

Evaluation of Local Hydrate Inhibitors Sustainability in Production Operations in Niger Delta

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Abstract— three key factors; economics, technology, and the environment are what drive the oil and gas business. It's a capital-intensive business that has to account for every investment made during each project phase. It's interesting to note that the search for oil and gas is moving from onshore to shallow marine and deep offshore environments, which has increased the formation of the hydrate due to favourable conditions, such as the presence of water molecules, high pressure, and low temperatures. These indices significantly increase hydrate formation and exacerbate flow assurance issues therefore they need to be actively mitigated to avoid reactive mitigation strategies that result in higher costs for things like damaged equipment, corrosion, clogged pipelines, etc. This study's objective is to assess the viability of regional hydrate inhibitors utilizing important parameters including cost, performance, accessibility, and environmental friendliness. The economics supported the comparability and understanding of the value rate of the inhibitors over a one-year projection utilizing the net present value (NPV) of these inhibitors (Costacea plant extract, LFKHI, LDKHI, surfactant X, LSS, and LSM) to a conventional inhibitor (polyvinylcapolactant). The local inhibitors outcompeted the traditional inhibitor favourably. The inhibition efficiency of these inhibitors was also used to evaluate the sustainability of local hydrate inhibitors in which the Costacea plant had the highest inhibition efficacy of 84.50% at 0.01 weight percentage compared to the other inhibitors which had 72.81%, 75.44%, 69.30%, and 72.81%. Additionally, these local inhibitors can be gotten from plants and agro-waste products and are available in large volumes, they pose no danger to the environment because they are eco-friendly (non-toxic) and biodegradable, and are recommended for industrial trial.

Index Terms— Local Inhibitors, Flow Assurance, Hydrate, Temperature, Sustainability, Plant Extract, Inhibition Efficiency.

1 INTRODUCTION

THE Petroleum industry over the years has successfully drilled and produced petroleum products for several utilization processes. Its successful operations have been hinged on three essential elements which are Economics, Technology, and Environment. Oil and gas exploration involves a high risk of uncertainties which has to be backed up by a period of sufficient geological analysis, seismic exploration, and economic analysis to carry out a final investment decision for project development. Global Energy demand is expected to rebound to pre-crisis level in 2023 and increase in population by 1.3B by 2040. Hence, energy demand will increase by 19% by 2040, and two times more energy will be required to run the populace. This will lead to continuous demand for energy for local and industrial use. Natural gas is cost-effective, abundant, and reliable; it produces 40-65% of emissions than coal and crude oil. It's the cleanest form of fossil fuel and a highly efficient source of energy.

Regarding flow assurance in the oil and gas production from the wellhead to the production plant, natural gas hydrate (NGH) has been a major source of worry. It is said to be a serious issue with ensuring the flow of fluids through pipelines, particularly in deep offshore productions. If it is permitted to happen, operating and capital expenditures (CAPEX) could rise. Operating costs when hydrates form or are prevented are estimated statistically to be more than \$500M annually. Over \$1 million could be spent on Natural Gas Hydrate plugging every day that production is stopped. (Guo et al., 2005). However, Hydrate formation, a production nightmare that always

leads to corrosion and pipe clogging in the system and high operating costs for corrective measures, is a problem that Natural Gas processing must deal with. Due to this threat, mechanisms of control have been developed to reduce the negative impact of hydrate formation during gas production and transmission. Inhibitors of hydrate formation have been developed.

Of the class of substances known as clathrates, hydrates are one. Hydrates are produced by the reaction of many natural gas constituents with water. The hydrogen bonds between water molecules are what allow water to form hydrates. Water molecules serve as the host, and molecules from other substances that aid in crystal stabilization serve as the guests. Van der Waals forces are principally responsible for the stability offered by guest molecules. The molecular attraction is represented by these forces. Molecules in hydrates do not share a bond. The guest molecules are unrestricted in their rotation and movement inside the cages created by the host molecules. Four hydration structures, including the S-I cubic structure, S-II cubic structure, Simple hexagonal (SH) structure, and a brand-new anonymous structure, may form depending on how the hydrate forms and which molecule is the guest. Molecules smaller than six (6), such as methane, ethane, carbon dioxide, and sulfide, are found in the S-I structure. The S-II structure is made up of larger molecules ($6 \text{ \AA} < d < 7 \text{ \AA}$), such as propane and isobutane. If there are smaller helper molecules like methane, molecules with a size range of $7 d$ to $9 d$, such as isopentane and neohexane, can produce S-H. For a

typical hydrate structure to form in a hydrocarbon system, the following three conditions must actively occur:

