Journal of Mining and Earth Sciences

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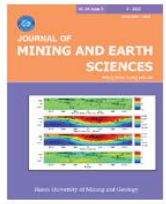

Solutions to improve the removal efficiency of salt deposition in the production tubing and surface equipment system at Blocks 433&416B, Algeria

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ARTICLE INFO

Article history:
Received 3th Feb 2023
Revised 28th May 2023
Accepted 22nd June 2023

Keywords:
Blocks 433a&416b,
Bull heading,
Coil tubing,
Irseba,
Salt deposition.

ABSTRACT

The salt deposition and existence in the production system cause the lower size of the flowing system as tubing, fluctuated or unstable production problems, high wellhead pressure, and flowline pressure, plug the choke valve, wellhead, and flowline pipeline. It negatively affects production. Bir Seba Structure (BRS) field production has high salinity content in oil, due to pressure and temperature change through the production system the salt scaling is deposited to be solid salt. Salt deposition during production damages the surface equipment such as the choke valve, clogging the flowline to the central processing facility (CPF). It causes fluctuated problems in flow rate and pressure in the wells, even blocking the tubing and oil couldn't flow to the surface. Reducing production and undertaking well shut-ins to remove salt deposits and repair equipment are factors contributing to decreased production. Therefore, finding urgent solutions to address salt deposition is crucial. Various methods have been employed to enhance production efficiency, such as the installation of water dilution pumps at the surface, and injecting water and chemicals for salt removal in tubing (e.g., bull heading, coil tubing). The present article focuses on the occurrence of salt deposition issues during production in Bir Seba Field, Blocks 433a & 416b, Algeria. The geological study conducted indicates that the deposition in the Hamra Quazite reservoir originates from a marine environment. The structural cross-section analysis reveals that the sealing salt Trriasis S4 zone acts as the reservoir's sealing zone for the HQ reservoir. Despite a minimal water cut content during production (less than 2%), continuous salt deposition occurs due to changes in reservoir pressure and temperature, high salinity content in oil production, and the presence of small amounts of water vapor from the reservoir. As a result, solid salt particles are transported with the oil to the surface.

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DOI: 10.46326/JMES.2023.64(3).02

1. Introduction

Blocks 433a & 416b are located in the Touggourt region of Algeria, approximately 550 km southeast of Algiers and 130 km from Hassi Messaoud. The original area is 6,472 sq. km. in the Sahara Desert over the Oued Mya Basin and has been first relinquished to have the retaining area of 4,530 sq. km, and 2nd relinquished to the current remaining area of 437.31 sq. km. in development and production phases. The extensive exploration and appraisal program has been performed since 2003 and led to the discovery of Bir Seba Structure (BRS) (Figure 1) (PIDC, 2007).

The contractor's group includes PVEP - 40%, PTTEP - 35%, and Sonatrach (SH) - 25%. The GBRS, a non-profit organization formed by the contractor's group, is responsible for the operations as a joint operator during the Development Period and Production Phase.

At present, the BRS and MOM structures have completed their exploration and appraisal program and are currently in the first development phase. The BRS was in production in August 2015 (First oil), the initial production rate is around 20 Kstb/d by 16 development producers. The MOM is planned to have the First oil at the time BRS production declines which is expected to be phase-II development. Oil is exported to Haoud El Hamra (HEH) by 120 km pipeline 12''. Associated gas is delivered to Sonatrach at the Z-CINA facility at Hassi Messaoud (HMD). All of the phase 1 producers are producing by way of natural depletion.

Phase 2 development is planned to be in 2026 by adding more production up to 40 Kstb/d. The total producer is 32 wells. The pressure maintenance (for Hamra only) is carried out by a water injection system with an injection flowline and facilities for 14 new injection wells. A gas lift compression system will be applied in 2026. The gas lift flowlines and facilities will be used for all Phase I and Phase 2 production wells since incremental water cuts or, lower wellhead flowing pressures. The gas lift system is applied for both Hamra and T1 producers to improve the field recovery. Both water injection and gas lift systems are available at the start of Phase 2.

Phase 1 field development started in 2008 with 12 new drilling wells, 2 re-completion appraisal wells, and 2 early phase 1 development

