

Evaluating the Economic Viability of Locally Sourced versus Foreign Enhanced Oil Recovery (EOR) Agents

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Abstract— *The high cost of imported chemicals and foreign exchange volatility pose significant challenges to the deployment of Enhanced Oil Recovery (EOR) in the Niger Delta. This study evaluates the technical and economic viability of locally sourced EOR agents against foreign synthetic alternatives. The crude oil used was characterized as heavy, with a density of 0.931 g/cm³, an API gravity of 20.6°, and a high Total Acid Number (TAN) of 3.02 mg KOH/g. A comparative laboratory analysis was conducted using synthetic agents (NaOH, SDS, and Xanthan gum) against a locally formulated ASP slug consisting of wood ash (alkaline), *Codiaeum variegatus* (surfactant), and potato peel powder (polymer). Core flooding results showed that the foreign ASP slug recovered 6.4 ml of oil, while the locally sourced slug achieved a competitive recovery of 6.1 ml. However, economic modeling using a Benefit-Cost Ratio (BCR) revealed a significant disparity. The foreign project was limited by a \$100,000+ importation cost, yielding a BCR of 1.78. In contrast, the local ASP slug, utilizing waste-to-wealth materials and incurring zero importation duties, achieved a BCR of 4.06. This demonstrates that the locally sourced agents are 2.28 times more economically viable than imported alternatives, providing a sustainable and cost-effective pathway for enhancing heavy oil recovery in the Niger Delta.*

Keywords— *Heavy Oil; Woodash; *Codiaeum Variegatus*; Potato Peel Powder; Benefit-Cost Ratio; Enhanced Oil Recovery*

I. INTRODUCTION

The surge in global population and rapid industrialization in developing countries has led to a significant increase in global energy consumption, exerting continuous pressure on available oil resources. Fossil fuels, particularly petroleum, are projected to remain a dominant component of the worldwide energy portfolio for decades, with demand estimated to rise by 30% by 2040 [8]. Recently, oil-producing companies are encountering increasing

difficulties in accessing new conventional reserves and are therefore resorting to far-reaching options like deep and ultra-deep offshore field exploration. Although reservoirs in these environments yield about 20% to 40% recovery, additional recovery of heavy crude oil has posed a major challenge to the industry [13].

Heavy oil is gaining greater importance for meeting global energy demand; however, these resources have historically proved not to be economically viable from an extraction point of view [14] while thermal recovery is commonly used, it is often expensive and associated with adverse environmental effects. As a result, non-thermal recovery methods such as chemical flooding utilizing Alkaline, Surfactant, and Polymer (ASP) are gaining attention due to their efficiency and affordable capital expenses [15], [4]. To maximize oil production, both synthetic and non-synthetic extracts are required [7], [1]. However, a critical barrier in the application of these techniques is the heavy economic burden imposed by the importation of synthetic chemicals. Local materials: Although Agricultural waste has been used for several beneficial purposes such as feed stock for energy production, raw materials in industries or chemical recovery [16], there have become an increasing concern in recent years as they may cause significant environmental concerns and poses serious health hazards when littered all over the environment as such could be converted to useful materials in the oil and gas industry for chemical EOR processes.

Agricultural waste and leaf extracts in our environment possess similar characteristics as the synthetic conventional materials [11]. Alkali, Surfactants and Polymers can be sourced from various agro-wastes materials such as plantain peel, paw-paw leave, wood ash, palm bunch, banana

leaves, cocoa pod, maize cob, and sugar beet contain good percentage of potash [6]. Food and agriculture organization estimated 5,879,000 metric tons of banana peels and 17,397,000 metric tons of plantain peels in Africa which could be used for the production of soap and other use [5]. Their utilization will minimize production cost as their cost will be theoretically independent of oil price, maximize profit, convert waste to wealth and create job opportunities [12]. Local ASP slugs performed competitively well against the foreign slug. With further research work, the local chemicals could yield improved performance as importation of oil field chemicals will gradually be eliminated. [9]. In many oil-producing nations, the reliance on imported Enhanced Oil Recovery (EOR) agents exposes projects to high procurement costs, international shipping tariffs, and extreme foreign exchange volatility potentially offsetting technical gains in displacement efficiency. To mitigate these challenges an economic analysis is essential. If the cost of executing a project is higher than the expected benefit such project should be abandoned [10]. This study employs Benefit-Cost Ratio (BCR) analysis to evaluate the viability of locally sourced EOR agents as a substitute for imported agents aiming to optimize project economics and inform investment decisions. Cost-benefit analysis involves comparing the total investment cost with anticipated benefits or returns from the project outcome [3]. It is an economic tool for determining the benefits and costs of a project discounted over a period of time using a basic monetary value [2].