1. Low temperature and high pressure
2. Pressure of hydrate formers such as CH₄, C₂H₄, CO₂, and H₂S
3. Sufficient amount of water

Hydrate plugs have caused the oil and gas companies to lose property and claim the lives of people by interfering with the normal flow of natural gas and other reservoir fluids in the production and transportation lines. (Sloan, 2008). When hydrate propagation occurs, a plug that divides the pipe into two pressure sections—one at high pressure between the well or high-pressure gas source and the plug and the other at low pressure between the plug and the gas recovery division—tends to form gradually. A pipe blast could happen in the upstream portion as a result of pressure buildup. When there is an increase in the pressure differential between the upstream and downstream parts, the plug can also act as a projectile that breaks the pipe. Both events can endanger personnel safety and damage production equipment (Sloan, 2008). This means that a hydrate formation mitigation plan is taken into account to ensure year-round production in major oil and gas-producing nations like Canada, Russia, and the USA, where surface temperatures may dip below freezing. Additionally, as the industry shifts toward deep-water and arctic production, where operational costs and conditions can be high and extreme, respectively, hydrate mitigation becomes increasingly important. To keep the transfer pipes from clogging, hydrate formation must be minimized (Makwashi et al., 2018). Hence, hydrate formation must be avoided to prevent the transfer pipes from becoming clogged.

The use of glycol or methanol, which are categorized as thermodynamic hydrate inhibitors, is a common practice to control hydrate formation. These are utilized in large quantities ranging from 30 to 60% of the total weight, which causes the hydrate equilibrium to shift away from the operating profile of the system. Because of this, they are costly and difficult to implement logistically, especially in distant and arid areas. Pollution is another issue that results from this and could become a problem if effective regeneration facilities are not utilized. Using low-dosage hydrate inhibitors (LDHIs), which are made up of kinetic hydrate inhibitors (KHIs) and anti-agglomerates, the oil and gas sector has been looking for alternative alternatives for the past 20 years. LDHIs are employed in extremely small doses, 0.1 to 3.0 weight percent (Kelland 2016,2018; Wang et al., 2019; S. Xu, et. al., 2016).

Several biofriendly kinetic hydrate inhibitors, including polysaccharides (starch, pectin, cellulose, and chitosan) and proteins, Kamal et al., (2016) have been studied in the last ten years to determine their potential. Although these studies have produced promising results, it is of great essence to evaluate the sustainability of these local hydrate inhibitors using the following indices; economics availability, performance, performance, and eco-friendliness.

Gas is the energy of the present and the future as there is an increasing need for cleaner energy. To prevent issues like flow strings, flow lines, choking of surface equipment, and other equipment, it is crucial to avoid hydrate formation circum-

stances. If hydrate is not prevented from forming, it can cause equipment damage if the plugs clump and move at high speeds, lowering the measured well head pressure in flow strings as well as total obstruction of flow lines and surface equipment. On locally produced green hydrate inhibitors, numerous studies have been conducted, hence evaluating these inhibitors for their sustainability is highly essential. In my study the following indices were used to assess their sustainability: availability, biodegradability, performance, and economic viability. These environmentally friendly hydrate inhibitors must be assessed for their accessibility, efficacy, costs, and biodegradability to achieve zero emissions of greenhouse gases.

2. CONDITIONS NECESSARY FOR HYDRATE FORMATION

2.1 Temperature within the Hydrate Risk Region

The production of gas hydrate often requires low temperatures. Although hydrates include 85% by mass of water, the system temperature cannot drop below 32F for the formation of these ice-like substances. Hydrates easily occur at temperatures of 70°F or higher, and even at greater temperatures (Sloan, 2000).

2.2 Pressure in Hydrate Equilibrium Region

Typically, high pressures increase the chance of hydrate formation. Gas hydrate is created by simple gases at a pressure of about 100 psi and 38°F. Because gas pipelines frequently operate at high pressures, reducing gas hydrate is crucial for ensuring smooth flow.