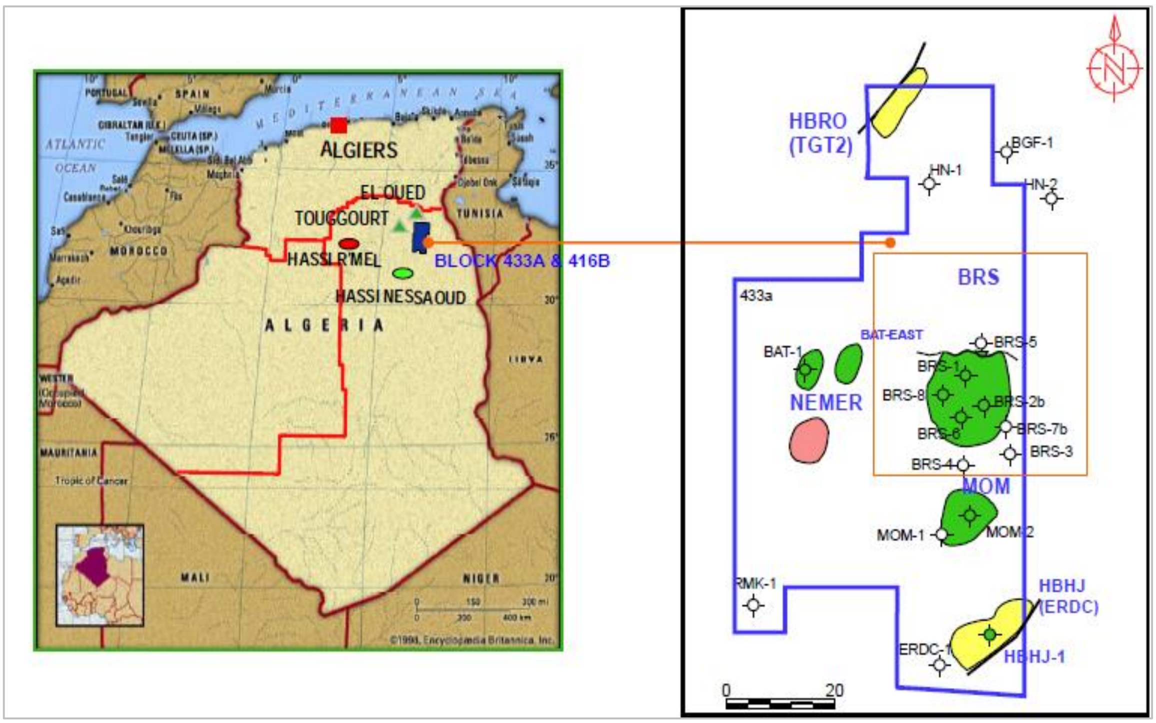


Figure 1. The Birseba Field and Block 433&416b location (PIDC, 2007).

wells. Construction of the EPC1 equipment system included: production system train 1, oil and gas pipelines from wells to a central processing facility (CPF). Oil is exported to Haoud El Hamra (HEH) by a 130 km pipeline 12” from the field to the Hassi Messaoud city. The living quarter including houses, roads, and offices is also built for staff living and working in phase 1 development. In 16/7/2015, ARH approved the oil production of phase 1 to the central processing facility (CPF), and on 12/8/2015 first oil was started by BRS-6b.

The field production peaked at 20.000 stb/d level on 27/9/2015. Up to 31/12/2022, the cumulative production is 45 MMstb, and 15 producers have been put into production.

Figure 2 and Figure 3 have shown the phase 1 field development production system and facility equipment.

2. Salt deposition and effects of production & transportation system of Bir Seba Field, Block 433a &416b, Algeria

The BRS field has 16 producers in the Hamra Quarzite reservoir, of which 12 have been working since Aug 2015. The field production rate is around 15,000÷20,000 stb/d. On the first day of production, the well BRS-21 is a very good oil producer with an oil rate of 2500÷3000 stb/d but the wellhead pressure was very fluctuated.

Figure 2. Wellhead producucer (a) and the gathering station of BRS field (b).

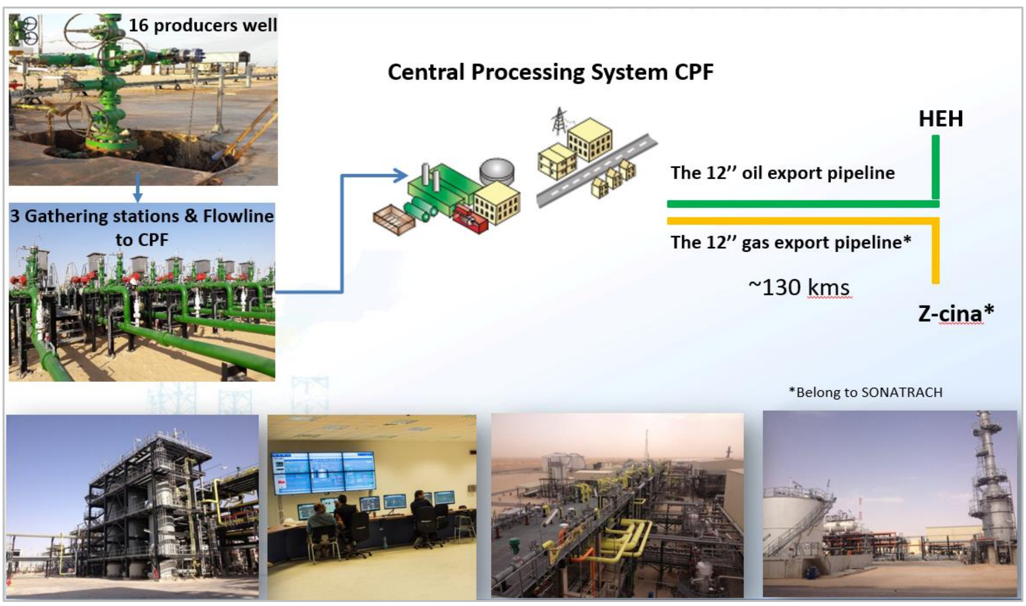


Figure 3. The overview production system, BRS field.

The wellhead pressure increased and flowline pressure was also highly increased. The well was often closed to find out the solution to high WHP and flowline pressure with safety requirements. The initial investigation showed that there was solid salt deposition in the choke valve and flowline system. GBRS had taken this sample and sent it to the laboratory for analysis.

