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# Production Well Microbial Mitigation and H2S Risk Management

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**Abstract:** One Field has been eternally acknowledged as a sweet arena without the presence of any souring phenomena. On the other hand, the Sulfate Reducing Bacteria (SRB) growth which has been lately observed in the field Water Injection System played a major role in increasing the $H_2S$ concentrations in particular A fields. The objective of this study is to mitigate the SRB growth in the A Water Injection System and manage the risk of the Hydrogen Sulfide ($H_2S$). In order to reduce the $H_2S$ concentrations and the return the Fields back to their original states. Thereafter, Biocide Treatment usage; based on the thorough evaluation performed in both the Lab and Fields by collecting more than 100 samples from designated wellheads and identified sampling points in the field Water Injection System network. Biocide field trial for one year was conducted with a persistent monitoring program. It appealed that the Biocide Treatment is influential, efficient and functional, carving deeper in the SRB mitigation and $H_2S$ risk management, the averaged $H_2S$ concentrations and trends in the Fields are being controlled and minimized in both the oil and gas phases.

**Keywords:** H2S risk management, SRB mitigation.

## 1. Introduction

In A fields, elevated $H_2S$ concentrations were detected and reported. Historically, this field has no presence of $H_2S$, it was decided to determine the $H_2S$ concentrations and trends, define the sources of souring, determine the root cause and develop a mitigation plan for curbing the alarming souring phenomena.

A relentless surveillance plan was also developed to utilize a wide range of scientific analysis. Several sampling campaigns were conducted to collect samples from Oil Producers and PWIs for the $H_2S$ concentration measurement with dragger tubes. In addition, thorough evaluation of the sampling results verified and confirmed $H_2S$ concentrations and trends in A Trend and Water Injection System. Thereafter, Microbial characterization was performed on produced water, crude and injection water using quantitative polymerase chain reaction (qPCR) technique. The qPCR provides information on the presence and abundance range of microorganisms and is regarded as one of the most accurate methods is Microbial studies. The analysis showed moderate counts of total bacteria, total archaea, Sulfate Reducing Bacteria (SRB) and Sulfate Reducing Archaea (SRA) which indicates the environmental conditions suitability for prokaryotic organisms growth. Both SRB & SRA are best known across the oil and gas industry for biological generation for $H_2S$. These findings points to the fact that SRB & SRA are maybe the root cause behind the detected souring phenomena.

In parallel with the microbial analysis, an isotope

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analysis was conducted to determine the source of $H_2S$. Three gas samples were collected and a Carbon isotope analysis was carried out. The results concludes the existence of biogeochemical processes at the reservoir level which further confirms that elevated SRB & SRA activity is the root cause behind the $H_2S$ generation.

Microbial colonization and elevated SRB/SRA activity are associated with ineffective treatment. Traditionally, water injection systems are treated with organic Biocide to control microbial counts and reduce SRB/SRA activity to a tolerable level. The discovered souring phenomena and detected counts of SRB/SRA proves that Water Injection System treatment (with Nitrate Treatment) was ineffective before the Biocide Treatment Switching Process took place back in November 14, 2017.

## 2. Nitrate Treatment

Nitrate Treatment was used over the conventional Biocide treatment in A field, which was deactivated back in 2008, to curtail the existed Sulfate Reducing Bacteria (SRB) in Water Injection System and prevent the accumulation of anticipated Sulfide in the surface facilities. Also, it was considered as an anti-SRB cleansing mechanism, 40% cost effective process and environmentally friendly treatment; since the Nitrate is usually consumed by its mode of action and its concentration where it is expected to be negligible at the end point (upstream of the Power Water Injector (PWI)).

The water injection system in A Field controls two major types of bacteria namely SRB and Nitrate Reducing Bacteria (NRB). Both (SRB/NRB) compete for Carbon source to complete their metabolism cycle. Nitrate treatment is merely a bio-modification process to control SRB. The goal of this process is competitive exclusion where NRB outcompete SRB for the limited Carbon source. This is done through continual dosing of Nitrate to curtail SRB activity. In summary, Nitrate treatment does not have a biocidal effect (does not eradicate/kill bacteria). Nitrate treatment will simply promote NRB activity and curb SRB activity in injection system and near wellbore area (where SRB are simply pushed deeper into formation).

## 3. Biocide Treatment

Since nitrate treatment was proven ineffective in field A, biocide as a replacement of nitrate for water injection system treatment was recommended to control SRB growth. Therefore, the selected best two-biocide pairs from the lab evaluation were recommended for the field trial.

Water injection system in A filed (Fig. 1) consist of production Center (PC), which located in the middle of the field and connected with four water injection plans (WIP). The biocide injection plan for the field trial was designed with microbial (SRB/GAB) and $H_2S$ monitoring program as following:

1) Baseline data for bacterial count and $H_2S$ monitoring during injecting Nitrate will be established for two months.

2) Stop Nitrate treatment for one month.

3) Biocide injection for both pairs; first pair will be injected in WIP- 2&3, and second biocide pair will be injected in WIP1&4 for three months.

4) Biocide optimization for both pairs for three months.

5) biocide-switching process will be conducted; first biocide pairs will be move to WIP-1&4, and second pair will be moved to WIP-2&3, for another three months.

6) Biocide optimization for both pairs for three months.

The timeline below summarizes the recorded activities (Fig. 2).

