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Cost description and characterisation of gas enhanced oil recovery processes.

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COST DESCRIPTION AND CHARACTERISATION OF GAS ENHANCED OIL RECOVERY PROCESSES

[1]Ofasa Abunumah, [1]Priscilla Ogunlude, [1*]Edward Gobina)
[1]Robert Gordon University, Centre for Process Integration & Membrane Technology, School of Engineering, Garthdee Road, Aberdeen AB10 7GJ

*Corresponding author e-mail: e.gobina@rgu.ac.uk

ABSTRACT

Cost optimisation is a critical subject in energy security, such as in oil recovery and production. The cost characterisation of Gas Enhanced Oil Recovery (EOR) has been evaluated using data mining and experimental methods. The underlying engineering and economic premise are that the respective gas EOR processes would experience discrimination in certain CAPEX and OPEX cost centres, such as injectant fluid, drilling infill wells, and power costs. Several authors have examined the cost burden of implementing an EOR gas or compared two EOR gases. However, no literature has simultaneously investigated the cost competitiveness of the four (CH_4, N_2, Air, and CO_2) EOR gases commonly used in Gas EOR technology. This study has been able to fill this gap with a focus on injectant cost. The data mining of field data reveals that cost is a significant driver for EOR project initiation. EOR reservoirs are characterisable by the injected fluid cost. The experiments indicated that injected gas could also be characterised by injectant fluid cost. The experimental results sufficiently validate the data mining results. The coupling of the two sets of results reveals the competitiveness of the EOR gases to be stated as: CO_2 > N_2 > Air > CH_4.

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Keywords: EOR cost, reservoir characterisation, Injectants, Gas EOR, Gas cost

INTRODUCTION

Cost is a major consideration in all kinds of energy production. However, crude oil has peculiar CAPEX and OPEX cost centres such as injectant, infill well, power, and compressor cost [1]. Common injectants are CH_4, N_2, Air, and CO_2 gases, and their ability to enhanced oil recovery differs [2]. The engineering and economic premise proposes that the injectant's coupling of effectiveness and efficiency would lead to a recovery and cost discrimination amongst the EOR gases. The utility of this analysis is both technical and economical. It would allow decision-makers to compare, in advance, their asset capacity to withstand the facility requirements of a proposed gas EOR process and the incidental economic feasibility of the cumulative injected gas quantity that would be required through the life of the EOR project. Economic optimisation is the definitive aim of EOR engineering management.

EOR projects are sensitive to oil price (as shown in *Figure 1*a), injectant cost, fiscal incentives, and complex oil recovery costs [3]. However, the injectant cost is often treated as a major cost element separate from the OPEX by some authors [3,4,5].

Other investigators have established that the oil produced in an EOR process is quantitatively proportional to the volume of displacing fluid injected [6]. Therefore it is expected that the oil recovered and revenue from recovered oil will be proportional to the cumulative gas injected and the cost, respectively. Previous authors have studied this topic from a limited perspective and a limited number of gases [4]. Few have compared the cost of two EOR processes [5]. However, no study has simultaneously compared the cost implication of the four EOR gases.