The laboratory analysis result has shown 99.37% composition of a solid is salt NaCl (Table 1) (PIDC, 2006). After a few years of production observations, the salt was deposited at many points of the production system from the bottom of the wellbore to the surface, flowline to the processing facility system (CPF).

Table 1. The Laboratory solid salt analysis result from the surface sample at the choke valve of BRS-21.

N°	Well	Br2 (%)	NaCl (%)
1	BRS-21	0.17	99.37
2	BRS-6b	0.06	86.73

The production process at the BRS field shows that salt was deposited everywhere in the good production system (Figure 4) (GBRS and Groupments in Algeria, 2016). Salt was deposited at the choke valve (Figure 5a) and flowline system, it destroyed the choke valve and caused flowline corrosion leading to leaking and stucking flowline. It caused fluctuating production and reduced production.

- Salt deposition at production tubing: solid salt was deposited in tubing, reducing the tubing size and restricting the fluid flow to the surface, reducing the wellhead pressure and oil production rate at all the producer wells (Figure 5b).

- Solid salt deposited at the bottom wellbore and tubing of production wells. Salt plugged into the wellbore and oil couldn't flow from the reservoir to the wellbore and surface of all wells (Figure 6).

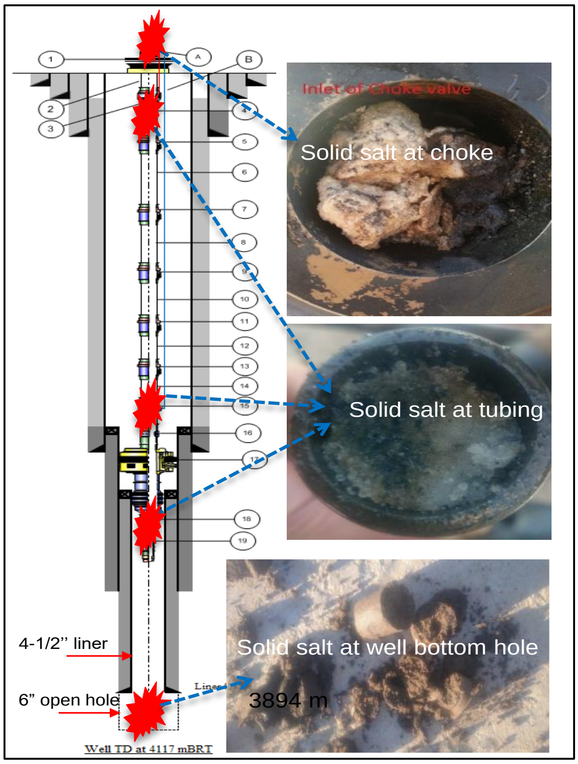


Figure 4. The solid salt deposition at the well production system (GBRS and Groupments in Algeria, 2016).

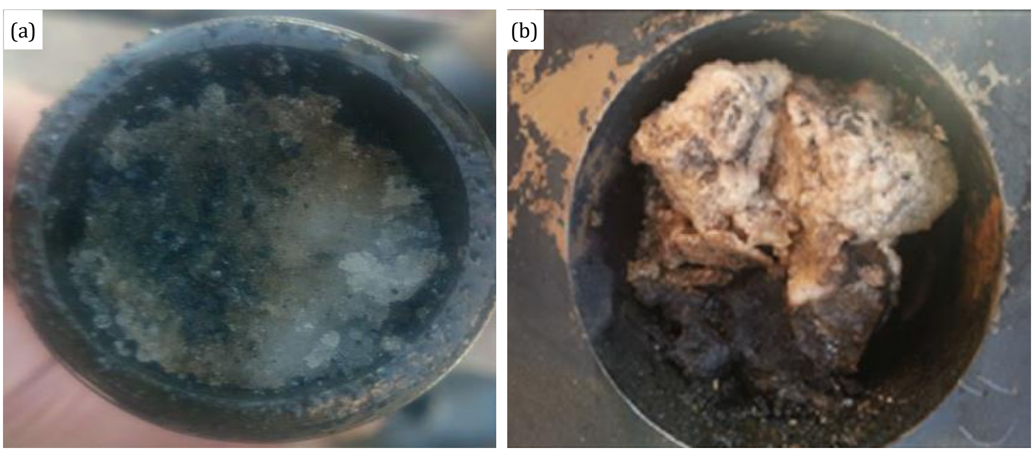


Figure 5. Solid salt deposited at well production tubing (a) and choke valve (b) (GBRS and Groupments in Algeria, 2016).

- Salt was deposited near the wellbore (high skin).

- Salt existed at the reservoir: according to the thin-section result, the cristal salt had existed at the rock cementing since the beginning (Figure 7) (PIDC, 2006).

Mechanical corrosion from sharp salt particles: high velocity flowing producing salt particles along with oil leads to mechanical corrosion in production system equipment (Figure 8).

In addition, electrochemical corrosion occurs due to the high salinity content in oil, leading to corrosion of the pipeline system on the surface, especially the gathering station (GS) collection pipeline system.

