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Economic Analysis for Chemical and Mechanical Well Intervention for ESP Well AWH-02 in the South Sumatra Basin

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Abstract

The accumulation of mineral scale, particularly calcium carbonate (CaCO_3), is the primary cause of mechanical failure in the Electrical Submersible Pump (ESP) at the Pendopo Field. Well AWH-02 has historically exhibited a low Run Life (RL) due to aggressive scale deposition. Well intervention is necessary to maintain production at this well. The method employed combines chemical (application of an organic scale inhibitor) and mechanical well intervention (pump repair). This study began by examining the potential of areca nut (*Areca catechu*) seed extract as an environmentally friendly organic inhibitor, obtained from the local community around the field. Solvent extraction, chemical characterization through phytochemical testing, and laboratory-based static inhibition efficiency testing showed a maximum efficiency of 92.5% at a concentration of 150 ppm. Field data analysis confirmed that mitigation using this organic inhibitor can double the ESP lifetime in this well compared to conditions without inhibition, which, from an economic analysis perspective, reduces well operating costs. Reduced well intervention costs and competitive raw material prices result in a 42% savings on total scale treatment operating costs.

Keywords: Chemical, Scale inhibitor, Electrical submersible pump, Production cost, and Well Intervention.

1. Introduction

The formation of mineral scale is one of the technical challenges that directly impacts well productivity and economic viability. Thermodynamically, scale forms due to a disruption in the equilibrium between formation water, injection water, and reservoir rock caused by extreme changes in physical conditions as the fluid moves from the reservoir to the surface (Kamal *et al.*, 2018; Zakir-Hassan *et al.*, 2022).

A drop in pressure and changes in temperature cause formation water to lose its ability to dissolve minerals, making the water supersaturated, which triggers the deposition of mineral crystals on pipe walls and subsurface equipment. Calcium carbonate (CaCO_3) is the most common type of scale found in oil wells, including in the Pendopo Field. The formation of calcium carbonate scale is significantly influenced by the release of carbon dioxide (CO_2) and reservoir

fluids. When CO₂ is present the pH of the water increases, thereby accelerating the crystallization reaction and triggering CaCO₃ precipitation. In wells using Electric Submersible Pumps (ESPs), this condition is highly dangerous because scale not only blocks the flow path but also disrupts pump performance. The ESP motor's load changes dynamically due to the additional resistance caused by scale. Noul-Mehidi and Bukhamseen (2019) demonstrated that rapid scale buildup on the pump stages can be identified through fluctuations in the motor current signal. This symptom typically appears several weeks before total failure of the ESP system occurs. In other words, monitoring the motor current signal can serve as an early indicator to anticipate failures caused by scale.

Issues with the integrity of Electric Submersible Pumps (ESPs) in wells with high levels of mechanical impurities and a tendency for scale formation are the primary factors limiting the equipment's service life. In addition to mechanical damage caused by dynamic torsional stress during startup with a soft-starter system (Rabbi *et al.*, 2020), the pump is also susceptible to hydro-abrasive wear on the impeller and diffuser due to solids, so that the ESP's service life can be drastically reduced sometimes lasting only a few days (Shishlyannikov *et al.*, 2021). Well AWH-02 at the Pendopo Field has historically faced similar issues. Aggressive scale deposits have caused premature ESP failure. This condition requires well intervention (well service) at a very high cost.

To date, scale removal has generally relied on hydrochloric acid (HCl). However, the use of HCl poses risks due to its highly corrosive nature toward the ESP's metal components and its adverse environmental impacts (Kamal *et al.*, 2018; Ahmad *et al.*, 2018). Research by Garcia-Olvera *et al.* (2018) indicates that the use of chelating agents as an alternative scale remover is safer. These agents can dissolve mineral deposits without damaging either the metallic or non-metallic materials of the ESP. Furthermore, this method can significantly increase production without damaging the equipment. As an innovative and sustainable solution, this study evaluates the use of an organic scale inhibitor based

on areca nut (*Areca catechu*) extract. Areca nuts are rich in polyphenol and tannin compounds, which possess free hydroxyl groups and thus act as natural chelating agents (Vanimakhal & Balasubramanian, 2016). The primary mechanism involves binding to ions and disrupting crystal growth, thereby preventing the formation of mineral deposits (Wang *et al.*, 2021). This paper aims to evaluate the effectiveness of this green technology at Well AWH-02, encompassing laboratory efficiency tests and economic simulations to establish new standards for effective, economical, and environmentally friendly scale management.

