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Enhancing Oil Recovery Techniques and Their Impact on Production Efficiency (An Applied Analytical Study on the Iraqi Oil Sector)

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ABSTRACT

Generally, enhanced oil recovery (EOR) techniques are paramount in improving the efficiency of oil production, particularly in mature and declining oil fields, which suffer from limited primary and secondary recovery technologies. Thus, this paper discusses the critical EOR models, thermal, chemical and gas injection methods and their impact on recovery factor and reservoir performance with the efficiency output. It showcases some of the technological tools used by EOR to decrease oil viscosity, elevate sweep efficiency, and retain pressure in the reservoir. From its theoretical and practical nature, it examines details about reservoir conditions, fluid types and field engineering for the preference or use of methods and procedures for EOR. It also shows that with correct and methodical implementation of the EOR techniques there can be a large recovery of the reserves and the life and production rates are to be improved at field level. Ongoing EOR procedures should be accompanied by a comprehensive reservoir management as it is claimed that efficient usage of oil production and the long-term sustainable use of oil resources can be achieved through these combination.

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1. Introduction

Crude oil is the mainstay of the Iraqi economy, the most significant resource in the country. This investment is a pillar of Iraq's oil infrastructure (the country's central government that is dependent on oil), the stability and efficiency of oil production is both an economic need as well as a development need and national security problem, and its efficiency and stability of oil production becomes a national security matter, not only an economic need. However, it's not great. The majority of major oil fields of Iraq (in particular, the vast ones in the south and central provinces) are mostly at or near their productive end-of-life. As reservoir pressures decrease, natural production is decreasing, and with the increase in water production comes a decrease in output. In response to these challenges, enhanced oil recovery (EOR) technology development is gaining significance. These practices focus on refining factor recovery and oil production of mature existing reservoirs. The aims of this study are to study feasibility of EOR methods in improving oil recovery performance of OOIP in Iraq. By doing so, the later part of the process involves: the justification of these methods from a theoretical point of view, comparative assessment of what they will do and what their practical implication might be to those implementing them, as well as analyzing the technical, economic and environmental issues in Iraq's oil production using our descriptive-analytical method (based on both published research and the literature, analyzing how this study is going and what Iraq (both the oil sector) is doing and the reservoir characteristics of Iraq). Our study implies that the implementation of EOR practices may increase oil production efficiency and future sustainability of the Iraqi oil industry. When implemented in a strategic way, in an organized manner and scientific, these methods can be cost-effective without compromising the protection of ecosystems. And oil is still considered a bedrock of the energy mix, especially for developing and oil-producing nations, though

renewable energy has risen to the front. Iraq is among the top five countries in the world for proven oil reserves, listed among the top five globally. It contains an estimated 112 billion barrels of oil deposits, one of the largest of any region's reserves. This country has the abundant hydrocarbon deposits and its potential to offer oil value but it also faces challenges of management - efficient and more yield oriented. For decades of years, Iraq has used primary and secondary recovery technologies. Those efforts entail putting water or gas underground in a pressure-dependent way so that the oil comes in. Though effective at first stages of field development, efficiency diminishes with the lowering of reservoir pressure and significant extracting of active oil. Traditional technologies only recover 30-35% of the original oil in place (OOIP), more than 50% recoverable oil is lost as the technology can not be improved. It emphasizes the growing significance of EOR techniques that modify the oil and consequently the reservoir's physical and chemical attributes. These processes have the potential to promote improved production efficiency by lowering oil viscosity, surface tension, and pore displacement. Due to the highly variable geologies of Iraq's oil fields consisting of numerous layers of rock and fluids, EOR techniques are crucial in increasing productivity. The country's reconstruction and development commitments require steady production levels— something that an approach using conventional methods can't guarantee. Specifically, the objective of this research is to systematically and comprehensively study the EOR techniques as well as to assess the potential for effective oil production over several stage formations, considering the specific geological, economic, and environmental conditions that could make a country an important source for developing oil production hubs.

2. Research Methodology

This particular study based on enhanced oil recovery (EOR) practices and its impact on oil production performance in Iraq was conducted using a research methodology of combining theoretical investigations with an empirical project.