II. MATERIALS AND METHODS

2.1.1. MATERIALS

The materials for this comparative analysis are categorized as follows:

- Synthetic (Foreign) EOR Agents: Sodium hydroxide (Alkaline), Sodium dodecyl sulphate (Surfactant), and Xanthan gum (Polymer).
- Locally Sourced EOR Agents:
 - Alkaline: Ashes from wood shavings and plantain peel
 - Surfactants: Leaf extracts from *Carica papaya* and *Codiaeum variegatum*.
 - Polymers: Potato peel powder and Aloe vera mucilage.

- Reservoir Samples: Niger Delta core plugs and Niger Delta Crude oil.
- Reagents & Solvents: Methanol, Toluene, Industrial salt, and Distilled water.

EQUIPMENT

The laboratory procedures utilized the following equipment:

- Sample Preparation: Blending machine, Drying oven, Digital mixer, Magnetic stirrer, Separating funnel, and Spatula.
- Measurement & Characterization: pH meter, Redwood viscometer, Fann rheometer, Digital weight balance, Pycnometer, Thermometer, and Measuring cylinders.
- Core Analysis: Soxhlet extractor, core flooding unit, and Porosimeter
- Microsoft Excel: to determine the cost-benefit ratio of the local agents compared to the imported synthetics.

2.2 EXPERIMENTAL PROCEDURE

2.2.1 CORE PREPARATION AND PETROPHYSICAL MEASUREMENT. Niger Delta core plugs are cleaned via the Soxhlet extractor using a Toluene/Methanol mixture and dried in the Drying oven. The Porosimeter is used to determine porosity, while permeability is determined by measuring the flow of brine through the cores held in the Core holders at a constant rate.

2.2.2 FLUID PROPERTY CHARACTERIZATION

Both local and synthetic agents are tested for viscosity (Redwood viscometer and Fann rheometer), density (Pycnometer), and chemical stability (pH meter and Thermometer).

2.2.3 CORE FLOODING

Cores are loaded into Core holders and saturated with Niger Delta Crude oil. Following secondary waterflooding (Distilled water and Industrial salt), the locally sourced agents are injected to evaluate recovery efficiency against the synthetic counterparts.

2.3 FORMULATION OF EOR AGENTS

2.3.1 ALKALINE PREPARATION

- Foreign Slug

Synthetic Sodium Hydroxide (NaOH): A solution of Sodium Hydroxide (NaOH) with a concentration of 10,000 ppm was prepared by dissolving 10 g of NaOH pellets in distilled water. The mixture was homogenized using a magnetic stirrer and diluted to a final volume of 1,000 ml to ensure a uniform concentration for the flooding experiments.

- Local slug:

A local alkaline solution was formulated from ashes from wood shavings and plantain peel at a concentration of 10,000 ppm, matching the concentration of the synthetic NaOH to ensure a consistent comparative baseline for the EOR experiments.

2.3.1 SURFACTANT PREPARATION

- Synthetic Surfactant (SDS): A solution of Sodium Dodecyl Sulphate (SDS) was prepared at a concentration of 3,000 ppm (0.3 wt%). This was achieved by dissolving 3 g of SDS in distilled water and homogenizing the mixture using a magnetic stirrer until a total volume of 1,000 ml was reached.
- Locally Formulated Surfactants: Bio-surfactants were extracted from the leaves of *Carica papaya* and *Codiaeum variegatum*. The leaves were processed through washing, sun-drying, and mechanical pounding to obtain a paste, which was then sieved and filtered to yield a pure liquid extract. To ensure parity with the synthetic agent, 3 ml of each extract was diluted with distilled water to a final volume of 1,000 ml, achieving a uniform solution for the flooding process.

2.3.2 POLYMER PREPARATION

- Synthetic Polymer (Xanthan Gum): A 10,000-ppm stock solution was prepared by dissolving 10 g of Xanthan gum powder in distilled water. To prevent the formation of "fish-eyes" and ensure complete hydration, the mixture was agitated using a magnetic stirrer and diluted to a final volume of 1,000 ml.