2. Methodology

The AWH-02 well is a directional well with artificial lift issues using an Electric Submersible Pump (ESP). This well has a total depth of 2482 mMD. The well structure consists of 20" casing at a depth of 103 mMD, 13-3/8" casing at 405.6 mMD, 9-5/8" casing at 1800 mMD, 7" liner from 1516.12 to 2,306 mMD, and a 4-1/2" liner from 2,198.96 to 2,482 mMD. Well AWH-02 produces from the productive Batu Raja Formation (BRF) in the South Sumatra Basin, with an average oil production of approximately 30 BOPD and total (gross) fluid production of approximately 650 BFPD. However, this well has a high water cut of 95.3%.

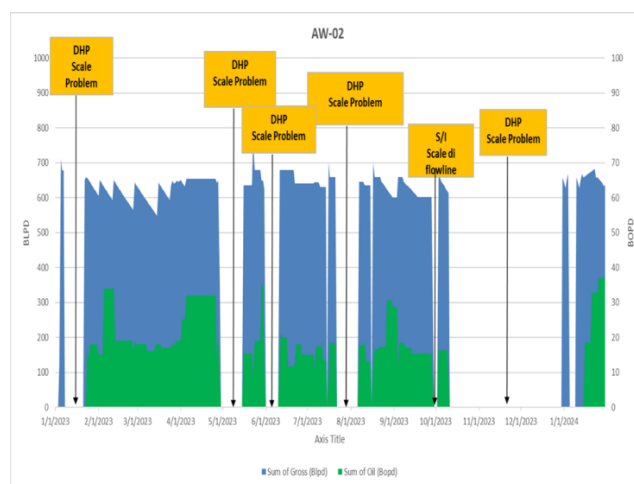


Fig. 1: Production History of Well AWH-02.

The BRF layer in the AHW structure consists primarily of limestone rich in calcium carbonate (CaCO₃). This makes the layer highly susceptible to scale formation. During the production process, particularly with the aid of artificial lift, there are

significant changes in pressure and temperature within the fluid, causing the calcium carbonate to become unstable and prone to precipitation, which then forms scale.

Fig. 1 shows the production history of Well AWH-02 with a Qmax of 811 BFPD. The production target for Well AWH-02 utilizes a Premiere brand ESP pump, type TD 750, operating at a frequency of 56 Hz; with 334 stages; at a pump set depth of 1,777 m, achieving an efficiency of 83%. During well servicing, scale formation was observed on the gas separator and inside the wellhead due to the accumulation of mineral scale deposits.



Fig. 2: Production Issues at Well AWH-02.

Production of Scale Inhibitor from Areca Nut Extract

The areca nut seed extract used as a scale inhibitor is produced by drying small pieces of areca nut seeds in the sun for approximately 2 weeks. Afterward, the seeds, which still contain moisture, are dried further in an oven until their weight remains constant, then ground into a fine powder using a blender. One gram of the powder is dissolved in distilled water to a total volume of 1 liter to produce a solution with an initial concentration of 1000 ppm. This solution is stirred using a magnetic stirrer for 2–3 hours at 90 °C, then filtered through filter paper to obtain a pure extract. From this initial solution, dilutions are prepared at 100 ppm, 200 ppm, and 300 ppm, which are then used as standards in laboratory testing of the inhibitor's effectiveness.

Calculation of the Effectiveness of Areca Nut Scale Inhibitors in the Laboratory

Laboratory test data were obtained using the bottle test (static test) titration method to determine the growth rate of CaCO₃ in accordance with NACE TM0374-2001, with observations taken over a 30-minute period in a water bath at 90 °C. Once the results of the laboratory test were obtained, the percentage effectiveness of the areca nut scale inhibitor could be calculated using the following formula:

$$\% \text{ efektivitas inhibitor} = 100 \times \frac{(Ca - Cb)}{(Cc - Cb)}$$

Where:

Ca = weight of the precipitate after the inhibitor was added at the equilibrium point (g/L)

Cb = weight of the precipitate without the inhibitor at equilibrium (g/L)

