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Systematic modelling incorporating temperature, pressure, and salinity effects on in-situ microbial selective plugging for enhanced oil recovery in a multi-layered system

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ABSTRACT

The microbial enhanced oil recovery (MEOR) process has been identified as a promising alternative to conventional enhanced oil recovery methods because it is eco-friendly and economically advantageous. Despite its various advantages, the technique is not widely applied because the reservoir conditions such as temperature, pressure, and salinity are extremely harsh for microbial survival. In this study, an accurate microbiological model incorporating the environmental effects has been developed. The efficiency of the MEOR process based on selective plugging by microbial biopolymer generation has been examined in multi-layered systems with high permeability contrast. The MEOR is applied to multi-layered reservoirs of different environmental conditions. When the MEOR is applied to a high temperature reservoir, there is an optimum injection temperature that can greatly improve the oil production. Oil productivity in a high-pressure reservoir is estimated to decrease by 15% when the pressure effect is considered. We simulated different salinity conditions and showed that oil recovery decreased with increasing salinity and only was affected by injected water salinity. The oil recovery obtained by the developed model included all three environmental effects and provided estimates 21% lower than that of a previous model that did not account for the environmental effects.

1. Introduction

Microbial enhanced oil recovery (MEOR) is an eco-friendly and economical technology alternative to the conventional enhanced oil recovery method. This method incorporates biotechnology into the oil production stage, utilizing various microbial products for enhancing oil recovery [1,2]. These substances affect both petrophysical properties such as porosity, permeability, and wettability as well as petrochemical properties such as viscosity and interfacial tension (IFT) [3]. The MEOR process can be applied in-situ or ex-situ [4–6]. The in-situ process is a method of stimulating the indigenous or injected microorganisms to generate the desired microbial material. The ex-situ process is a method in which necessary substances are produced under surface conditions and are injected into the reservoir through an injection well. Though both methods can improve oil recovery, in-situ processes are considered to have greater potential in the oil industry [7–10].

Various reservoir conditions that significantly affect microbial growth, such as temperature, pressure, and salinity, must be considered in the analysis of MEOR [3,7,11–13]. Temperature, which has a significant impact on microbial growth and activity, is the most important factor affecting the MEOR process. The rates of bacterial growth and bioproduct generation decrease at low temperatures. On the other hand, enzymes and proteins are denatured and destroyed at high temperatures [14]. Among microorganisms applicable to MEOR, there are species whose survival is affected by the high-pressure environment of the reservoir. This high-pressure environment destroys their cells and adversely affects population growth. Salinity is also known to have a significant effect on the MEOR process. Reservoirs are often high salinity conditions. In some areas, the salinity is within the range of 100 mg/L to over 300 g/L [15]. The microbial activity is reduced in high salinity conditions [16,17].

Among the various microbial materials, biopolymers can help increase sweep efficiency. One of the major causes of lower oil recovery is the presence of a high permeability layer called the thief zone. This zone

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