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A NEW MODEL FOR PRODUCED WATER TREATMENT IN ELEMIR OIL FIELD

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ABSTRACT

The oil reservoirs of the southeastern part of the Panonian basin are characterized by considerable presence of water,i.e.waterdrive. The hydrocarbon reservoirs are mostly in the middle and final production stages. The water production is especially significant in wells producing with an installed Electrical Submersible Pump (ESP). As production continues, it is a realistic expectation that the water cut increases as well.The rapid production of water has affected fluid production in a significant way.Produced water in the Elemir oilfield is gathered, treated and then injected into the porous layers through several wells.The current system for the preparation and treatment of produced water in the Elemir oilfield has functioned with evident technical issues.The main problems are increased volumes of produced fluids and the deposition of solids (scales) in water treatment system. In thisarticle, a new model for produced water treatment is presented, including technical, economic and environmental aspects. A new model fulfils volumetric requirements, improves oil/water separation and suspended solids removal which lead to better injection performance.

Key words: *Elemir oilfield, produced water treatment, scaling tendency, scale inhibition*

INTRODUCTION

Naturally occurred underground porous and permeable formations are generally filled with fluids such as water, oil, gas or mixture of these fluids. According to the theory, the most of the oil bearing formations were saturated with water before accumulation of oil. Over time, oil is migrated, displacing some water and form a reservoir [1]. Produced water is the largest byproduct generated during the oil and gas production and the main source of pollution in offshore platforms. The presence of water is identified in every stage of oilfield life, from the exploration, development, production and abandonment [2,3,4]. The water - oil ratio (WOR) in increasing during the life cycle of the oilfield and the current global ratio is 4:1 [5].

The composition of produced water is very complex, including dissolved and dispersed hydrocarbons, dissolved formation minerals, heavy metals, suspended solids, naturally occurred radioactive materials and treatment chemicals [6,7,8].The properties of produced water depends from many factors including age, depth, geology of the hydrocarbon formation and chemical composition of produced hydrocarbons [9,10].Generally, the most of the onshore produced water treatment facilities are designed to remove suspended solids and dispersed oil compound in order to avoid disposal formation plugging. In offshore facilities, the common practice is discharging the treated produced water into the sea. To meet discharge quality and avoid toxicity effects on the marine environment, the content of hydrocarbons in producing water must be significantly lower [11].

At present, the fluids produced at the Elemir oil field are collected from the production wells and are then subjected to primary preparation (separation), secondary preparation (dehydration) of gas from oil, transport of oil and gas, and subsurface disposal of treated produced water. Produced water, which is separated from oil, is injected into non-productive geological layers at depths ranging from 900m to 1500m, through a system of water disposal wells. The current capacity of the injection system is 360 m3 / day in three injection wells.The produced water treatment system is currently working at its maximum volume capacity. The currently available volume capacities (the number of pumps and injection wells) do not satisfy the elimination of the current amount of produced water. There are no alternative systems for water treatment in this oilfield. In case of system malfunctioning, the entire system must be shut down and non-productive time is accumulated. Problems that occur during the operation of pumps for water injection are:

- Damage of the sealing elements of pumps, due to the deposition of suspended solids
- The deposition of solid particles on pipe walls.

The tendency of produced water to precipitate calcium carbonate, calcium sulfate, barium sulfate and strontium sulfate was determined by the Oddo - Tompson method. A set of calculations was performed to determine the maximum theoretically possible amounts of precipitate in those cases where the index showed that the water had a tendency to form calcium carbonate and barium sulfate on all tested temperatures (20, 30, 40 ^{o}C). The chemical composition of the water produced at the entrance of the treatment system is not uniform and varies inconsistently.

During the treatment process, the concentration of oil in water decreases while the amount of suspended solids increases. The pH of water during the treatment process decreases and the hardness increases which causes scale precipitation in the later stages of separation.The suspended solids particles can pose a major problem in the pumping and piping system during the injection into the subsurface layers. Therefore, problems with high injection pressures, abrasive damage of pumps and pipelines and blocking of near wellbore zones of injection wells can occur.

It is necessary to redesign the water treatment system to achieve maximum efficiency and capacity in an economically viable way

ELEMIR OIL FIELD

The Elemir oilfield is located in the southeastern part of the Pannonian Basin in the Republic of Serbia - Autonomous Province of Vojvodina, near the town of Zrenjanin. This oilfield belongs to the series of oil - gas fields discovered along the southern edge of the Pannonian Basin in the central part of Banat. A total of 80 wells were drilled in the Elemir oilfield and there are 40 wells currently in the production mode. The reservoir is a very heterogeneous one and consists of several lithological layers with different petrophysical characteristics. This reservoir is under the effect of a strong waterdrive and the annual production of water and oil has consistently varied through the production time interval. The last few years have introduced the process of hydraulic fracturing as a stimulation method as well as using ESPs as an artificial lift method. The geographic position of the Elemir oilfield is shown in Figure 1.