Cc = initial precipitate weight (g/L)

From the test data of formation water from well AWH-02 without the addition of a scale inhibitor, the weight of CaCO₃ precipitate was found to be 2.842 grams/liter. Subsequently, testing of formation water from well AWH-02 using areca nut scale inhibitor at various concentrations (ppm) yielded CaCO₃ sediment weights of 2.275 grams/liter at a 100 ppm inhibitor dose, 2.192 grams/liter at a 200 ppm dose, and 2.078 grams/liter at a 300 ppm dose. The following table shows the results of the scale inhibitor tests in the laboratory. From this data, the percentage effectiveness of the areca nut scale inhibitor can be calculated.

Scale inhibitor solution at a concentration of 100 ppm

$$\begin{aligned} \% \text{ Inhibitor Effectiveness} &= \frac{100 \times (2.275 - 2.842)}{(0 - 2.842)} \\ &= 19.95\% \end{aligned}$$

Scale inhibitor solution at a concentration of 200 ppm

$$\begin{aligned} \% \text{ Inhibitor Effectiveness} &= \frac{100 \times (2.192 - 2.842)}{(0 - 2.842)} \\ &= 22.87\% \end{aligned}$$

Scale inhibitor solution at a concentration of 300 ppm

$$\begin{aligned} \% \text{ Inhibitor Effectiveness} &= \frac{100 \times (2.078 - 2.842)}{(0 - 2.842)} \\ &= 26.88\% \end{aligned}$$

Planning and Implementation of Organic Scale Inhibitor Injection

Scale inhibitor injection is planned for well AWH-02 to prevent mineral scale deposition, thereby extending the pump's service life. Based on laboratory test results, the effectiveness of the areca nut scale

inhibitor was calculated to determine the optimal dosage. Based on the laboratory tests conducted, it was found that a dosage of 300 ppm is the optimal dosage for the initial reference of the organic scale inhibitor pilot project. A dosage of 300 ppm was selected because it demonstrated the highest scale inhibitor effectiveness value of 26.88%. The required injection volume can be calculated based on the optimal dose determined by comparing it with the estimated daily formation water production at a target flow rate of 80% of 811 BFPD, or 650 BWPD. With a scale inhibitor concentration of 300 ppm, the daily volume requirement for the chemical scale inhibitor is 31 liters per day.

$$LPD = \frac{Ppm \times BFPD \times 159}{1000000}$$

Dimana:

LPD = Liters per day

Ppm = Parts per million

BFPD = Barrels of fluid per day

$$LPD = \frac{(300 \times 650 \times 159)}{1.000.000}$$

LPD = 31 liters / day

Economic Evaluation

An economic evaluation was conducted to determine the economic viability of the production target for well AWH-02 in relation to the additional operating costs from the injection of organic scale inhibitor derived from areca nut extract, the investment cost of capillary tubes for injection into the well, and the reduction in well maintenance frequency resulting from the increased lifespan of the ESP pump in well AWH-02.

Table 1 shows the costs required for the implementation of organic scale inhibitor injection using areca nut seed extract into the downhole of well AWH-02, assuming there are no costs for the chemical injection pump since it is company-owned equipment.

Table 1: Costs of Implementing Organic Areca Nut Scale Inhibitor Injection.

Item	Jumlah	Unit	Harga (USD)	Total (USD)
Schale inhibitor biji pinang per hari	31	liter	\$ 8,42	\$ 8,42
Capillary tube	1777	m	\$ 2,92	\$ 5.188,84
Pompa injeksi chemical	0	Ea	-	-
Sewa ESP	1	per hari	\$ 392,41	\$ 392,41
Biaya Rig 350 HP	1	per job	\$ 26.216,56	\$ 26.216,56

3. Results

Based on the test data for the formation water from well AWH-02 without the addition of a scale inhibitor, the weight of the CaCO₃ precipitate was found to be 2.842 grams per liter. Subsequently, testing of the formation water from well AWH-02 using areca nut

scale inhibitor at various concentrations (in ppm) yielded CaCO₃ sediment weights of 2.275 grams/liter at a 100 ppm inhibitor dose, 2.192 grams/liter at a 200 ppm dose, and 2.078 grams/liter at a 300 ppm dose. The following table shows the results of the scale inhibitor tests in the laboratory.