## 4. SRB Mitigation

To mitigate the SRB growth, therefore, all required data collection and analysis are being accomplished by A field lab based on the monitoring program to

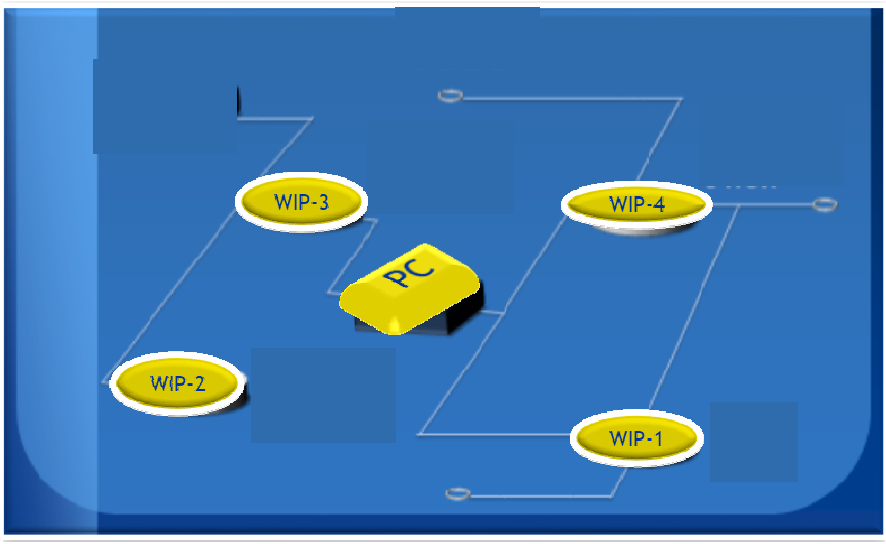


**Fig. 1 Filed A water injection system.**

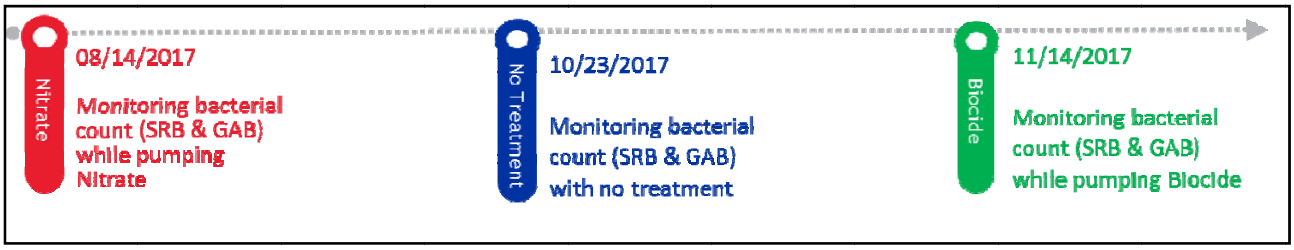


**Fig. 2 Three Treatment Phases – biocide injection plan.**

ensure effective treatment. The samples are being collected from 9 points as follows; PC, WIP-1, WIP-2, WIP-3, WIP-4, Coupon Strips at WIP-1, Coupon Strip at WIP-2, Coupon Strip at WIP-3, and Coupon Strip at WIP-4. The following graphs (Figs. 3-6) represent the bacterial count trends in Water Injection System from August 14, 2017 to June 25, 2018. It is worth noting that the ongoing Biocide testing is conducted on both SRB & General Anaerobic Bacteria (GAB) utilizing serial dilution method "Most Probable Number" (MPN) to streamline and sustain the Biocide Treatment Switching Process.

As seen in these graphs (Figs. 3-6), there is a clear indication that the existing Biocide treatment is effective in controlling the SRB as the bacterial count was significantly reduced. Moreover, the bacterial count was maintained at low levels.

Likewise, an obvious impact is noticed on GAB count further confirming the effectiveness of the existing Biocide Treatment in reducing bio-mass population and maintaining the bacterial count at low levels, as shown in Figs. 5 and 6.

In parallel, similar conclusion can be attained from plotting the data on normal scale as demonstrated in Fig. 4.

In Conclusion, the existing Biocide treatment is effective and functional in reducing the overall bacterial count, maintaining low count of bacteria and the consequent controlling the SRB manifestation. By tackling the root cause of elevated SRB activity and $H_2S$ generation, a positive impact is anticipated on the $H_2S$ generation souring control. In fact, promising sings were already remarked as it will be exhaustively explained in the next section ($H_2S$ Risk Management at A Fields).