Salt is one of the solvents that increase the possibility of electrochemical corrosion. The electrochemical corrosion mechanism is shown in Figures 9 and 10. Salt can deposit at any point of the production system, especially at the changing flowing points (Figure 4). The production well was often closed to clean the salts by some intervention activities which caused the high downtime of the well and reduced the well production. Figure 11 shows the good uptime of

Figure 6. Solid salt deposited at down hole well (GBRS and Groupments in Algeria, 2016).

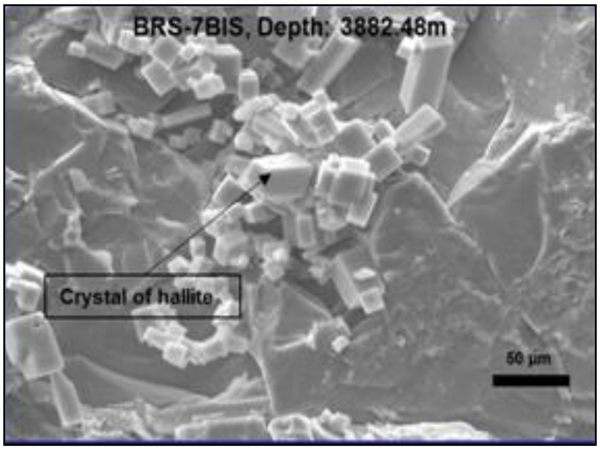


Figure 7. Cristal salt in thin-section of BRS-7 (PIDC, 2006).

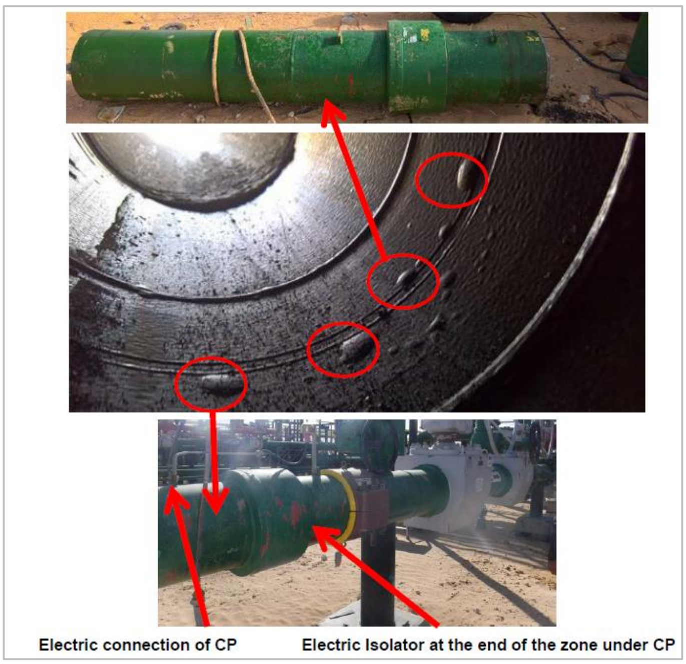


Figure 8. The solid salt deposition at the well production system, BRS field (RIA, 2019).

producers in the BRS field. The figure shows a high well downtime of 2÷25%, some well even has higher well downtime as BRS-19, BRS20, BRS-18, and BRS-15. A good intervention for cleaning up can make any risk as stuck slackline/coil tubing, tubing leak, or fishing. It takes a lot of time and money for the clean up interventions activities and also reduces oil production.

3. Origin and mechanism of salt deposition

The geological studying result has shown that the Hamra Quazite reservoir formation deposition is from a marine environment.

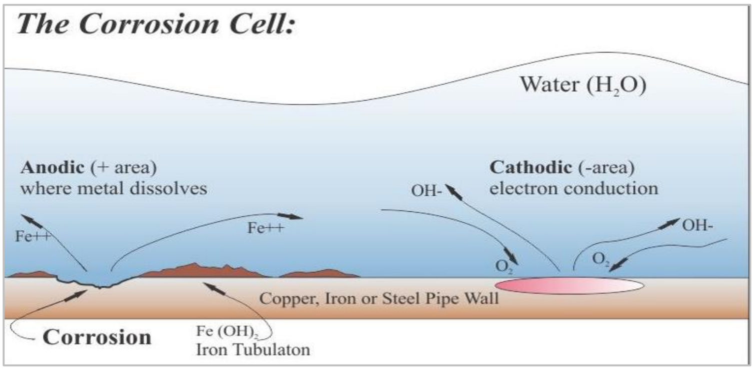


Figure 9. Mechanism of electrochemical corrosion BRS field.

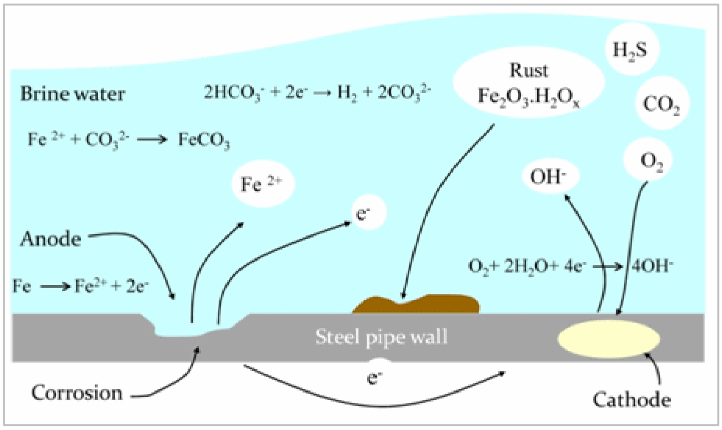


Figure 10. Mechanism of electrochemical corrosion BRS field (https://www.sperchemical.com/polyphosphate/corrosion-inhibition/).

