooding, CHOPS, or Cold Heavy Oil Production. The 1980s is the best time for chemical EOR flooding in sandstone reservoirs, where polymer flooding was the most applied method in 1990. In sandstone reservoirs, polymer flooding EOR is still the essential EOR chemical process [6]. There is a large scale of polymer flooding projects in Canada (Pelican Lake field), Argentina (El Tordillo Field), Canada (Horsefly Lake Field), Brazil (Voador offshore Field), China with around twenty projects (e.g., Gudong, Gudao , Daqing, Karamay fields and among others), the U.S. (North Burbank, Oklahoma field) and India (Jhalora Field). During the 1980s, polymer flooding was developed in North Burbank to increase oil recovery in 19-mature wells [7]. Also, India has a polymer flooding in Sanand field. Also, Marmul Field documented a polymer flooding in Oman; twenty years later, a large-scale study is in progress. Several EOR chemical processes other than polymer flooding, such as ASP flooding, have been studied and examined in Daqing for more than 15 years [8]. Gudong, Karamay, Liahoe, and Shengli fields are other examples of Chinese ASP projects documented in the literature. During the last decade, additional EOR chemical flooding was recorded as [9-11].

A. ASP flooding in Viraj Field, India, West Kiehl, Sho-Vel-Tum, Cambridge Minnelusa, and Tanner fields in the U.SA.

B. AP flooding projects in David Pool field in Canada and Xing Long Tai Oil Field in China.

Recently, a reservoir with specific characteristics in Mexico was selected to simulate the mature field performance with thermal pilot projects are theorized. As a consequence of this study, it had been proven that at specific conditions and adding up incentives package, there is a win-win schema where the operators and government obtain higher revenues than exploiting conditions of the fields only with natural depletion. So in Mexico, the potential for Enhanced Oil Recovery (EOR) is characterized by 80% than the total production from mature fields [12].

Conclusion

Thermal recovery methods, exclusively steam injection, still dominate as the preferred Enhanced Oil Recovery (EOR) method for heavy oil reservoirs. Gas injection methods continue to be the preferred recovery process in condensate gas reservoirs, offshore fields, and fields in remote locations without access to gas markets. CO_2 injection is the most method attraction in EOR methods and potentially as a sequestration strategy in recent years. But still, EOR projects by CO_2 are primarily concentrated in the U.S. and associated with CO_2 natural sources. But chemical EOR methods have been made a small impact on the world's oil production throughout the last decades. Even with the increasing research on chemical flooding by a different approach to improving oil recoveries in carbonate formations, these projects are not expected to impact global oil production soon.

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