## 5. $H_2S$ Risk Management at Fields

It has been always a safe operation throughout the

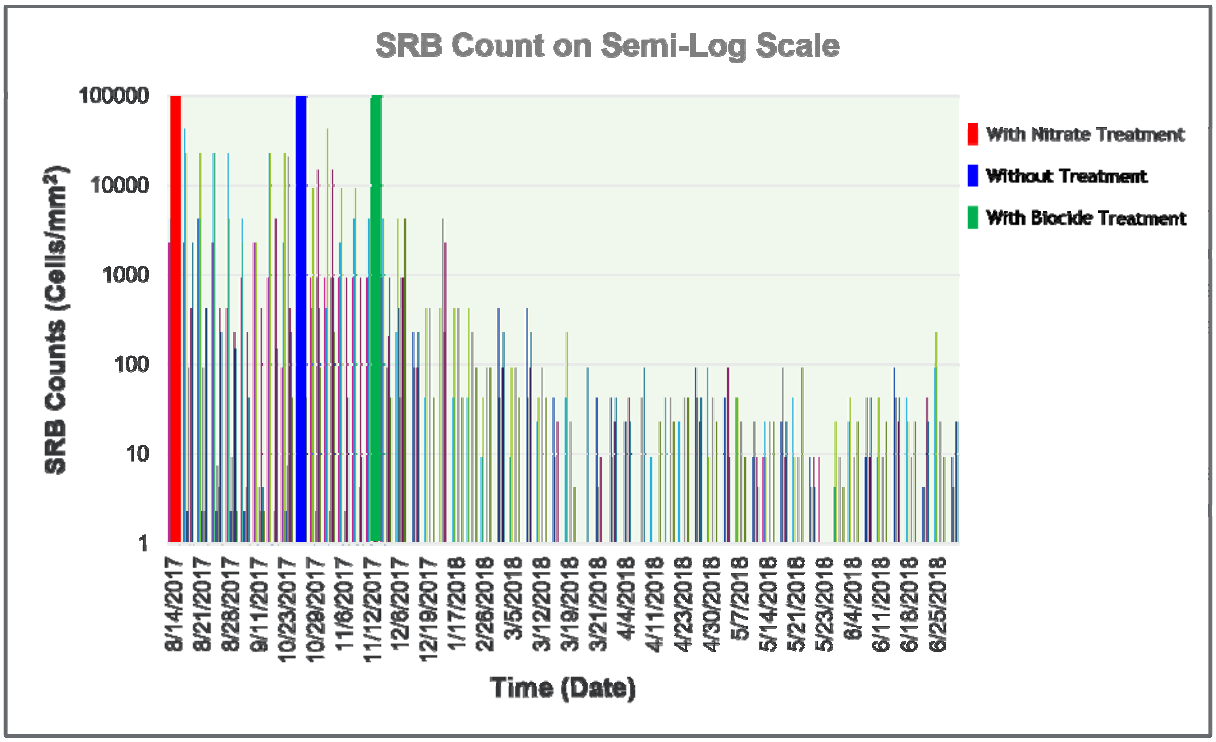


**Fig. 3 SRB Count Represented on Semi-Log Scale (blue marks halt of Nitrate Treatment while green marks start of Biocide injection).**

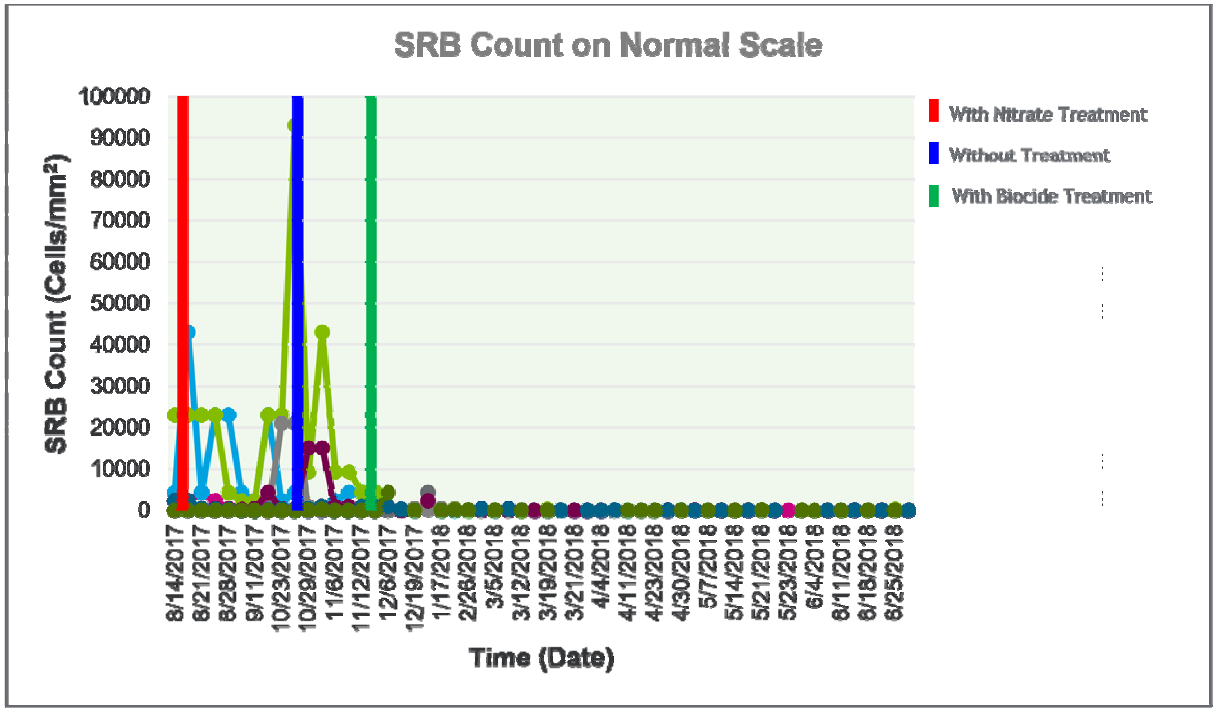


**Fig. 4 SRB Count Represented on Normal Scale (blue marks halt of Nitrate Treatment while green marks start of Biocide injection)**