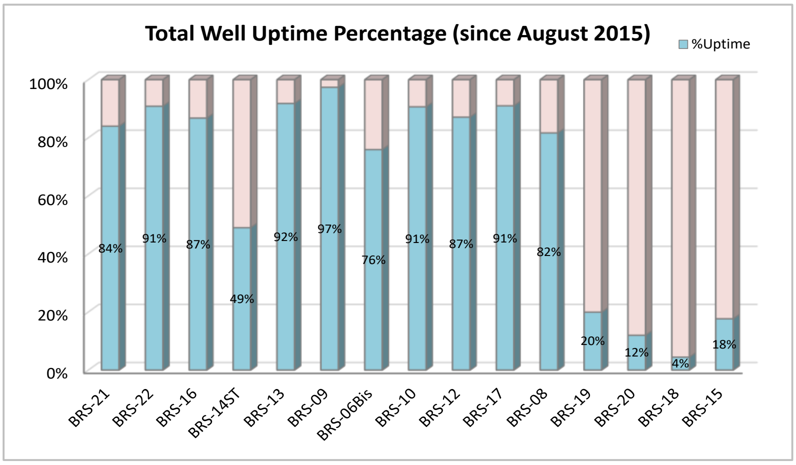


Figure 11. Summary of well uptime, BRS field (GBRS and Groupments in Algeria, 2016).

The structure cross-section shows the sealing salt Trriasis S4 zone (Figure 12) (Furgo Robertson, 2006) plays a role as the sealing zone of the HQ reservoir. Figures 13 and 14a, and b show the mechanism of salt deposition (Eni Exploration & Production Division, 2015). The geological thin-section and mineral compositions lab analysis also shows that there is existing crystal salt formed and playing a role as cementing in the reservoir. The content of andehite is 2÷12% of the rock. The result of a water sample analysis shows a very high salinity content in the water from 280÷567.6 g/l (Figure 15) (PIDC, 2007). The surface oil sample analysis result shows that there was also high salinity content in the production oil around 10÷5,000 mg/l.

During the production process, even though the water cut content was very small (less than 2%), the crystal salt is continuously deposited. Solid salt flows with oil to the surface due to the reservoir pressure and temperature changes. High salinity and a small vapor of water exiting from the reservoir were found in the content of oil and gas production. The salt deposition existing in the production system causes the lower size of the flowing system as tubing, fluctuating or unstable production problems, high wellhead pressure, and flowline pressure, plugs the choke valve, wellhead, and flowline pipeline. It negatively affects production.

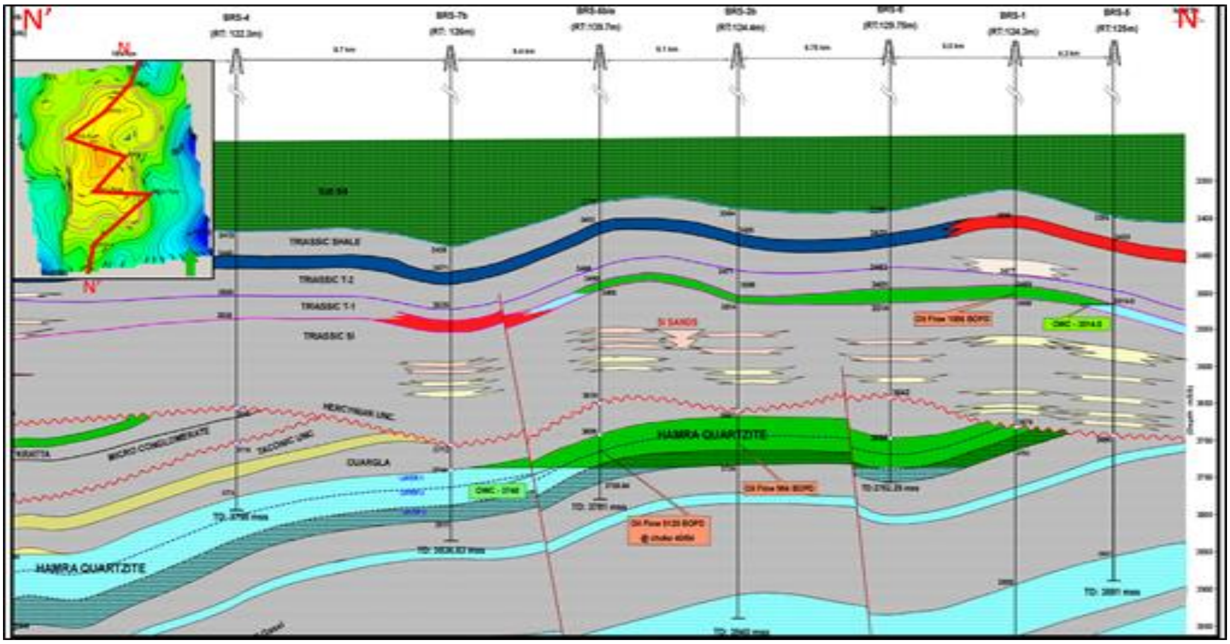


Figure 12. Cross-section through N_S of BRS field. (Furgo Robertson, 2006).