First: Research Problem

That's the basic issue, because oil production is not very effective in the great majority of Iraqi fields which is why primary recuperation methods and secondary recovery techniques are still used many years later. Mature fields have particular challenges in keeping up the level of consistent production -- a situation that presents technical and financial challenges.

Second: Research Objectives

This research now aims to achieve the following objectives:

1. A theoretical and engineering basis for EOR processes.
2. Relationship between recovery factors and oil production performance from EOR procedures.
3. Determining a practical application of several EOR techniques in the oil fields in Iraq.

For instance, the relevant technical, economic and environmental features of EOR methodologies

Third: Research Questions

To take scientific guidance which is meant for decision making in Iraqi oil industry,

1. How effective are traditional oil recovery techniques in mature Iraqi oil fields?
2. Given characteristic features of Iraq's reservoirs, what are the most suitable EOR methods?
3. What is the effect of EOR strategy on recovery factors and oil recovery efficiency?
4. Are EOR activities feasible in Iraq?
5. What are the possible environmental impacts of EOR technologies and how would these be minimized?

Fourth: Research Hypotheses

The research is based on a set of scientific hypotheses, the most prominent of which are:

1. Applying enhanced oil recovery techniques contributes to increasing the efficiency of oil production in mature Iraqi fields.
2. There is a direct relation between these types of EOR processes and an increase in the Recovery Factor.
3. The efficiency of improved oil recovery methods depends on the nature of Iraqi oil fields.
4. Despite the high initial cost, the potential to apply EOR techniques in the long-term can provide high economic viability.

Fifth: Research Limitations

There are several limitations of the study:

•Geographical Limitations: The study is limited to exploring the Iraqi oil sector more general and does not include a local specific area.

•Temporal Dimension: Concentrating on comparably recent information which reflects the status of the oil market in recent years.

•Thematic Limitations: This study focuses on improved recovery methods for oil and their role in production efficiency, not exploration methods.

Part 1

1.1 Primer of Oil Recovery and Production Efficiency

Despite developments in extraction technology, oil recovery is very poor because oil is very difficult to extract due to small pores of rocks that trapped the oil. Three recovery phases are likely to dominate: primary, secondary and EOR. At each stage, technologies that are developed to increase the efficiency of the original oil in place (OOIP) take place. In the primary recovery period, oil can be recovered by using the natural energy contained in the reservoir such as pressure from dissolved gas, expansion/expiration of gas or a natural addition of water through the reservoir. It's one of the earliest stages, in general, with very low operational costs, yet very poor recovery rates and a recovery rate of typically between 10 and 15% of the original oil in the reservoir. The majority of Iraqi fields (particularly the larger ones) already have exhausted this phase too soon in the first decades of production. Secondary recovery occurs when hydrocarbon pressure in a reservoir is lowered to such a low level that economic production is not feasible. Water flooding or gas injection methods are used at this level to keep pressure within this maximum and allow oil discharged from a reservoir into producing wells — e.g. recovering 30-35% at best. The effectiveness of this approach eventually fails due to the water breakthrough process and unique rock formations in the reservoirs, Exploring Oil Recovery: Iraq's Challenges and their Remediation.

(see Figure 1).