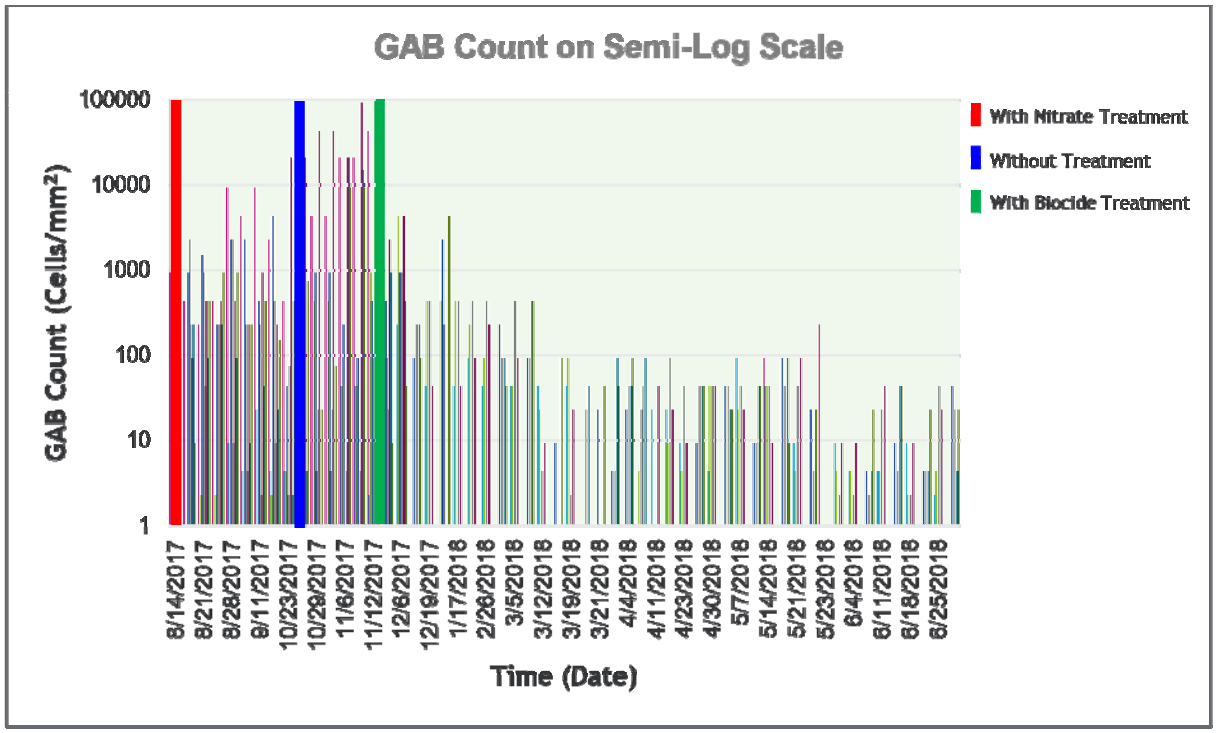


**Fig. 5** GAB count represented on semi-log scale.

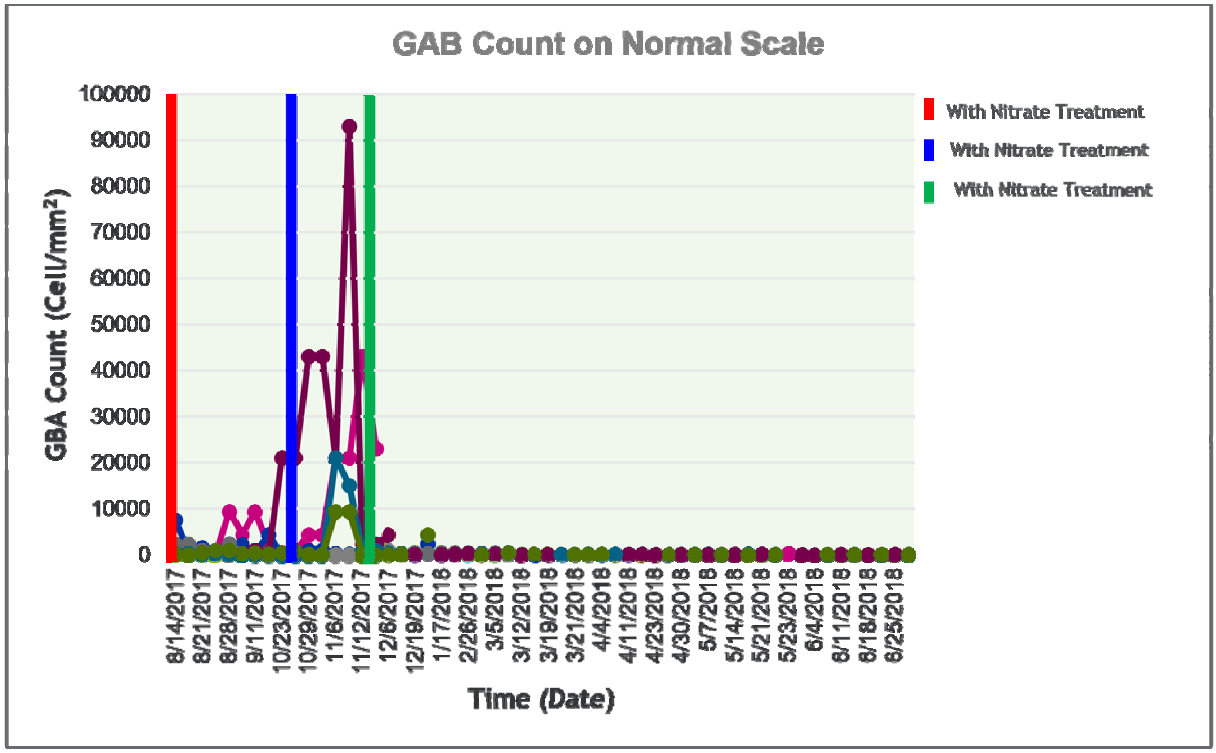


**Fig. 6** GAB count represented on normal scale.

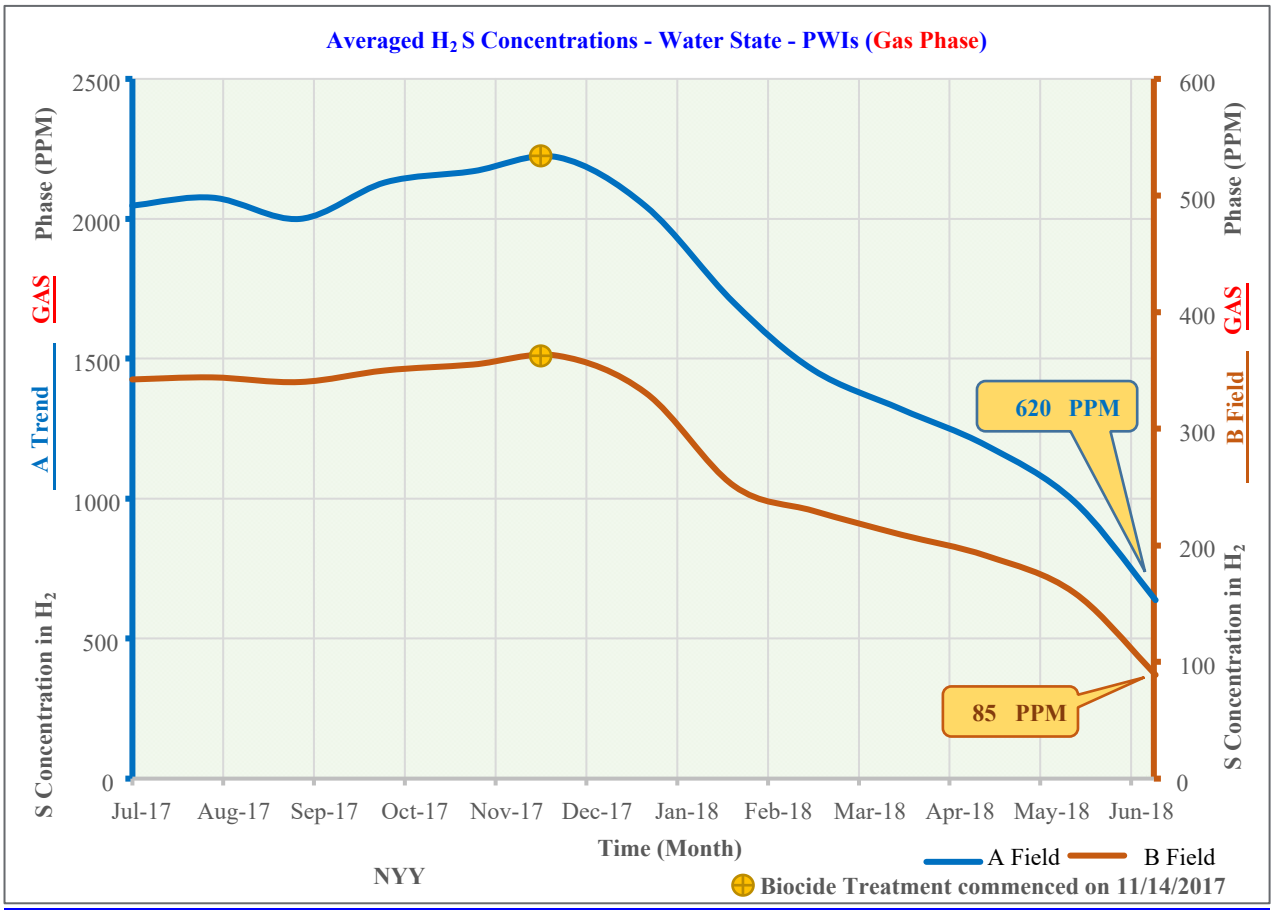


**Fig. 7 Averaged $H_2S$ concentrations at a field – Water State - PWIs (gas phase).**

Afiled hub, despite of the $H_2S$ presence, which has been restrained by recognizing the SRB growth as a main root cause. As it was explained in this comprehensive study (SRB Mitigation section), the Water Injection System is being well-maintained by the Biocide Treatment Switching Process to mitigate the SRB growth. Also, the required surface samples from variety locations within field facilities and certain wells were collected and analyzed which in turn demonstrated a drastic declination in the SRB growth (refer to Bacterial count graphs in the SRB Mitigation section "Figs. 3-6").

Carving deeper in the SRB mitigation and $H_2S$ risk management, there is an ideal and direct relationship between the SRB and $H_2S$; since SRB produces enzymes capable to accelerate the reduction of the Sulfate Components to a corrosive $H_2S$ content. With these considerations, the $H_2S$ concentrations in A Fields are being controlled and minimized in both the oil and gas phases (from Oil Producers and PWIs).

Figs. 7-12 display the magnified achievements for the significant reduction in $H_2S$ concentrations as follows:

*5.1 Water State – PWIs (Gas Phase)*

The water state at A field PWIs in the gas phase, the averaged $H_2S$ concentrations fell from 2060 PPM to 620 PPM with a reduction of 70% while it reduced from 365 PPM to 85 PPM at B field with 77% reduction, as demonstrated in Fig. 7. This is a direct result of the SRB/SRA growth/activity control.

*5.2 Crude State – Oil Producers (Gas Phase)*

Considering the crude state at Afield Oil Producers in the gas phase, the averaged $H_2S$ concentrations stayed at zero PPM in B field Oil Producers (Fig. 8).