Table 2: Laboratory Test Results for Well AWH-02 Using Areca Nut Scale Inhibitor.

Dosis SI (ppm)	Suhu	Waktu	Berat endapan akhir (gram/ 50 mL)	Berat endapan awal (gram/ 50 mL)	Penambahan berat CaCo3 (gram/ 50 mL)	Berat endapan akhir CaCO3 (gram/L)
blank	90	5	0,1342	0	0,11342	2,684
blank		30	0,1421	0	0,1421	2,842
100		5	0,10945	0	0,10945	2,189
100		30	0,11375	0	0,11375	2,275
200		5	0,09735	0	0,09735	1,947
200		30	0,1096	0	0,1096	2,192
300		5	0,0666	0	0,0666	1,332
300		30	0,1039	0	0,1039	2,078

Based on the laboratory tests conducted, it was determined that a dose of 300 ppm is the optimal dose for the initial reference of the pilot project-scale organic scale inhibitor. The 300 ppm dose was selected because it demonstrated the highest scale inhibitor effectiveness value of 26.88%. The required injection volume can be calculated based on the resulting optimal dose by comparing it with the estimated daily formation water production at a target Q of 80% of 811 BFPD, or 650 BWPD. With a scale

inhibitor concentration of 300 ppm, the daily volume requirement for the chemical scale inhibitor is 31 liters/day. To compare the economic parameters of well production, the one-year economic calculations for well AWH-02 in **Table 3** which compare the base case without scale inhibitor application-are contrasted with the case involving the implementation of an organic scale inhibitor in **Table 4**. The comparison covers lifetime, frequency of well service operations, production maintenance costs, and LPO.

Table 3: Economic Calculation Results for Well AWH-02 without Scale Inhibitor.

Parameter	Tanpa SI Biji Pinang	Unit
Lifetime	2	Bulan
Pekerjaan Well Service	6	Per Tahun
Biaya Maintenance Produksi		
- Biaya Well Service	\$ 157,30	6 xPer Tahun
LPO dari pekerjaan Well Service	\$ 81,00	Per Tahun
Total Loss (Biaya Maintenance Produksi + LPO WS)	\$ 238,30	Per Tahun

Table 4: Economic Calculation Results for Well AWH-02 Using a Scale Inhibitor.

Parameter	Tanpa SI Biji Pinang	Unit
Lifetime	5	Bulan
Pekerjaan Well Service	2,4	Per Tahun
Biaya Maintenance Produksi		
- Biaya Well Service	\$ 62,92	2,4 xPer Tahun
- Biaya Scale Inhibitor	\$ 3.073,30	Per Tahun
- Biaya Pembelian Capillary Tube	\$ 5.188,84	1x Per sumur
LPO dari pekerjaan Well Service	\$ 32,40	Per Tahun
Total Loss (Biaya Maintenance Produksi + LPO WS)	\$ 103,58	Per Tahun

From the economic comparison results, it was found that the implementation of a scale inhibitor derived from areca nut extract can reduce production maintenance costs and lost production opportunity by \$133,968 per year compared to not using a scale inhibitor.

4. Discussion

Well AWH-02 is a production well in the Pendopo Field that uses an Electrical Submersible Pump (ESP) for artificial lift. This well has experienced serious operational issues. Throughout 2023, Well AWH-02 underwent 6 well service operations. Following the well service operations, it was found that the primary cause of pump failure was the presence of mineral scale deposits (scale) that clogged and damaged the

pump impeller. This issue resulted in an average ESP pump lifespan of only 2 months; leading to a Loss of Production Opportunity (LPO) of approximately 5 weeks per year and a significant increase in operational costs due to the high frequency of well service operations. Therefore, the high frequency of well service operations at the AWH-02 well is not merely an internal technical issue for the operator, but also a strategic concern regarding operational cost efficiency and the maximization of national production.

Historical production data for the AWH-02 well throughout 2023 shows an increasing trend in the frequency of well service activities; there have been six well service operations triggered by issues with the ESP unit due to scaling. This situation reflects

operational instability, as the average pump lifespan is only two months before failure occurs. When compared to global industry standards, where ESPs can have a service life of two to five years depending on well conditions, performance at AWH-02 falls far below the efficiency threshold.