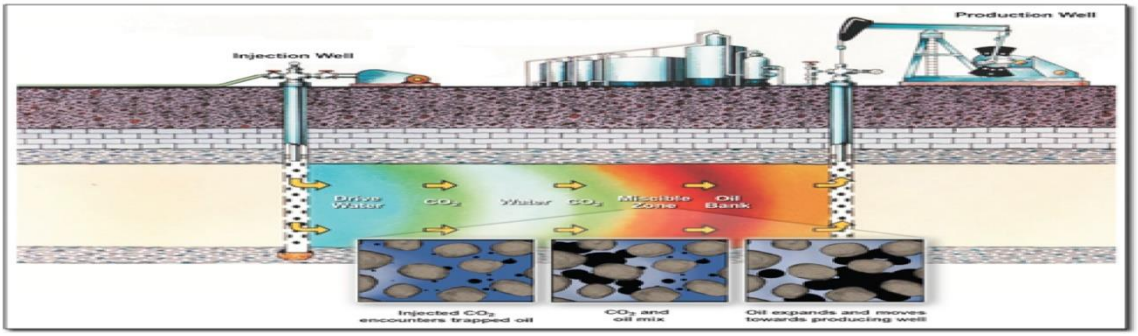


Fig. 1 Oil Recovery

It begins with primary recovery, primarily based on the natural energy of the reservoir. Then there comes secondary recovery, where water or gas is injected to support oil at its surface. And not everything can be replaced by conventional technologies. With new or improved technology, it may be possible to obtain a much more complete recovery of oil. Finally there is EOR: Oil recovery is actually more complicated to transform than it would be in prior oilfields and reserves. There are limitations to such methods, particularly in aging oil fields (Iraq), and these indicate that development practices should be improved. These characteristics also provide a great deal of reserves, whereas traditional oil recovery methods are very difficult for recovering energy. They can also access previously non-economical formations and better spatially distribute the production between different wells.

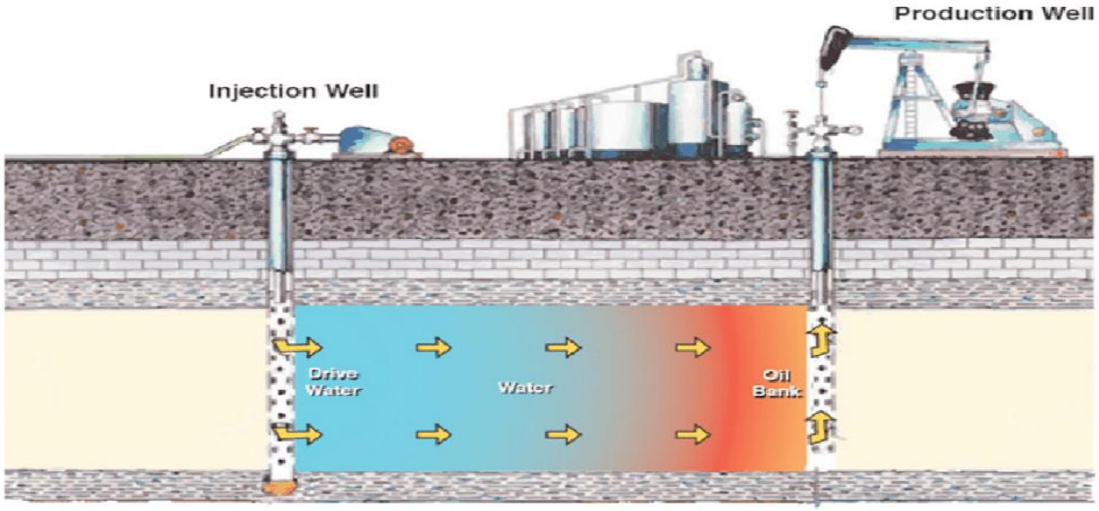
1.2 Economic impacts of Enhanced Oil Recovery (EOR) techniques.

While EOR methods are associated with significant initial investments, according to long-term economics these approaches yield high returns with a special high economic impact in oil-rich and oil-rich countries such as Iraq. Increasing the recovery factor is all about increasing the amount of recoverable oil being added to the recovery factor, while at the same time decreasing costs of exploring new fields and so reducing the likelihood of drilling in new areas; in a giant oil field alone, an increase of only 5% in the recovery factor translates into hundreds of millions of barrels being added to recoverable reserves, with huge financial returns throughout the lifetime of the field. Additionally, enhanced oil recovery (EOR) techniques also prolong the productive life of oil fields providing greater spreads in capital costs and improving indicators of the economic viability of multiple oil projects.

1.3 EOR Technique Impact on Recovery Factor

Impact on Production Rate Economic Impact Applicability in Iraq. Thermal EOR High increase (up to 15–20%) Significant heavy oil improvements High cost – long-term return Limited / Potential. Chemical EOR Moderate increase (10–15%) Increased production stability Moderate cost – decent feasibility

Expandabl; Gas Injection (CO_2 EOR) High increase (15–25%) Production is stable and improved High feasibility + environmental benefit Highly promising.