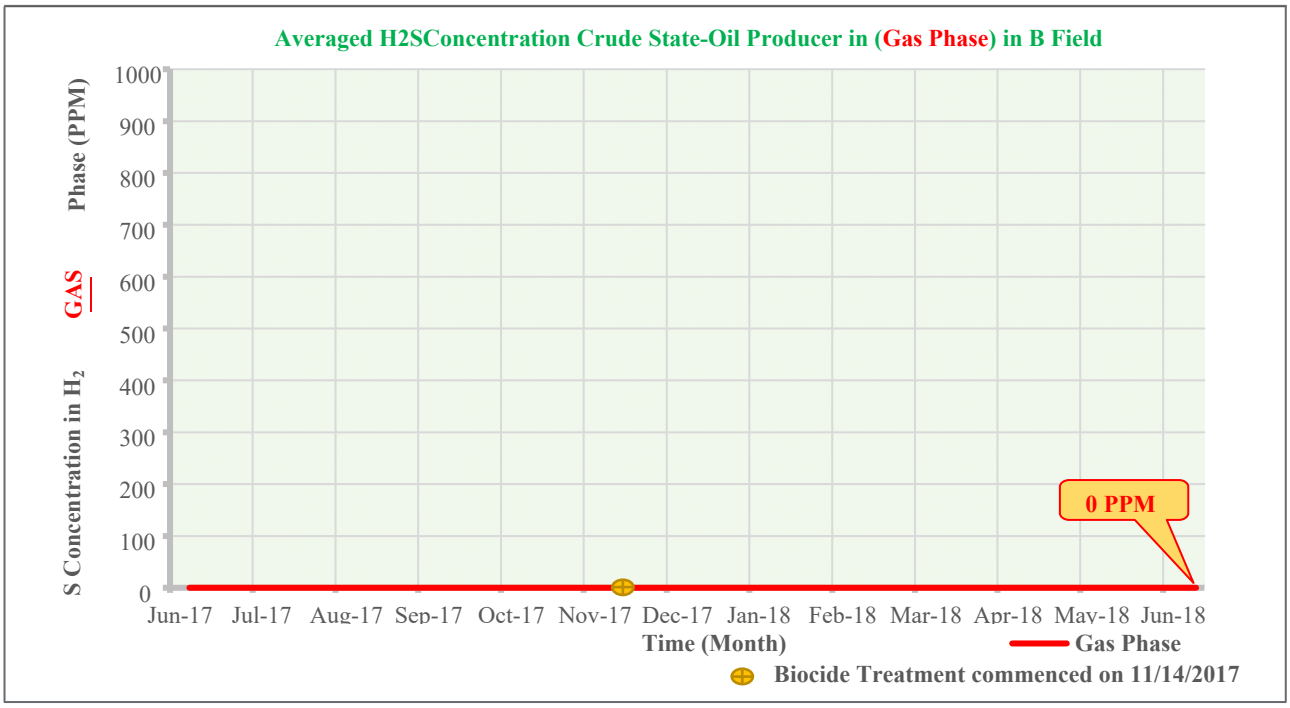


**Fig. 8 Averaged $H_2S$ concentrations at B field oil producers – Crude State (gas phase).**

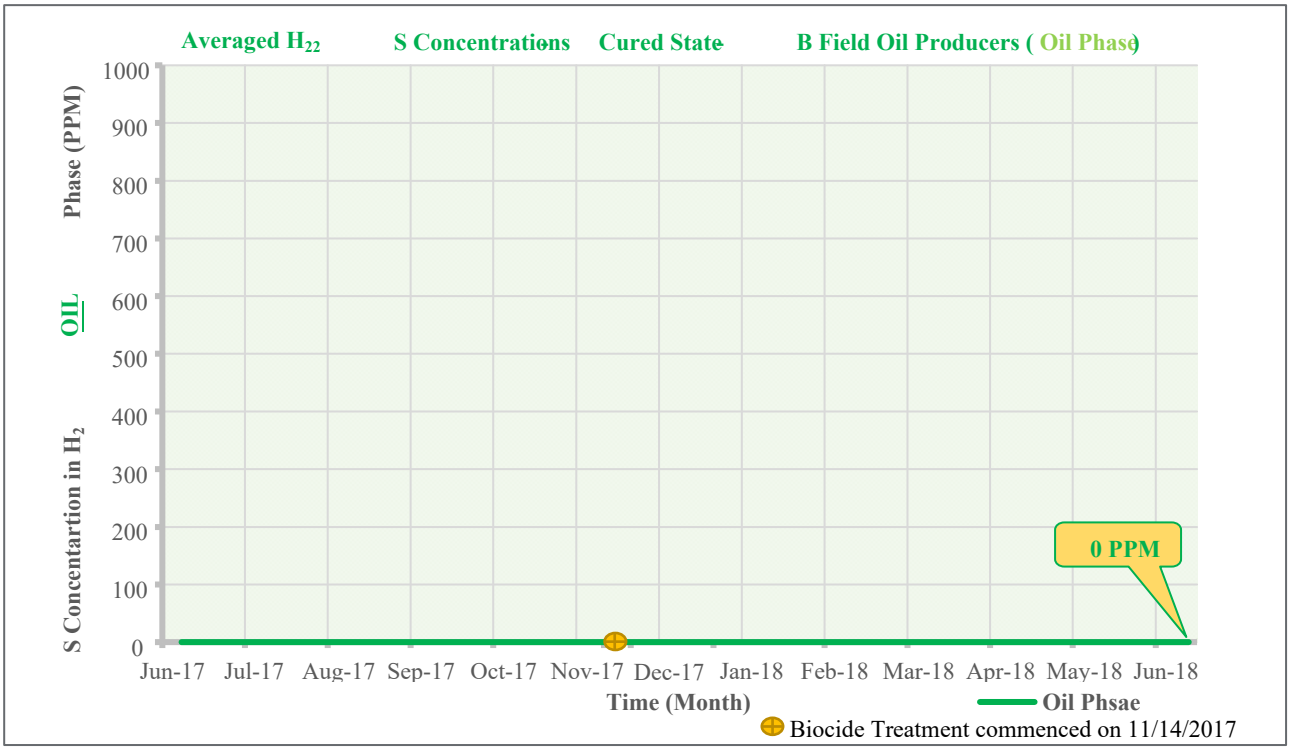


**Fig. 9 Averaged $H_2S$ concentrations at B field oil producers – Crude State (oil phase).**

However, the averaged $H_2S$ concentrations at A filed trend Oil Producers become apparent from Fig. 9 that the concentration is more than a dichotomy in the Gas phase from 845 PPM to 320 PPM which is equivalent to 62% $H_2S$ reduction. It is worth noting that the contaminated produced water from A field trend was

terminated from being part of the B field water injection system back in 2016.

*5.3 Crude State – Oil Producers (Oil Phase)*

Similarly, the crude state at B Field Oil Producers in the gas phase, the averaged $H_2S$ concentrations stayed at zero PPM in B Field Oil Producers (Fig. 9) while it recorded a noticeable reduction from 25 PPM to 4 PPM in Afield trend Oil producers with $H_2S$ reduction of 84% (Fig. 10).

Figs. 11 and 12 presented below summarize the raw data of $H_2S$ concentration per well per month in both gas and oil phase as follows:

As clearly seen in the graphs above, a major continuous improvement has been started since February 2018 due to the effective Biocide treatment, which will be endured to return the A fields to their original states.

Spotting the light on the A fields, Tables 3-5 summarizes the averaged $H_2S$ concentrations for A Trend and Saudi B Field in mol% and PPM as follows:

- Water State:
  - ✓ Gas Phase.
- Crude State:
  - ✓ Gas Phase.
  - ✓ Oil Phase.

As revealed in Tables 3-5, the $H_2S$ concentrations have been vividly reduced after the deployment of the Biocide Treatment Switching Process; which will continue to ensure the A field Water Injection System is being effectively treated.