2.3 Adequate Water Molecules for Hydrate Cavities

Gas hydrates are made up of water molecules that may come from several sources. Sometimes the water is unrestricted water drawn from the reservoir. It might also be condensed water generated from cooling hydrocarbon fluid. Sometimes the pipeline's residence time is insufficient to prevent hydrates from forming from water that is still present, water that has evaporated in a gas medium, or water that is present in a hydrocarbon fluid.

2.4 Adequate Gas Molecules to Stabilize Hydrate Cavities

The typical gas molecules in hydrate range in size from methane to butane. H₂S, N₂, and CO₂ are among the gases that form hydrates well. High speed, turbulence, and places like valves and boiling points are additional elements that intensify these phenomena.

3. TYPES OF HYDRATE INHIBITORS

3.1 Thermodynamic Inhibitors

Alcohols and electrolytes are commonly used as thermodynamic inhibitors. These substances cause the hydrate to form at the same pressure but at a lower temperature by shifting the hydrate's pressure-temperature (P-T) thermodynamic equilib-

rium curve to the left. As thermodynamic inhibitors, substances such as methanol, ethanol, monoethylene glycol, diethylene glycol, triethylene glycol, and chloride of the first and second elements of the periodic table have been utilized. These inhibitors have several drawbacks, including the fact that they must be employed in considerable quantities (up to 50% by weight of the water phase) to have good effectiveness, aside from being costly, difficult to separate, and damaging to the environment. According to Behar et al., (1991), thermodynamic hydrate inhibitors were used to prevent the production of hydrates in quite substantial quantities (1.4 million tons at a cost of roughly \$ 500 million). As an example, alcohols, glycols, and inorganic salts are strongly polar molecules or ions that disrupt the hydrogen-bonded network of water molecules (Lafond et al., 2012). Strong electrostatic charge or hydrogen bonding to water molecules are prerequisites for their ability to block effectively (Li et al., 2011). As production pipelines travel to colder and deeper regions, there are disadvantages such as higher injection rates and greater storage (Mono Ethylene Glycol (MEG) is better than methanol (MeOH)), as well as health problems (Giavarini Hester, 2011).

3.2 Kinetic Inhibitors

Kinetic inhibitors that have been developed in recent years at a low amount (<2% by weight of the water phase) can solve the problem of hydrate formation. The mechanism of action of these inhibitors, unlike thermodynamic inhibitors, does not involve phase shifts. These inhibitors delay the hydrate nucleation of hydrates or prevent the growth of hydrate crystals. Antiagglomeration inhibitors and kinetic inhibitors are the two types of inhibitors. The inhibitors used in antiagglomeration use surfactants that cause water to be suspended in solution and only hydrate small water particles. A large amount of gas is used to form hydrates; however, the surfactant prevents small hydrate particles from sticking together and large particles from forming, which can clog the gas pipeline. Consequently, a liquid hydrocarbon phase is necessary. The amount of surfactant employed ranges from 0.5% to 2% by weight in contrast to thermodynamic inhibitors, which must be used in huge quantities. Additionally, 25% weight percent of methanol performs as well as 1% of Anti-Agglomerant. The existence of a liquid hydrocarbon phase is not necessary for the kinetic inhibitor, in contrast to the antiagglomeration inhibitor. This technique delays hydrate nucleation and inhibits the growth of hydrate crystals to bigger sizes.

3.2 c) Green Inhibitors (GIs)

These are non-polluting, biodegradable, and environmentally friendly inhibitors, hence their designation. Among these are antifreeze proteins (AFPs), natural and biodegradable polymers (NBPs), and ionic liquids (ILs), the majority of which are liquids with imidazolium bases and have been tried for reducing gas hydrates. Ionic liquids serve as both THIs and KHIs for the suppression of gas hydrates. Since they are predominantly organic salts with low melting points, they are liquid at room temperature or relatively low temperatures (about 32°C) (Jiang et al., 2009). Common cations include imidazolium and pyridinium, whereas anions include tetrafluoroborate (BF₄), dicyanamide (C₂H₃N₃), nitrate, chloride, and bromide. An in-

vestigation by Xiu et al., (2010) demonstrated that some ILs have large electrostatic charges and the ability to establish a hydrogen bond with water, which can slow the rate at which hydrates develop. The primary purpose of kinetic hydrate inhibitors is to establish hydrogen bonds with water, in addition to altering the thermodynamics of the system. Tetrafluoroborate anions, which include ILs and have some THI properties, have demonstrated excellent KHI performance. 1-ethyl-3-methylimidazolium bromide (EMIM-Br) and 1-ethyl-3-methylimidazolium tetrafluoroborate are examples of ILs (EMIM-BF₄). Various studies on green hydrate inhibitors have been required as a result of the concern for a greener environment. These inhibitors include natural and biodegradable polymers, antifreeze proteins, and plant starches.