It shows that gas-based EOR techniques, specifically carbon dioxide injection techniques, have the utmost increases in the recovery factor and the most stable production rates, along with their relatively positive environmental impact. The table also implies that the success of EOR in integrating with the integrated reservoir management also significantly contributes for sustainable production, increasing sustainable production which in turn, reduces annual decline in the oil production. 3.3 Environmental Impacts and Sustainable Development. Environment has increasingly been considered as a factor in evaluating oil projects due to the worldwide move toward reducing carbon emissions and sustainable development. In this context, some EOR techniques, such as carbon dioxide injection, are seen as two-fold positives. They boost oil production on the one hand and cut emissions over geological carbon storage; through EOR, these projects are able to enhance petroleum production. In Iraq, where the flaring of associated gas is a major environmental and economic challenge, this gas exploitation can potentially provide a very practical approach to reducing wastage and improving the environmental performance of the oil industry in EOR activities. On top of that, proper control over injection processes as well as the treatment of produced wastewater may assist in reducing hazardous effect on the local ecology.

1-4 Factors Affecting Oil Recovery Efficiency

1.4 Future challenges and development possibilities in Iraq in the future.

For all its enormous potential, oil recovery, new EOR, like the current state-of-the-art EOR technologies, the realization of successful implementation in Iraq needs to overcome the abovementioned problems. This would include the establishment of national technical capabilities, provision of accurate reservoir and reservoir data, as well as improvement in management and planning systems. Interaction of government institutions and operation companies is also necessary for proper application of these technologies. Recent technical innovations, including digital reservoir simulator and AI, present large opportunity for improving EOR project specific design and project implementation under the characteristics of the local geological variables in the Iraqi oilfield.

1.5 The effect of EOR technologies on the sustainability of Oil production.

Production sustainability is among the biggest challenges for the Iraqi oil industry because, as currently well capitalized fields account for a significant share of the market production, Iraq is heavily dependent on mature fields. In this light, Enhanced Oil Recovery (EOR) technologies are instrumental in increasing the productive life of oil fields through enhanced reservoir responsiveness to extraction processes and minimizing annual production decline rate (PDR). The deliberate and systematic implementation of methods for Enhanced Oil Recovery (EOR) will ensure relatively stable rates of production, while also mitigating the abrupt price changes that frequently occur in the later stages of oil field development. While in the Iraqi example oil revenues are very dependent economic and financial condition making the consideration of the EOR approach is more appropriate to attain the equilibrium between the maximum current production and the future storage capacity, consistent with the principles of natural resource management. Part Two: Enhanced Oil Recovery (EOR) Techniques and Their Applications in Iraqi Oil Fields

Part Two

2.1 EOR for Energy and Economic Security in Iraq

Enhanced oil recovery techniques in Iraq will have broader, strategic and local implications, beyond technical/ production-level impacts; this development would provide leverage in bolstering national energy and economic self-reliance. Oil is Iraq's primary source of revenue, and enhancing oil production performance can be a major driver to fund development projects, help domestic and foreign development and foster the economy. In this context, EOR methods can be considered as a strategic means to achieve an Iraqi energy security by maintaining the level of sustained oil production in Iraq at stable and predictable amounts. Finally, increasing recovery factor reduces the need for the rapid growth of expensive explorations and helps with the efficient utilization of resources at the lowest possible cost. So EOR technologies in the energy technologies should be embedded to guarantee the economic returns from the economic development from the best utilization of oil.

2.2 Features of Iraqi Oil Reservoirs and Their Influence on Recovery Efficiency

One of the defining facts of some of the Iraqi oil fields is the complicated geological content of this region: Rumaila, West Qurna, Majnoon, Zubair and Kirkuk:

•Heterogeneous carbonate reservoirs.
•Large variations in porosity and permeability.
•Present natural fractures.
•Some fields are rich in heavy and medium oil.