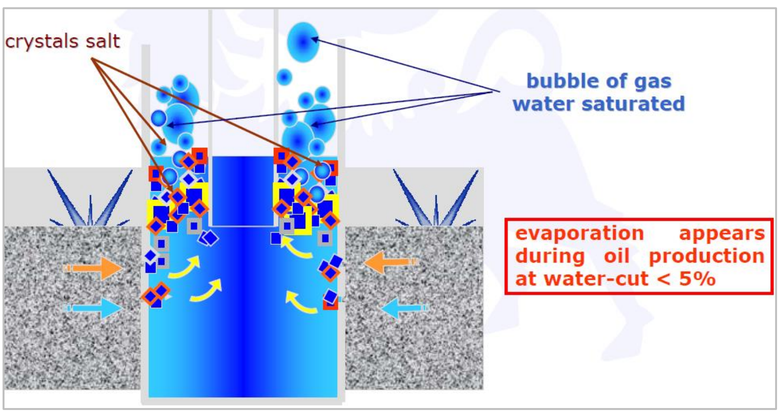
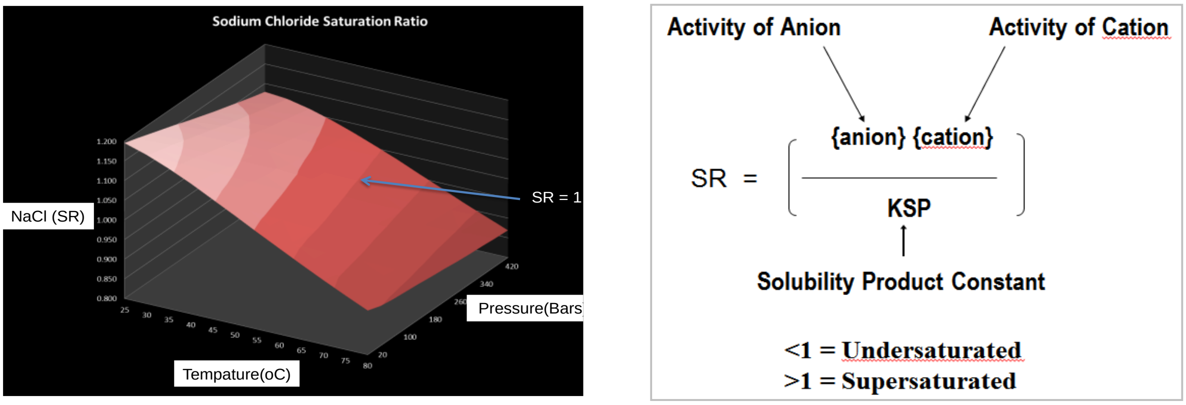


Figure 13. The mechanism of salt deposition in the production well. (Eni Exploration & Production Division, 2015).



(a) (b)

Figure 14. Sodium Chloride saturation ratio (a) and the mechanism of salt deposition (b).

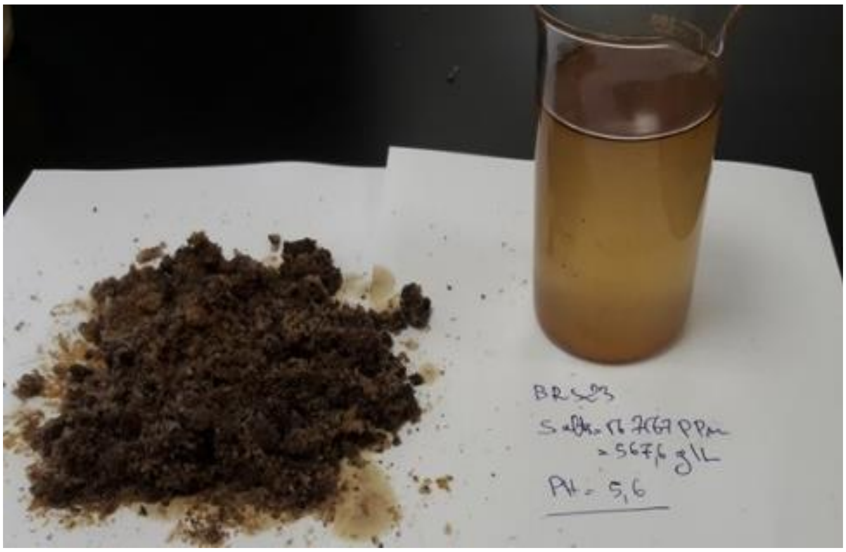


Figure 15. Reservoir water sample analysis result at BRS field.

Figure 16. The permanent surface up choke dilution water pumping system (1/2" injection line).

4. The salt deposition solutions at the BRS field

4.1. Salt deposition at the surface

The salt deposition at the choke valve caused a block or limited the flow through the choke valve to the flowline. The sharp salt particles with high velocity along with the oil lead to mechanical corrosion in production system equipment. It caused the breaking of the choke valve after a short time of production. The flowline pipe was crossed or leaked due to salt corrosion.