Hydrates have been a problem for the oil and gas sector since Hammerschmidt discovered them in 1939. Gas hydrates, also known as clathrates, are crystalline solid formations that resemble ice and arise when water molecules create a cage-like structure around a smaller guest molecule. Methane, ethane, propane, butane types I and II, nitrogen, carbon dioxide, and hydrogen sulfide are among the most frequent guest molecules. Although they don't have the same solid structure as ice, they resemble ice crystals or wet snow in appearance. Water molecules build the structure of hydrate crystals Babakhani and Alamdri (2015) looked at how maize starch is used in the development and dissociation of gas hydrates. Five levels of maize starch were examined (200,400,600, 800, and 1000 ppm). Based on the results, it can be concluded that hydrate formation was not significantly affected by low concentrations, although enhanced hydrate formation rates were observed at concentrations above 400 ppm. They claimed that hydrate can hold methane 2.5 times more effectively at a concentration of 800 ppm than it could at a concentration of pure water devoid of maize. They also looked at the stability of hydrate under conditions of normal temperature and pressure. It was demonstrated that, for all concentrations, the maximum rate of dissociation occurred at the start of the process and afterward the rate declined. This was below the ice points of 272.2K and 269.2K. They also concluded that the mol% rate of dissociation for all concentrations at 269.2 K.

Folin and Rajzinger (2014) researched natural gas hydrate production and prevention using friendly inhibitors. The investigation was conducted in the North Sea region, and inhibitors were categorized based on how much of them degraded within 28 days. With a degradability of >60%, green inhibitors were rated as the best; yellow inhibitors scored between 20 and 60 percent, and red inhibitors scored under 20 percent.

Elechi et al. (2018) conducted a study on gas hydrate inhibition utilizing a natural plant extract in keeping with the green agenda slogan. The experiment was carried out in a lab mini-flow loop. Plant extracts (PE) with varying weight percentages (1, 2, and 3wt%) that contained bioactive substances like alkaloids, saponins, tannins, and flavonoids were employed with water cuts. Plots of pressure versus time, temperature versus time, differential pressure and pressure, and temperature versus time for both inhibited and uninhibited scenarios were used to evaluate the performance of the PE. Plant Extract (PE) at 1 and 2 weight percentages outperformed Mono Ethylene

Glycol at the same weight percentages in suppressing hydrates (MEG).

Odutola et al (2015a; 2015b) research focused on LPG hydrate development and prevention using ethanol and methanol as well as efficient hydrate management during gas expansion. In a laboratory flow loop using Polyvinylpyrrolidone and 2-(Dimethyl amino) ethyl methacrylate, Odutola et al. (2016) also investigated hydrate prevention.

Odutola et al., (2017) designed, constructed, and validated a 39.4-inch (12-meter) long laboratory flow loop made of 0.5-inch 316 stainless steel pipe that was housed in a 4-inch PVC pipe skid mounted with temperature and pressure gauges, mixing vessels (gas and inhibitor), and a natural gas cylinder for hydrate studies. The loop has been used to screen and choose Kinetic Hydrate Inhibitors since it was able to anticipate hydrate formation in an accurate manner (KHIs). All of these employed artificial compounds, but the goal of this work is to use plant extract (PE), which is readily available in Sub-Saharan Africa, as a gas hydrate inhibitor.

Plant extract (PE) was described as a gas hydrate inhibitor by Elechi et al. (2018). The experiment was carried out using a miniature flow loop apparatus with a 39.4-inch length and a 0.5-inch internal diameter that was enclosed in a 4-inch polyvinyl chloride (PVC) pipe skid set on a metal framework (Odutola et al., 2017). The local inhibitors known to include bioactive substances such as alkaloids, saponins, tannins, and flavonoids in diverse weight percentages were employed for water in different weight percentages (1, 2, and 3wt%). To assess the effectiveness of the plant extract, plots of pressure vs time, temperature versus time, differential pressure and pressure, and temperature versus time for both inhibited and uninhibited scenarios were employed (PE). In comparison to mono ethylene glycol at the same weight percentages, plant extract (PE) at 1 and 2 weight percentages showed greater inhibitory capacity (MEG).