MATERIALS AND METHODS

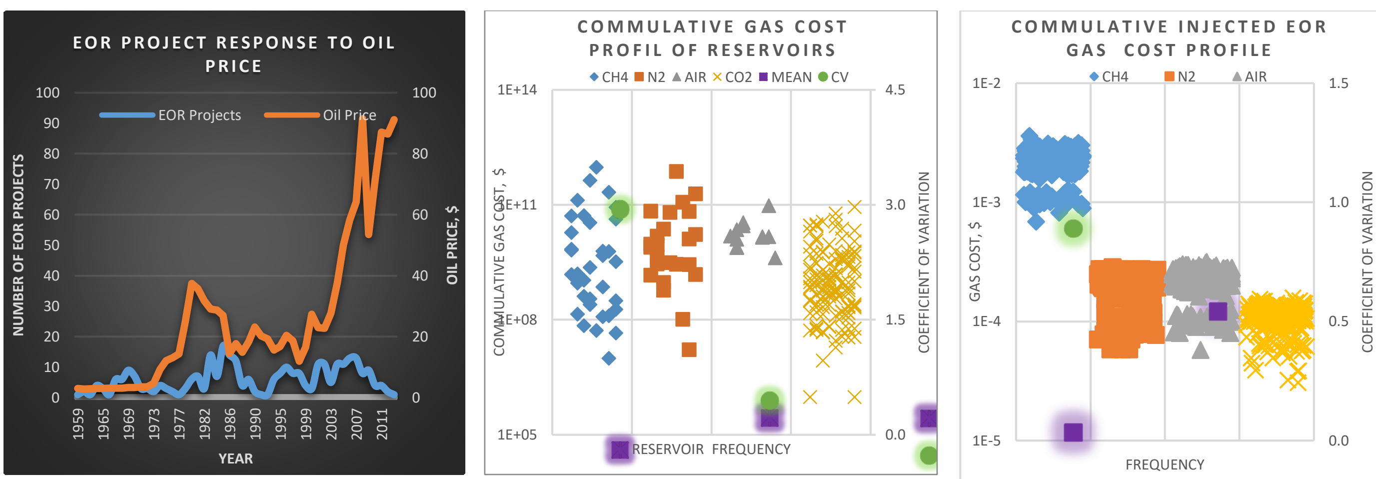
The data mining phase analysed 484 EOR projects. The reservoirs were grouped into CH_4, N_2, Air, and CO_2 gas EOR processes. First, the potential cumulative recoverable oil was estimated using a modified Darcy equation for radial flow and the petrophysical parameters and properties of the reservoirs in the respective EOR groups. Then a statistical technique was applied to the data in each group to plot a cluster graph.

Core experiments were carried out for CH_4, N_2, Air, and CO_2, using five core samples, varying pressure (20 to 300KPa), and temperature (293 to 673K) to examine the cumulative gas production profile of the respective gases. The results were then applied to the gas-oil production proportionality principle mentioned in [6]
The optimisation objective is to minimise cumulative injectant cost.

The research used BOC gas pricing quotation for CH_4 (\$4.5E-05/cm^3), N_2 (\$5.7E-06/cm^3), Air (\$6.1E-06/cm^3), CO_2 (\$3.4E-06/cm^3) as an industry benchmark for making the analysis. The gas price was normalised to the United States Dollars of January 1st, 2021. The competitiveness of the benchmarked unit cost of the EOR gases is, therefore: CO_2 > N_2 > Air > CH_4

CONCLUSIONS

This study contributes to engineering knowledge and reservoir practices such that it has been identified, through data mining clustering (*Figure 1*b), that Gas EOR processes can be characterised by the cumulative injectant cost. Air was found to be most sensitive to the cumulative injectant cost. The length of the clusters in *Figure 1*b and the intersects of the clusters demonstrate that there may be other factors influencing the cumulative cost of gases. Nevertheless, the mean cumulative injectant cost in *Figure 1*b indicates that CO_2 EOR offers the least cost, while N_2 EOR offers the most cost. The order of cost competitiveness is, therefore: CO_2 >Air > CH_4 > N_2.
Furthermore, the clusters from the experimental analyses (*Figure 1*c) indicate that CO_2 offers the least cost, while CH_4 offers the most cost. Surprisingly, the cumulative cost of injecting N_2 and Air is higher than that of CO_2 in both reservoir and experimental data. Considering the free availability of Air has been previously mentioned to be a cost opportunity for Air EOR projects, it was expected that Air EOR would translate to a comparatively lower injectant cost, how this was not the case with the findings of this study. The study, therefore, speculates that the practical cost of processing Air for injection in an oil field may not be as expensive as the BOC quotation. Nevertheless, for theoretical purposes, the experimental ranking of the cost competitiveness of EOR gases is, therefore: CO_2 > N_2 > Air > CH_4.
The coupling of the data mining and experimental results shows some similarities and differences. In both phases, CO_2 is ultimately established to be the least expensive process injectant-wise.
Consequently, without loss of generalisation, it can now be concluded that for a given reservoir suitable for all gas EOR, CO_2 is the most cost-effective gas to inject.



a. b. c.

Figure 1 shows the historical response of EOR projects initiation to oil price, and invariably to oil revenue (a) cumulative gas cost description and characterisation for global EOR reservoirs (b) and experimented EOR gases (c).

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