To mitigate the salt deposition at the choke valve and surface pipeline system, GBRS has rented the high-capacity dilution water to inject fresh water before the choke valve to dissolve salt minerals and clean up the choke valve and flowline pipeline. For each pumping time, it takes 4÷6 hrs. It makes the wells regularly closed and affects production and high operation cost. For that reason, GBRS installed a permanent pumping system with a suitable capacity to continuously pump fresh water rate of 4÷5 m^3/d to dissolve salt in the choke valve and flowline system. Figure 16 shows the permanent surface up choke dilution water pumping system (Hai et al., 2015).

Figure 17 shows the relationship between temperature and fresh water to dissolve solid salt NaCl (SGS company, 2015). According to this chart, at 60⁰C 1 little fresh water can dissolve 390 g solid salt. At the higher temperature of 120⁰C (reservoir temperature condition) 1 little of fresh water can dissolve 410 g salt NaCl. Combing with

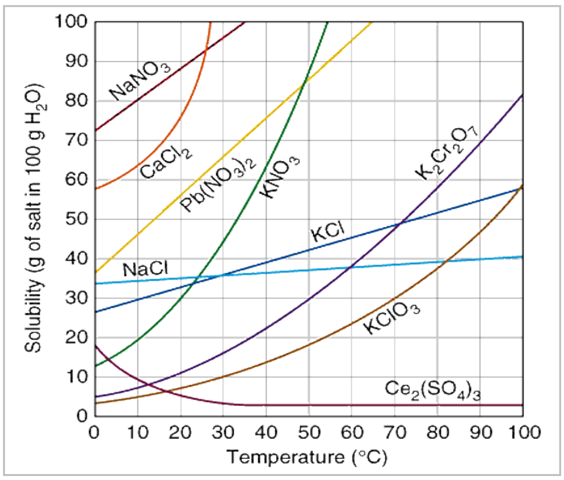


Figure 17. The relation between the salt dissolving by fresh water and temparature condition (SGS company, 2015).

the salinity content in oil production, the salinity of oil is from 10 mg/l to 5,000 mg/l. The average production rate is 1,500 stb/d, and the maximum dilution water injection rate is 5,000 mg/l*1,500 stb/d*159l/stb*1l/390g =3.05 m^3/d.

4.2. Salt deposition through the production system from reservoir to surface.

Salt deposition in the production well affects well behavior as unstable flow, fluctuation of pressure, and oil rate of the well. The existence of salt in the tubing and well bore causes the lower size of the tubing, plugs the reservoir, and restricts flow through the well to the surface, reducing the wellhead pressure and well production rate. In some cases, the salt had deposited in the choke valve and plugged the choke, flowline, so the well couldn't flow.

On the other hand, after a long time of production, the reservoir pressure is depleted so the salt can deposit near the wellbore and cause high skin of the well which reduces well productivity.

The solutions that GBRS has applied to these problems are as below:

- Bull heading: The freshwater is pumped through the wellhead to the tubing and reservoir to clean the salt. At the beginning of the bull heading intervention, the salt at the tubing is cleaned, and the wellhead pressure (WHP) and oil rate are improved (Figure 12). However, the salt at the bottom of the well and near the wellbore has not been cleaned. If the bull heading is continuously interventing, the solid salt will be compacted and plug the well bore, the oil couldn't flow from the reservoir to the wellbore. It happened at wells BRS-6b, BRS-13, and BRS-19. The bull heading also needs a high-capacity pump, so it is costly. The pump might cause high leaking or tubing crack due to very high pumping pressure, as it can exceed the limited tubing pressure.

- Injecting fresh water and chemical through the chemical injection line. However, the size of the chemical injection line is very small, the maximum rate which can be injected is only 33 l/d. It is not enough to dissolve the salt deposition.

- Using the slickline to check the salt deposition and clean up a part of the salt in the tubing.

- Using Coil tubing clean up: The water and chemical are injected through Coil tubing and they clean the salt deposition from the wellhead to well TD. This is the best solution that GBRS has been applying up to now. The coil tubing frequency is around every 1÷3 months/campaign. This intervention has a low risk of being stuck. Figure 15 and Table 2 have shown the result of coil tubing intervention on production performance. The negative oil improvement of BRS-22 in this table is due to the lower choke size after clean-up intervention (11/64'' vs 17/64''). The WHP is much improved after cleaning up, and if the well has the same choke size (after and before cleaning up) oil rate will be higher.

With all interventions mentioned above, field production has been improved. The salt deposition has been mitigated and the risk of problems such as stuck, tubing leaks, and the fluctuated problem has also been minimized. However, the interventions need to be conducted frequently. In the phase 2 development, GBRS has planned to install ½" dilution water in tubing and annulus for freshwater injection to the reservoir and dissolve the salt and clean the well continuously to maximum production and minimize the interventions. Figure 18 shows the phase 2 well-completion design (GBRS, 2016a).

5. Conclusion

BRS field production has high salinity content in oil due to pressure and temperature change throughout the production system. The salt scaling is deposited to be solid salt. The salt deposition strongly affects the production system and production performance of the BRS field. It causes many problems such as a choke valve broken, the well and flowline system plugged, mechanical and electrochemical corrosion, leaking problems in tubing, trunkline, Gathering Stations, etc.