A study on plant family extract as a gas hydrate inhibitor was conducted by Elechi et al., in 2019. They concluded that Costacea family Extract (CFE), which is thought to perform best for CFE, competed favorably well with the traditional hydrate Mono Ethylene Glycol (MEG) in all weight percentages. However, it did slightly better than MEG in 2wt%, which is considered the optimum for CFE.

Okon et al. (2018) also investigated the usage of locally produced materials based on agro-waste as gas hydrate inhibitors. The locally developed agro-based kinetic hydrate inhibitor outperformed the conventional N-VinylCaprolactam (N-VCap) and 2-Di (methylamino) ethyl methacrylate gas hydrate inhibitors (2-DMEM).

hydrate inhibitors are readily available in their local areas and are derived from plant sources. They should be researched and developed as gas hydrate inhibitors instead of MEG, N-VCap, and 2-DMEM, which are hazardous to both humans and the environment because they are environmentally friendly (in the sense that they are biodegradable).

Okon et al. (2022) evaluated the inhibitory potency of a kinetic hydrate inhibitor (KHI) made locally from agricultural waste to that of two conventional kinetic hydrate inhibitors (KHIs), N-Vinylcaprolactam (N-VCap) and 2-Di(methylamino)ethyl Methacrylate (2-DMEM). Pressure decreases from 150 psi to 122, 127, and 1200 psi for 0.01 to 0.03 wt%, respectively, indicating the locally designed kinetic hydrate inhibitor (LDKHI) to be a better inhibitor. Plots of pressure vs time, temperature versus time, and initial and final pressures also demonstrated this. N-VCap had pressure values of 114, 124, and 117 psi for the same concentration range while 2-DMEM had values of 95, 120, and 116 psi. The LDKHI dosage that worked best was 127 psi at 0.02 wt%. The high volume of gas present in the loop at the end of 120 minutes showed that LDKHI was still the best at reducing the loop pressure decrease for all inhibitor concentrations of 0.01 to 0.03 wt%. With inhibition efficiencies of 75.44, 79.82, and 73.68%, the standard kinetic inhibitors performed worse than LDKHI, according to the plot of inhibition efficiency versus weight percentages. In comparison, the 2-DMEM inhibited system had values of 51.75, 73.68, and 70.18% for 0.01, 0.02, and 0.03 wt%, whereas NV-Cap had values of 68.42, 77.19, and 71.05%. When compared to N-VCap and 2-DMEM, these values for LDKHI are the highest.

4 METHOD

The methodology adopted in this study is analytical, with a focal point on the evaluation study of the sustainability of locally made hydrate inhibitors using the following indices;

- I. Economics
- II. Performance
- III. Eco-friendliness
- IV. Availability

4.1 ECONOMIC ANALYSIS

The economic analysis of green hydrate inhibitors seeks to evaluate their economic viability using net present value (NPV)

a) Net Present Value

The net present value (NPV) of an investment project is the present value of the net cash flows less than the initial cash outflow. If a project's NPV is greater than or equal to zero, the project should be accepted. Three local inhibitors were analyzed for their net present value. These inhibitors are Costacea family extract, Agro waste-based inhibitors, and locally formulated kinetic hydrate inhibitors. The project is acceptable when the NPV of an investment at a given discount rate is positive. The project with the highest NPV should be accepted after considering mutually exclusive projects. A negative net present value (NPV) implies that the investment is not profitable, and the project should be rejected. If the NPV is zero, the decision maker is undecided because the investment yields the

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According to Elechi et al. (2019) and Okon et al. (2018), Costacea Family Extract (CFE) and the agro waste-based gas hy-

same return as the alternative use of the funds. Other criteria, such as the degree of risk involved with each project, should then be used to make the decision. It is a question of corporate policy in which a discount rate is utilized to compute the net present value. Some companies prefer a fixed discount rate over the project lifetime while other companies use a declining discount rate. It is defined by the formula.

$$NPV = \frac{\text{Revenue} - \text{Expenditure}}{(1 + r)^t}$$

Where r = discount rate
t = time (years)

Assumptions:

The following assumptions were made to effectively analyze and compare the NPV of the various local hydrate inhibitors used in this analysis

- Costaceae plant extract (CPE) \$2.5/kg (N1, 100)
- Locally formulated kinetic hydrate inhibitor \$1.5/kg (N660)
- Locally Developed Kinetic hydrate inhibitor \$1.5/kg (N660)
- Surfactant X (Surf. X) \$2.0/kg (N880)
- Locally Sourced Surfactant \$2.0/kg (N880)
- Locally Sourced Material (LSM) \$2.2/kg (N968)
- Chemical inhibitor (polyvinylcapolactant)\$10/kg (N2933.92)
- \$1 (USD) is equal to N440

4.2 COST ANALYSIS OF THE LOCAL HYDRATE INHIBITORS (LHI)

The cost analysis shows the costs of different green hydrate inhibitors. Designated Values were calculated for the cost of each inhibitor.

1000kg of Costacea Plant Extract (CPE)	= \$1,250
1000kg of LFKHI	= \$750
1000kg of LDKHI	= \$750
1000kg of Local Surfactant X	= \$1000
1000kg of Local Sourced Surfactant	= \$1000
1000kg of Locally Sourced Material	= \$1100
1000kg of Polyvinylcapolactant	= \$10000

4.3. PERFORMANCE

The performance of the local hydrate inhibitor analyzed in this study will be evaluated using inhibition efficiency and stability (temperature and pressure changes). To know how well the inhibitors performed was evaluated from experiments done using the weight percentages of the different inhibitors considered in this study. The inhibition factor was first calculated after which the inhibition efficiency follows as a function of pressures for the inhibitors.

To know how well these inhibitors performed, the efficiency of inhibition determined for all weight percentages of the local hydrate inhibitors was used. The inhibition factor is first calculated after which the inhibition efficiency is determined as a function of pressure and temperature. The inhibition efficiency is defined by:

$$I.E = 1 - X \quad (1)$$

Inhibition efficiency percentages

$$\%IE = (1 - X) \% \quad (2)$$

Where X stands for the inhibition factor and is given as

$$X = \Delta P_{\text{inhibited}} = P_i - \Delta P_{\text{uninhibited}} \quad (3)$$

$$\Delta P_{\text{inhibited}} = P_i - P_{\text{inhibited}} \quad (4)$$

$$\Delta P_{\text{uninhibited}} = P - P_{\text{uninhibited}} \quad (5)$$

Were,

$\Delta P_{\text{inhibited}}$ is the difference between the initial and final pressure of the inhibited experiment.

$\Delta P_{\text{uninhibited}}$ is the difference between the initial and final pressures of the uninhibited experiment.

P_i is the initial pressure for both the inhibited and uninhibited systems.

$P_{\text{inhibited}}$ is the final pressure for the inhibited systems. $P_{\text{uninhibited}}$ is the final pressure for the uninhibited system.

To evaluate the performance of these various local hydrate inhibitors I used their inhibition efficiencies (secondary data).

To determine this, I plotted the inhibition percentages and weight percentages of each inhibitor.

4.4 AVAILABILITY

The availability of these local hydrate inhibitors is evaluated based on their commercial quantity (volume). These inhibitors are locally sourced from our natural environment and can be purchased from the marketers of these local inhibitors.

4.5 ECO-FRIENDLINESS

These kinetic hydrate inhibitors are sourced from plants and are biodegradable as they are organically formed. They are better inhibitors, unlike chemical inhibitors which are toxic and environmentally harmful to the ecosystem. Furthermore, these inhibitors are biodegradable when subjected to high temperatures and pressure.

5 DISCUSSION OF RESULTS

5.1 ECONOMICS ANALYSIS USING NET PRESENT VALUE (NPV)

Analysis of the local inhibitor (CFE)

If 1kg = \$2.5

$$1000\text{kg} = \$2.5 \times 1000 = \$2500$$

Assume facilities expense and other operations to be \$15,000,000

$$\text{Overall expenditure} = \$15,000,000 + \$2500 = \$15,002,500$$

Revenue = (\$2.21 * Volume of gas Recovered in SCF)

Assuming the Recovered volume is = 1MMMScf * \$2.21
\$2.2MMMScf

Injection time 54 weeks (365 days)

$$\text{Therefore time (in years)} = 365 / 365 = 1\text{year}$$

$$NPV = \frac{\text{Revenue} - \text{Expenditure}}{(1 + r)^t}$$

$$\text{Revenue-Expenditure} = \$2,200,000,000 - \$15,002,500 = \$2,184,997,500$$