Further analysis of pump components retrieved from the wellbore consistently revealed the accumulation of solid scale material on the intake, impeller, and diffusers. Geological and reservoir data indicate the well is producing from the Batu Raja Formation, which consists of limestone. Evaluation data confirmed that the dominant component of the scale deposits is calcium carbonate (CaCO_3) in the calcite mineral phase. Calcite is the most thermodynamically stable form of CaCO_3 and often forms a crust that is difficult to remove mechanically during production, where a pressure drop and CO_2 release occur, which increases the fluid's pH and reduces the solubility of calcium and carbonate ions.

To extend well life in the face of scaling issues, one approach is chemical treatment using scale inhibitors to slow the rate of scale growth. One type of scale inhibitor is organic; research has shown that tannin content in areca nuts can function as a scale inhibitor. The static bottle test method was used to evaluate the efficiency of chemical concentrations in preventing CaCO_3 precipitation. Based on the evaluation of the inhibitor's effectiveness, the optimal dose of scale inhibitor that effectively prevents CaCO_3 precipitation is 300 ppm, with an efficacy of 26.88%. The daily injection volume requirement for the scale inhibitor, calculated at a dose of 300 ppm for a well with a gross production of 650 bfpd, is 31 liters per day.

An economic evaluation was conducted to compare the one-year production scenarios for well AWH-02 without a scale inhibitor (the base case; **Table 3**) and with the implementation of an organic areca nut scale inhibitor (**Table 4**). Although there are no scale inhibitor costs, high production losses and repair costs make this scenario less economical, with a total loss per year of \$238,299. In the scenario with a scale inhibitor, there are additional production maintenance costs, namely the initial investment cost for purchasing capillary tubes and the ongoing operational cost for

producing the organic areca nut scale inhibitor. However, these costs are offset by significant savings from a reduction in well service frequency to 2.4 times per year and a decrease in LPO from well service work.

Based on a comparison of the two scenarios, the implementation of a scale inhibitor demonstrates significant economic advantages. This proves that a preventive approach through chemical treatment is more economical in the long term than a curative approach that only involves repeated repairs. The increase in ESP lifetime from 2 months to 5 months is the primary contributor to cost savings and increased revenue from production at well AWH-02.

5. Conclusion

The primary cause of scaling issues in the AWH-02 well is calcium carbonate (CaCO_3) scale. Its formation is triggered by changes in pressure and temperature conditions within the well, which disrupt the chemical equilibrium of the formation water. Evaluation of laboratory test data shows that the injection of an organic scale inhibitor derived from areca nut at a dose of 300 ppm demonstrated the highest inhibitory effectiveness in preventing CaCO_3 scale formation, with a value of 26.88%. The required chemical volume is 31 liters per day, which is feasible as a pilot project for continuous injection at the bottom of the well using a capillary tube and a chemical pump. An economic evaluation demonstrated that the prevention scenario using a scale inhibitor yielded better economic parameters than the scenario without an inhibitor. This strategy increases the average well life from 2 months to 5 months; it also significantly reduces operational costs by lowering the frequency of well servicing from 6 times to 2.4 times per year and minimizes production loss, with a total loss of \$103,582. In contrast, for the scenario without a scale inhibitor, production maintenance costs are dominated by well servicing work performed 6 times per year. Although there are no scale inhibitor costs, high production losses and repair costs make this scenario less economical, with a total annual loss of \$238,299. The scale inhibitor used is an organic type derived from areca nut seeds, through which the company seeks to enhance the value of its CSR program for areca nut cultivation by utilizing areca nut products to support the company's production

operations. Based on the evaluated data, scale prevention using an effective organic scale inhibitor derived from areca nut seeds can extend well lifespan, maintain production continuity, optimize well economics, and improve the company's industrial relations with local stakeholders.

6. Author Contributions

H.: initiated and developed the research concept, designed the study methodology, performed the economic evaluation of chemical and mechanical well intervention alternatives, analyzed the results, and prepared the manuscript. N.S.; B.S.; A.W.H: contributed to field data collection, production and intervention data processing, data validation, and technical analysis. They also assisted in reviewing the findings and improving the manuscript. All authors participated in the interpretation of the results, reviewed the manuscript critically, and approved the final version for publication.

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8. Conflicts of Interest

This publication is free of any conflict of interest.

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