These characteristics make it:

•Irregular fluid flow.
•Reduced displacement efficiency.
•Large amounts of oil stuck in low permeability layers. Application and Proposed Enhanced Oil Recovery (EOR) techniques in Iraq.

2.3 Advanced Water Flooding

Although water injection is a secondary recovery method, the development of this method through:

• Intelligent injection rate management
• Optimized well layout
• Advanced simulation models
• Improved Sweep Efficiency
• Reduced water penetration rate
• Recovery factor increases by 10–20%

2.4 Smart Water Technology (Low Salinity Water) Table 3

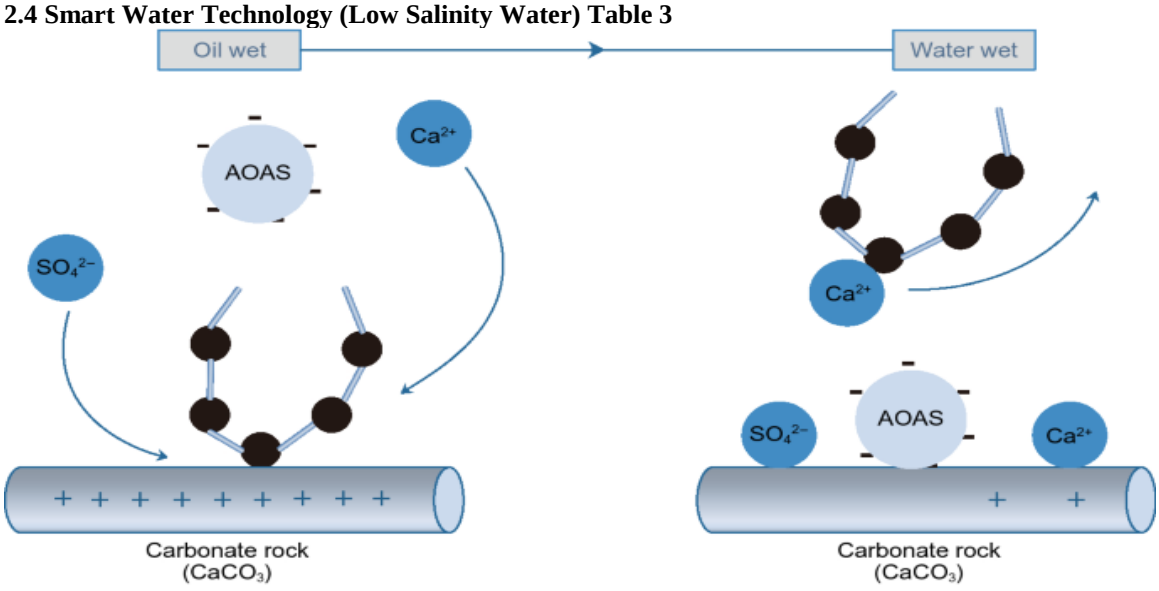


Table 3 show Low Salinity Water (smart technique)

This technique is more suitable for oil production from Iraqi carbonate reservoirs Mechanism of Action

•Changing the ionic makeup of the injection water
•Enhancing the wetting capacity of rocks

•Lowering oil-rock bonding forces
• Enhanced recovery 5–12%
•Reduced water production
•Reduced operating costs over thermal methods

**2.5 Gas Injection (Gas & CO_2 EOR) Injection of gases and nitrogen) ** It is one of the most effective EOR methods used in Iraqi reservoirs and its merits lie in:

•Used to maintain pressure
•Works well in gas-capped reservoirs
•Partial or complete miscibility with oil
•Reduced viscosity
•High recovery factor of up to 30–45% CO_2 injection may be integrated into carbon emission reduction projects, improving its environmental performance in Iraq.