Assume a Discount factor of 10%

$$(1 + 0.01)^t = (1.1)^1 = 1.1$$

$$NPV = \$2,184,997,500 / 1.1$$

$$NPV \text{ for CPE} = \$1,986,361,363.63$$

5.2 PERFORMANCE

The performance of the local hydrate inhibitor analyzed in this study will be evaluated using inhibition efficiency and stability (temperature and pressure changes). To know how well the inhibitors performed was evaluated from experiments done using the weight percentages of the different inhibitors considered in this study. The inhibiting factor was used to calculate the inhibition efficiency. To know how well these inhibitors performed, the efficiency of inhibition determined for all weight percentages of the local hydrate inhibitors was used. The inhibition factor is first calculated after which the inhibition efficiency is determined as a function of pressure and temperature.

The inhibitor efficiency and weight percentage of each local hydrate inhibitor are given below.

TABLE 1 WEIGHT AND INHIBITION EFFICIENCY PERCENTAGES

Weight %	CFE	Surfactant X	LDKHI	LSS	LSM
0.01	84.21	72.81	75.44	69.30	72.81
0.02	60.53	81.58	79.82	80.71	81.58
0.03	73.68	75.44	73.68	78.09	72.81
0.04	73.67	75.44	73.66	79.82	72.80

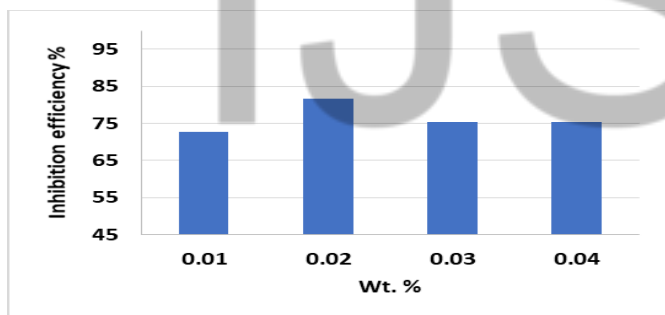


Fig. 1. Weight vs Inhibition Efficiency % of Costacea Plant Extract.

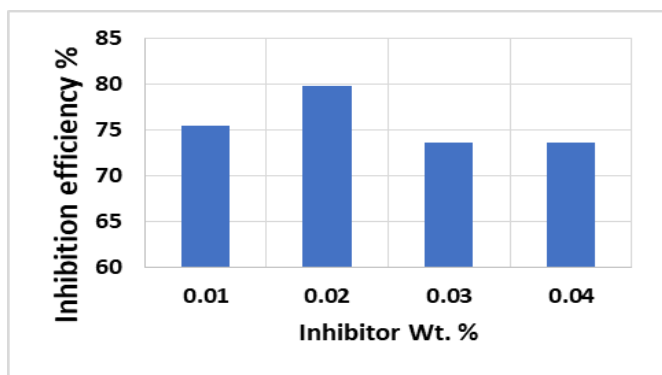


Fig. 2. Weight vs Inhibition Efficiency % of Surfactant X.

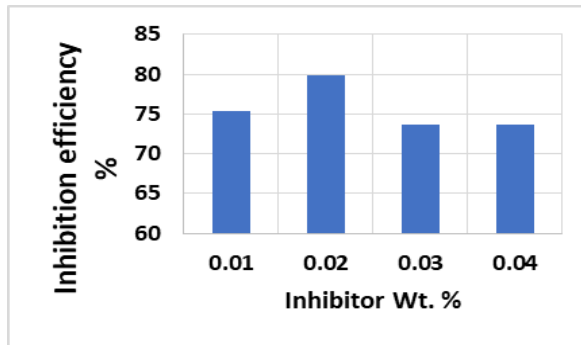


Fig. 3. Weight vs Inhibition Efficiency % of (LDKHI).