To mitigate the salt deposition some intervention actions have been conducted at the BRS field, such as dilution water injection up the choke and down choke, bull heading, slickline activities, Coil tubing cleaned up… With all the interventions mentioned above the well could flow stably, the production has been improved, and the problems such as corrosion, unstable production problems, and leaking problem have been minimized.

Optimizing Phase 2, the designed well completion will be conducted by installing two ½" water dilution lines through the tubing until the bottom of the well to better mitigate the salt scaling problem and optimize production.

6. Contributions of authors

Khoan Duy Do - methodology, writing, review & editing; Thinh Van Nguyen - writing, review & editing, supervision.

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Table 2. Coil tubing cleaning result.

Well	Date	Before CTU			After CTU			Comparison		
		Choke	THP	Oil rate	Choke	THP	Oil rate	THP	Oil rate	%
		/64	psi	Stb/day	/64	psi	Stb/day	psi	Stb/day	
BRS-6b	27/2/2016	6	30	142	5	180	1503	150	+1361	958
BRS-13	13/3/2016	9	149	1461	9	187	2535	38	+1074	74
BRS-17	24/3/2016	9	120	743	2	135	1071	15	+328	44
BRS-21	1/3/2016	20	193	3162	20	195	3284	2	+122	4
BRS-22	17/3/2016	17	187	3319	11	202	2537	15	-782	-24
BRS-10	19/3/2016	9	102	270	9	145	1410	43	+1140	422

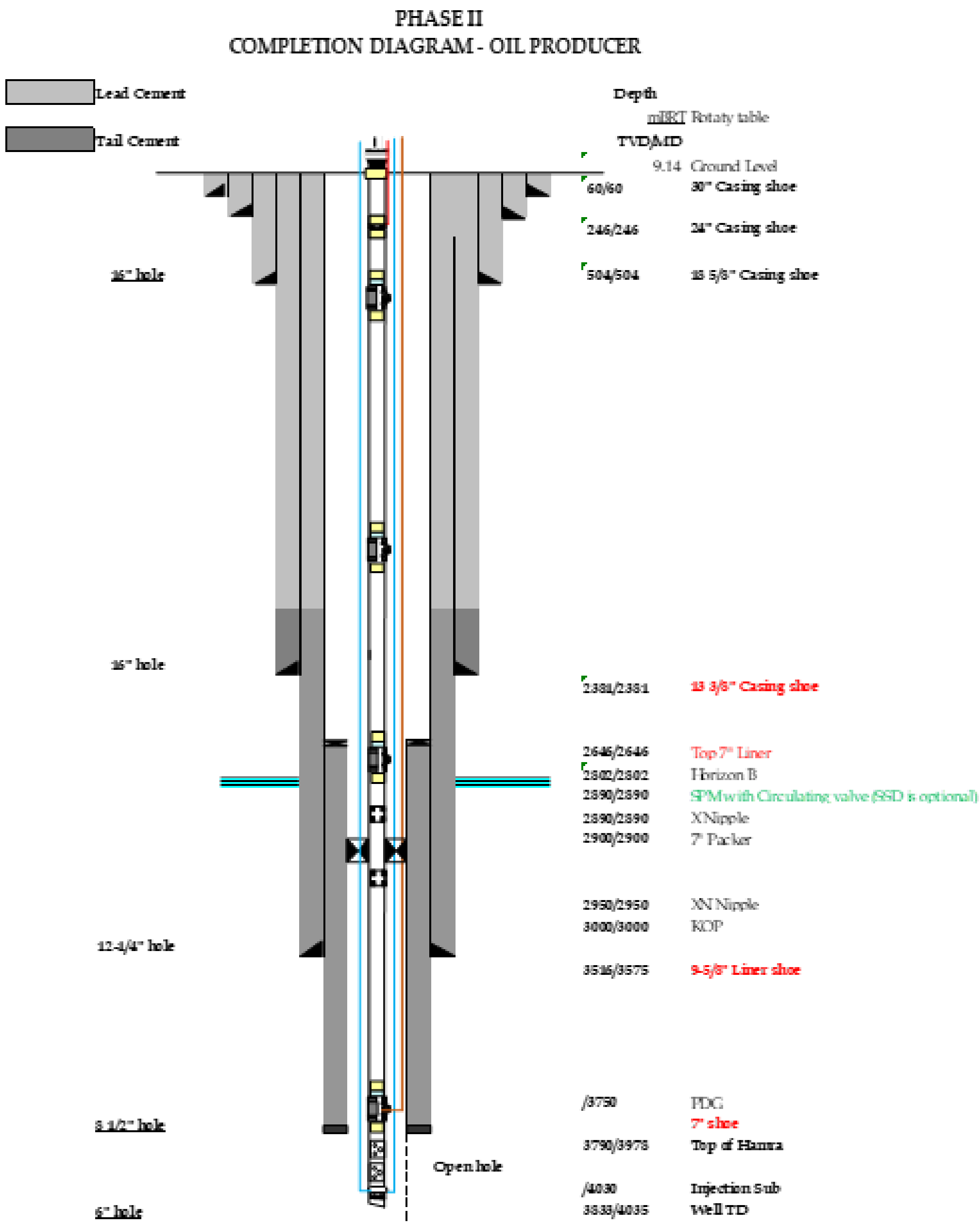

Figure 18. Phase 2 optimized well completion design (GBRS, 2016a).

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