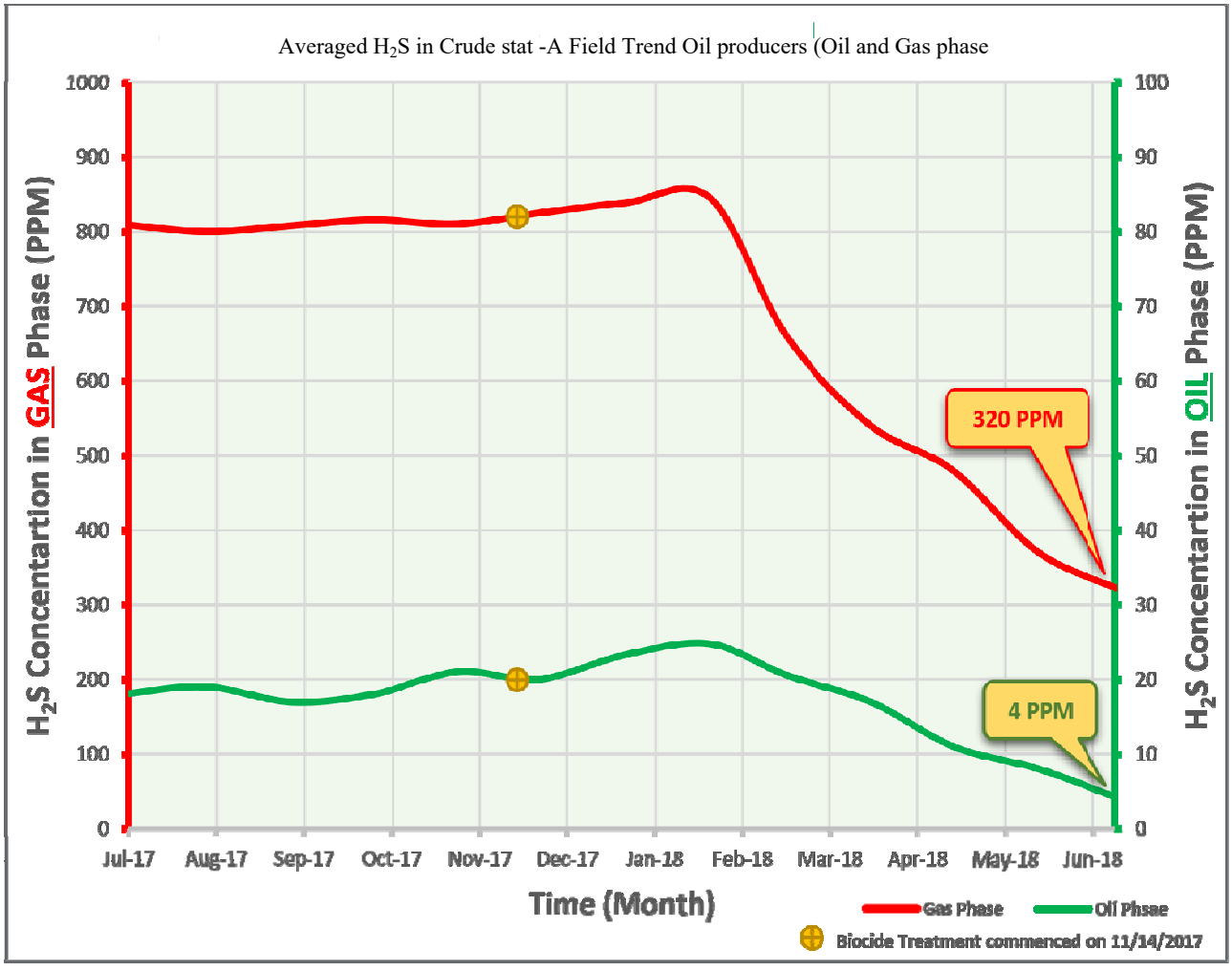


**Fig. 10 Averaged $H_2S$ concentration at A field trend oil producers – Crude State – (oil and gas phases).**

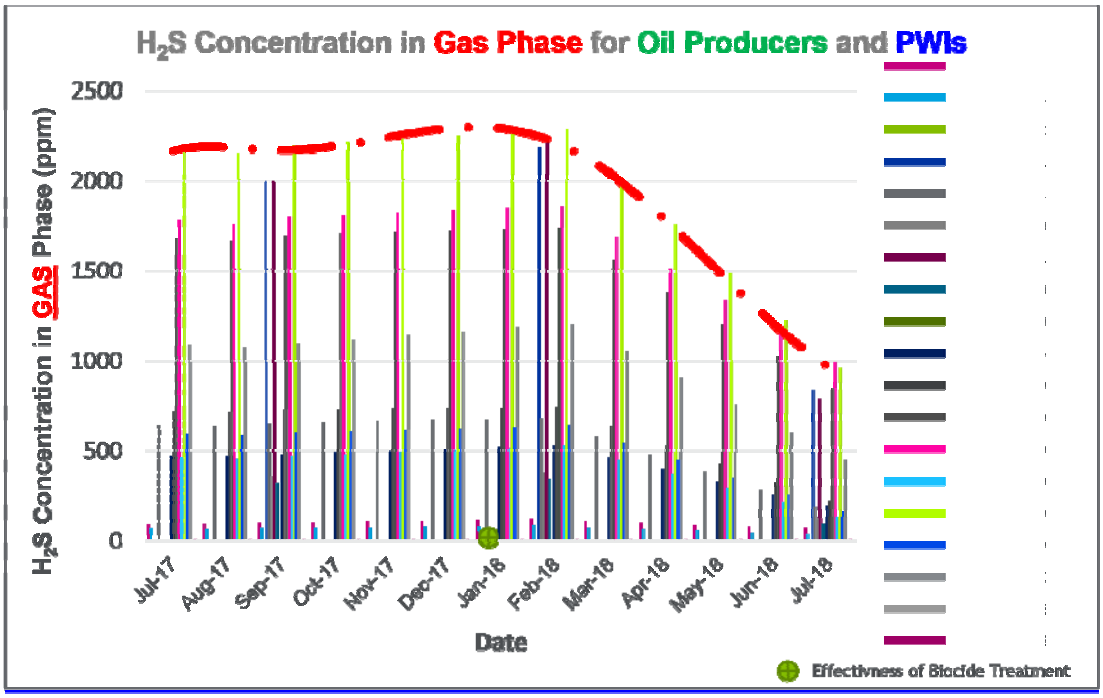


**Fig. 11** $H_2S$ concentration in gas phase per well per month.

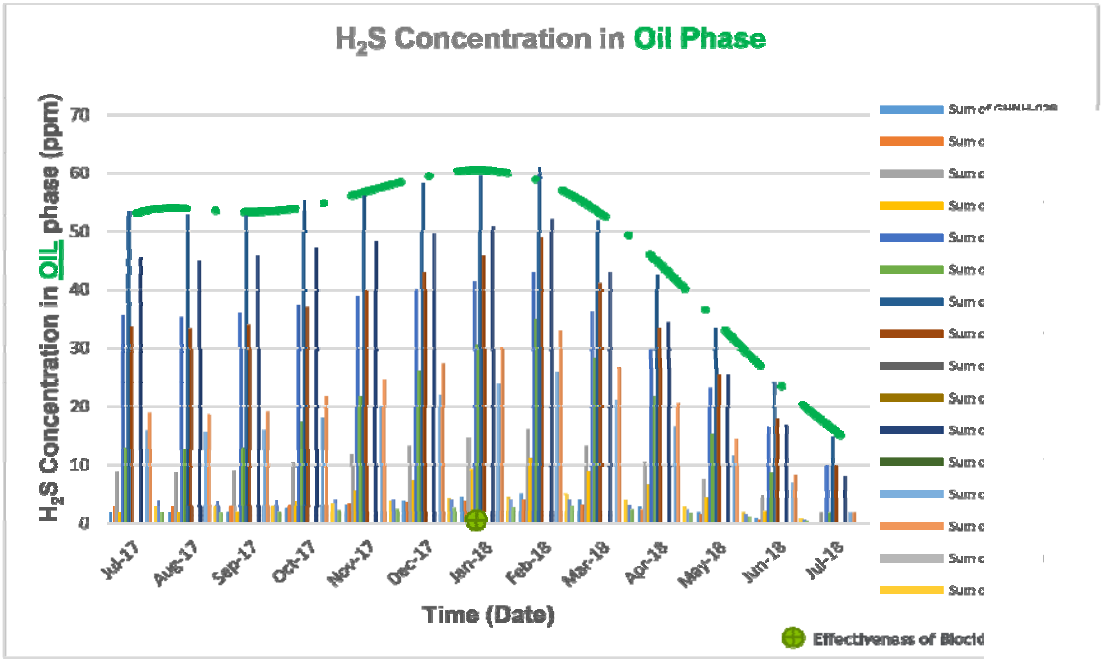


**Fig. 12** $H_2S$ concentration in oil phase per well per month.

**Table 3** Averaged $H_2S$ concentrations (water state – gas phase) in mol% and PPM for A field trend and B field

| Averaged $H_2S$ Concentrations (Water State – *Gas Phase*) in mol% and PPM | | | | | |
|---|---|---|---|---|---|
| Field | Before Biocide Treatment | | With Biocide Treatment | | % of $H_2S$ Reduction |
| | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | |
| Field A | 0.20 mol% | 2060 PPM | 0.06 mol% | 620 PPM | 70% |
| Filed B | 0.03 mol% | 365 PPM | 0.008 mol% | 85 PPM | 77% |

**Table 4 Averaged $H_2S$ concentrations (crude state – gas phase) in mol% and PPM for A trend and B field.**

| Averaged A field $H_2S$ Concentrations (Crude State -*Gas Phase*) in mol% and PPM | | | | | |
|---|---|---|---|---|---|
| Field | Before Biocide Treatment | | With Biocide Treatment | | % of $H_2S$ Reduction |
| | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | |
| Field A | 0.08 mol% | 845 PPM | 0.03 mol% | 320 PPM | 62% |
| Filed B | 0 mol% | 0 PPM | 0 mol% | 0 PPM | 100% |

**Table 5 Averaged $H_2S$ concentrations (crude state – oil phase) in mol% and PPM for A field trend and B field.**

| Averaged A field $H_2S$ Concentrations (Crude State -*Oil Phase*) in mol% and PPM | | | | | |
|---|---|---|---|---|---|
| Field | Before Biocide Treatment | | With Biocide Treatment | | % of $H_2S$ Reduction |
| | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | Average $H_2S$ Concentrations (mol%) | Average $H_2S$ Concentrations (PPM) | |