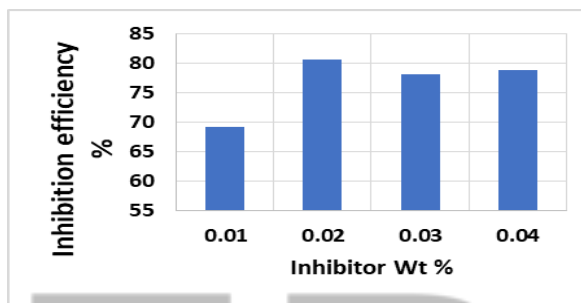


Fig. 4. Weight vs Inhibition Efficiency % of locally sourced surfactant (LSS)

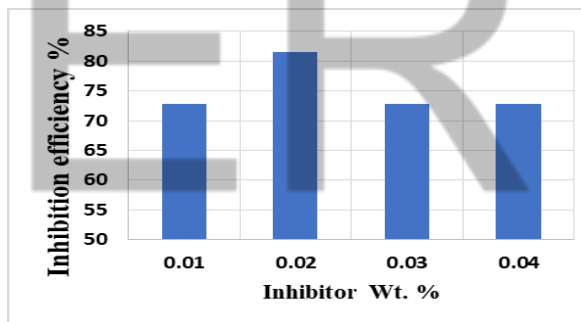


Fig. 5. Weight vs Inhibition Efficiency % of locally sourced material (LSM)

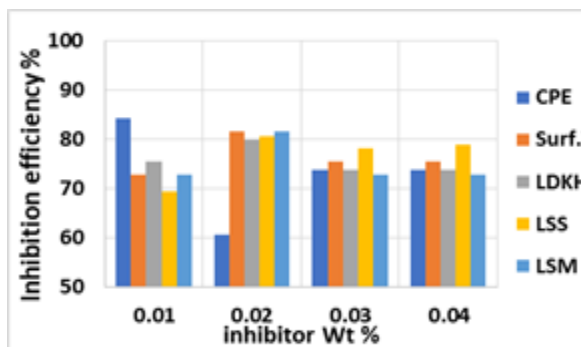


Fig. 6. Summary of Weight vs Inhibition Efficiency % of various Local Hydrate.

6 DISCUSSION OF RESULTS

6.1 Economics

To determine the net present value of the inhibitors I calculated the revenue and expenditure of the inhibitors and compared them with a conventional inhibitor (polyvinylcaprolactant). The following net present values were obtained after calculations.

NPV for Local hydrate kinetic inhibitor = \$1,986,361,363.63

NPV for Conventional hydrate Kinetic inhibitor = \$1,986,354,545.40

Results obtained show that the local inhibitors competed favorably against the conventional hydrate inhibitor.

6.2 Performance

The performance was determined by obtaining secondary data on the inhibition efficiency and weight percentage of these local inhibitors. Thereafter, I plotted the inhibition efficiency percentages against the weight percentage. The graphs obtained in (fig 1-fig 5) show that the Costacea plant extract had a better inhibition efficiency at weight percentage (0.01), and the surfactant X also showed a competitive inhibition efficiency but it was at (0.02 wt) percent. The Costacea plant extract performed better against all other local inhibitors. It is economically efficient as less weight percentage is required for its inhibition efficiency. Unlike the Surfactant X, it will require more weight percentage of the inhibitor to have a good inhibition efficiency, and this will incur more cost (CAPEX).

7 CONCLUSION

The local hydrate inhibitors evaluated for sustainability in this project are; Costacea plant extract, locally formulated hydrate inhibitor (LFKHI), locally developed hydrate kinetic inhibitor (LDHKI), Surfactant X, locally sourced surfactant (LSS), locally sourced material (LSM), etc. These local hydrate inhibitors were evaluated for their sustainability based on the following indices; economics, performance, availability, and eco-friendliness.

The economics was evaluated using net present value. The net present value of each inhibitor was determined and the most viable one was compared with a conventional inhibitor (polyvinylcaprolactant). Results obtained show that the local inhibitor competed favorably with the conventional inhibitor. It had a higher NPV value of (\$1986361363.63) and that of the conventional kinetic inhibitor has a value of (\$1986354545.4).

The performance of these inhibitors was assessed based on their inhibition efficiency and weight percentage. Then, a graph demonstrating inhibition effectiveness against weight percentage was plotted. The graphs plotted indicate that the Costacea plant extract had the maximum inhibition efficiency, i.e., a high level of hydrate formation inhibition. They are easily accessible and environmentally friendly. They are readily available and can be obtained in large quantities. Because they are made from plants and are biodegradable and non-toxic.

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