Part Three

3.1 Reservoir Simulation Technology in Iraqi Regions

Reservoir simulation instruments have become a cornerstone of the oil and gas field and provide equipment for operators from different oil producing activities to enhance their production, deal with risks and achieve increased recovery in geological environments. In one of the world's largest hydrocarbon reserves, Iraq, very useful reservoir modeling techniques are in place. This is not all so: For example, it requires practical and environmentally sound management methods to make use of the available resources, the hydrocarbon recovery technology and its availability, the technological evolution of the reservoir simulation technology under the state of the art in Iraq with a view to maximizing hydrocarbon recovery efficiency. What does the strategic significance of oil and gas sector of Iraq look like? Iraq holds the 5th largest proven oil reserves globally (estimated at approximately 145 billion barrels) and substantial natural gas (roughly ~3.7 trillion cubic meters) reserves (Global Energy Monitor). The vast majority of these reserves sit primarily in the southern parts of the country, such as the Basra, Zubair and Nahr Umr, where we can find large layers of multi-layer carbonate and sandstone. Such reservoirs display significant heterogeneity, high permeability contrasts and major geological problems with sand production and wellbore disturbance. Relying on oil and gas revenues, which comprise more than 90% of its government coffers, is another reason the country so badly needs to manage its reservoirs well. But Iraq’s hydrocarbon industry has its challenges — its aging infrastructure, low tech uptake and the legacy of years of war. Reservoir simulation technologies are an exciting approach for solving these problems, allowing an in-depth understanding of reservoir behavior and data-driven decision-making. Reservoir simulation is a mathematical tool used in order to describe the process in a reservoir. These geologies, petrophysical and flows models provide models and predictions of reservoir performance, depending on different production conditions. The role of the implementation of simulation technologies like 3D mechanical earth models (MEMs) and hydro-geomechanical simulations in the field in the special problems have been shown to play a significant role in Iraq. Such case study in the Nahr Umr Formation located in southern Iraq, in order to reduce sand output, MEMs needed to carry critical drawdown pressure assessment (Iraqi Journal of Chemical and Petroleum Engineering). As such, similar efforts in combination design of 3D MEMs was conducted for the wellbore instability alleviation in the Zubair field, to effectively shorten drilling time and enhance drilling efficiency and productivity (The Iraqi Geological Journal). This article proposes on simulation in Iraqi reservoir and the problem facing it. The feature that the Iraqi reservoirs present has a certain kind of set of problems to solve that might be addressed using the latest simulation techniques: High Stability - Many aquifer like in formations Zubair and Nahr Umr tend to have production of sand and unstable wells, weak formation of rocks and high stressing. This type of geomechanical behaviour is easy to predict and geomechanical plans can be constructed from simulation tools by their capacity to predict the slope-geomechanical behaviour through drilling. Water shortage and management: Iraq has an increasing demand for water-intensive EOR technologies such as water flooding, which is compounded by extreme water scarcity. Sustainable water management, identified in research by the use of simulation models through simulation to improve the quality of water injection and lower wastage (Environment Systems and Decisions). Reservoir heterogeneity: The heterogeneous recovery profile for hydrocarbons in Iraq's reservoirs due to diverse permeability and porosity profiles resulting from different types of oil seepage makes hydrocarbons in Iraq's reservoirs result in variations in recovery as a function of heterogeneity in reservoirs. High potential zones are delineated through simulation models, and wells with optimal lay-out for maximum production have been set up.

Many of Iraq's oil resources were exploited decades ago and lacked modern technologies. Reservoir simulation is a cheap way to improve the longevity of these fields by emphasizing infill and secondary recovery opportunities.

3. Results

1. Improved oil recovery (EOR) technologies have also been demonstrated to enhance oil recovery effect and improve oil production efficiency for the mature fields. These methods are a tactical option for Iraq to sustain oil production and increase economic benefit. The correct use of EOR techniques contributes to mitigating the negative environmental impacts associated with oil production through EOR. Iraqi environment and nanotechnology in Iraq is still a subject of research and experimentation, but it is very promising because of: • Its ability to improve carbonate rock hydration • Reduce surface tension • Release the oil trapped in microspores.

4. Conclusion and Recommendations

1.Continue to apply EOR methods gradually to more established Iraqi oil fields.
2.Spend on R&D and enhance national technical skill in EOR technologies.
3.Encourage the utilization of associated gas in extraction processes (rather than flaring it).
4.Adopt strict environmental standards for sustainability and minimizing the negative repercussions.

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