| Field A | 0.002 mol% | 25 PPM | 0.0004 mol% | 4 PPM | 84% |
| Field B | 0 mol% | 0 PPM | 0 mol% | 0 PPM | 100% |

## 6. Conclusion

In conclusion, the implementation of the Biocide Treatment Switching Process to mitigate the SRB growth in the A field Water Injection System and manage the risk of the $H_2S$ presence in A field reservoir was very effective with following conclusions items:

- Soring phenomena (bio-generation of H2S) was verified and confirmed in certain A fields.
- Root cause behind souring is mainly due to the elevated SRB activity.
- Afield reservoirs might be contaminated with SRB and need to be verified and treated
- Nitrate treatment was proven as ineffective treatment in controlling SRB growth and manifestations for surface pipelines facilities.
- Biocide treatment is used for treating A filed Water Injection System as per lab recommendations.
- Biocide treatment is recognized as an effective and successful treatment process in curbing microbes and SRB growth/activity.
- A prevailed Biocide treatment and monitoring program being implemented.
- SRB counts were reduced as a result of using an effective Biocide treatment in the A field Water Injection System.
- SRB counts were mitigated and maintained at a low tolerable level as shown in the aforementioned plots and trends.
- Based on the A field wellhead samples taken from several oil and water wells, the H2S contents were found in A Field Trend Oil Producers and PWIs along with B Field PWIs. However, the $H_2S$ contents stayed at zero PPM in both oil and gas phases at B Field Filed Oil Producers.
- $H_2S$ concentrations were restrained because of reducing the SRB count/activity at A fields.
- Biocide treatment will be endured in the A field Water Injection System to return the fields to their original states.

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