- Locally Formulated Polymers: The local polymer agents were derived from potato peel powder and Aloe vera mucilage. The potato peels were dried and pulverized, local polymer was formulated to a concentration of 10,000 ppm by dissolving the required mass in distilled water and adjusting to a total volume of 1,000 ml to match the synthetic baseline.

2.4 ECONOMIC EVALUATION ANALYSIS

Experimental recovery results are recorded and analyzed using Microsoft Excel. The economic viability of the Enhanced Oil Recovery (EOR) agents is evaluated using the Benefit-Cost Ratio (BCR). This metric determines if the value of incremental oil justifies the investment in chemicals, logistics, and operations. A $BCR > 1.0$ indicates a profitable investment, while $BCR < 1.0$ suggests the project is not financially viable.

2.4.1 Economic Evaluation Parameters and Assumptions

To evaluate the comparative economic viability of the foreign and locally sourced ASP slugs, the following assumptions and field-scale conversion factors were applied:

Assumptions

- Field Scaling (Volume): 1 ml of laboratory recovery is scaled to 1,000 barrels (bbl) of field production.
- Field Scaling (Mass): 1 gram of laboratory chemical is scaled to 1,000 kg for field injection.
- Time Scaling: 1 minute of laboratory time is equivalent to 1 week of field operational time.
- Project Duration: The total project lifecycle is estimated at 1.004 years based on the experimental flooding duration.
- Slug Volume: A total injection volume of 9,100 bbl was used, comprising Alkaline (31.82%) Surfactant (18.94%) and Polymer (49.24%)
- Crude Oil Price: A constant market price of \$70/bbl
- Discount Rate (i): A weekly discount rate of (0.8%) 0.008

- Exchange Rate: A conversion rate of 1,508.39/USD was utilized for local currency evaluations.
- Operating Expenses (OPEX): A fixed operational cost of \$32,000 was allocated for pumping, labor, and maintenance.
- Importation Costs (*Cimport*): \$8/kg was applied to all foreign agents, while local agents incurred \$0/kg in importation fees.

Table 1: The costs per kilogram for the chemicals are summarized below: Table 1: The costs per kilogram for the chemicals are summarized below:

Agent	Local cost (\$/kg)	Import cost (\$/kg)	Total cost (\$/kg)
Foreign alkaline	\$6.00	\$8.00	\$14.00
Foreign surfactant	\$11.00	\$8.00	\$19.00
Foreign polymer	\$12.00	\$8.00	\$20.00
Local alkaline	\$4.50	\$0.00	\$4.50
Local surfactant	\$6.50	\$0.00	\$6.50
Local polymer	\$6.50	\$0.00	\$6.50

2.4 MATHEMATICAL FRAMEWORK

$$BCR = \frac{\sum PV_{Benefits}}{\sum PV_{Costs}} \quad (1)$$

$$BCR = \frac{\sum PV_{Benefits}}{\sum PV_{Costs}} \quad (2)$$

Where:

$PV_{Benefits}$: Present value of all future revenues (market value of the incremental oil)

PV_{Costs} : Present value of all project expenditures (chemical purchase, transportation, storage, and injection costs)

To determine the Present Value (PV) of any future amount, discount formular was used

$$PV = \frac{FV}{(1+r)^n} \quad (3)$$

$$PV = (1+r)^n \quad (4)$$

FV : Future value (the actual cash amount in a future year).

r : Discount rate

n : Number of years in the future.

$$BCR = \frac{\sum_{t=0}^T \frac{(Q_{oil,t} \times P_{oil})}{(1+i)^t}}{\sum_{t=0}^T \frac{(M_{chem,t} \times (C_{chem} + C_{import}) + OPEX_t)}{(1+i)^t}} \quad (5)$$

Where:

$Q_{oil,t}$ = Volume of incremental oil recovered at time t

P_{oil} = Price of crude oil

i = Discount rate

t = Time in weeks

$M_{chem,t}$ = Mass of ASP chemicals injected at time t

C_{chem} = Unit cost of the chemical (\$/kg).

C_{import} = Importation cost

$OPEX$: Operation cost

For $BCR > 1.0$: The project is profitable.

For every \$1 spent, you earn more than \$1 in return.

For $BCR = 1.0$: The project is at break-even.

Benefits exactly equal the costs.

For $BCR < 1.0$: The project is not viable.

You are spending more than you will recover in value.

III. RESULTS AND DISCUSSION

CHARACTERIZATION OF EOR AGENTS

The physical properties of the reservoir fluids and formulated agents are presented in Table 2. The Niger Delta crude oil exhibited a density of 0.931 g/cm³ and a viscosity of 252.82 cP, which, combined with a 20.6° API and a TAN of 3.02 mg KOH/g, classifies it as a heavy crude. Local surfactants (SLE) achieved a density and viscosity parity with the synthetic SDS. Furthermore, the local polymers—Potato Peel Powder (PPP), exhibited viscosities of 1253.10 cP . These values are very close to the synthetic Xanthan gum (1285.42 cP), confirming the technical capability of local bio-polymers to provide the necessary mobility control for heavy oil displacement

Table 2: Petrochemical Properties of the Fluid Samples

Sample	Density (g/cm ³)	Viscosity (cP)
Crude oil	0.93	252.82
Brine	1.03	1.01
NaOH	2.13	1.06
SDA	0.91	1.01

SDS	1.01	1.02
SLE	1.01	1.01
Xanthan gum	1.05	1285.42
PPP	1.02	1253.10

Comparing the Oil Recovery performance of EOR Agents

The foreign EOR agents achieved marginally higher oil recovery, consistent with the optimized purity and formulation of commercial-grade chemicals. However, this expected outcome is overshadowed by the highly significant finding that the locally sourced agent achieved 95.3% of the foreign agent’s performance (figure 1). This minimal performance gap demonstrates that locally sourced materials can compete favorably with imported synthetics. The results strongly indicate that local EOR agents possess the necessary chemical interactions and physical properties to be effective in heavy crude oil displacement.

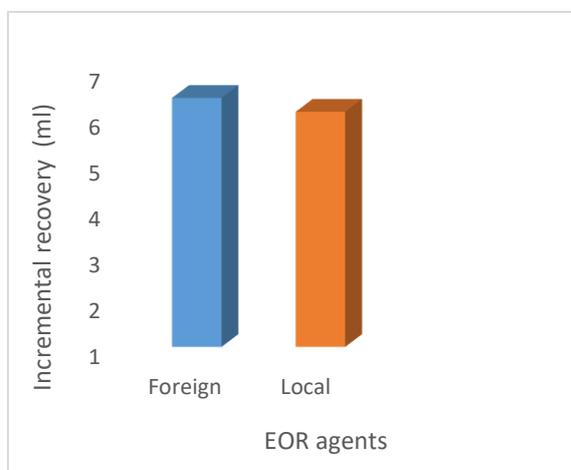


Figure.1: Oil Recovery performance of EOR Agents

Comparative Expenditure and Economic Analysis

The economic viability was assessed by comparing the Present Value of Benefits against Total PV Costs Table (3). Foreign ASP BCR: 1.78, Locally Sourced ASP BCR: 4.06. The analysis revealed that the profitability of the Foreign ASP agents is notably reduced due to substantial importation fees and high acquisition costs, with importation alone exceeding \$100,000, In contrast, the Locally Sourced ASP yields a return of \$4.06 for every \$1 invested. This demonstrates that the local agents are 2.28 times more economically viable than imported alternatives for Niger Delta heavy oil applications.

Table 3: Comparative Economic Analysis and Benefit Cost Ratio for Foreign vs. Locally Sourced ASP Agents

Metric	Foreign ASP slug	Local ASP slug
Total cost	\$249,188.02	\$104,409.07
Oil recovery	6,400bbl	6100bbl
Discounted benefit	\$444,430.28	\$432,597.26
BCR	1.78	4.06

IV. CONCLUSION

This study evaluated the technical and economic viability of locally sourced EOR agents against imported synthetic alternatives for applications in Niger Delta heavy oil reservoirs. Based on the experimental results and economic analysis, the following conclusions were reached:

1. The locally sourced ASP slug, comprised of wood ash, leaf extracts (*C. variegatus*), and bio-polymers (potato peel) demonstrated competitive displacement efficiency. It recovered 6.1 ml of oil compared to 6.4 ml from the synthetic foreign agents.
2. The local ASP agents are significantly more cost-effective. While the foreign project was limited by \$100,000+ in importation duties and high polymer costs (resulting in a BCR of 1.78), the local agents achieved a BCR of 4.06. For every dollar invested, the local agents returned \$4.06, making them 2.28 times more economically viable than foreign agents.
3. Harnessing Nigeria’s rich natural resources to produce local EOR chemicals can help cut importation cost, enhance domestic engagement in the oil and gas industry and strengthen the sector with indigenous innovation.

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