The water treatment plant consists of the following processes:

- Collecting fluids from production wells.
- Dehydration of fluids,
- Dosage of chemicals for the treatment of oil and water.
- Disposal of reservoir water

After the primary separation, the liquid phase flows to the free water knockout (FWKO) where, due to the reduction of flow velocity and the density difference between the oil and free water, the free water separates from the liquid mixture. On the inlet of the free water knockout, the fluid temperature is approximately 30°C and the pressure is about 2.2 bar. The thermodynamic conditions of the free water knockout are P = 1.8 - 2.2 bar and T = 20-30°C. Separated water is discharged over the mechanical level regulator and discharge valve to the water collecting reservoir. Emulsified oil flows to the heater treater.

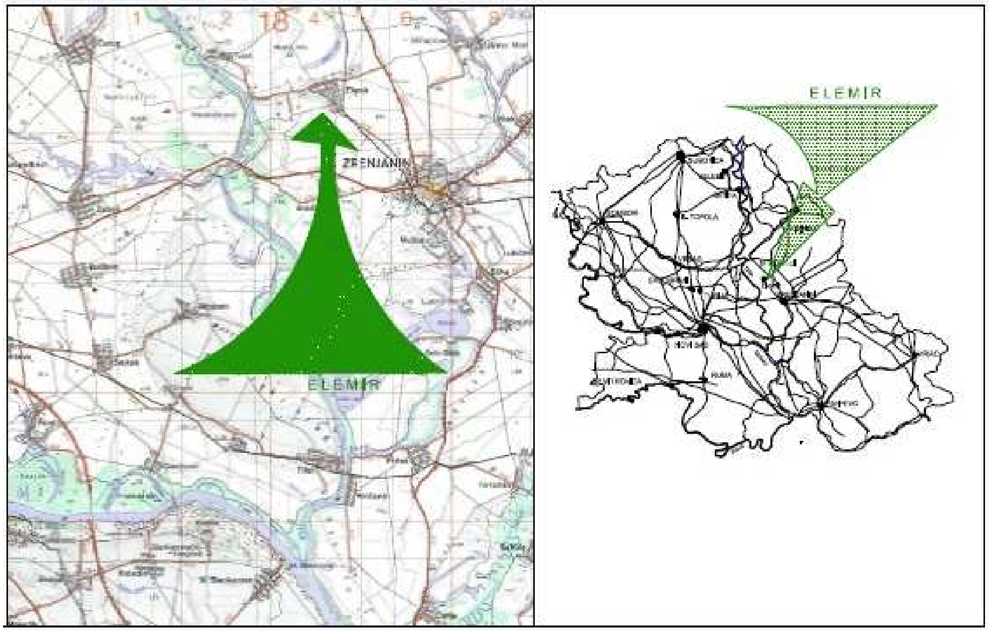

Fig.1. Geographic position of the Oilfield Elemir

A scheme of the Elemir water treatment plant is shown in Figure 2.

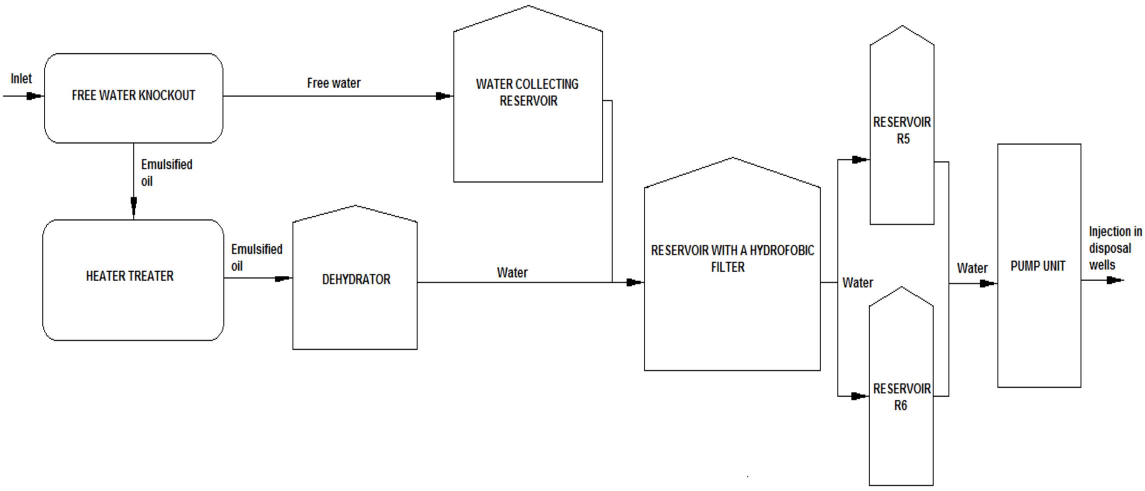

Figure 2. A simplified scheme of the Elemir water treatment plant

After the free water knockout, the emulsified oil flows to the heater at an approximate temperature of 36°C and a pressure about 2.2 bar (the working conditions of heater treater are P = 1.6 - 1.8 bar, T = 15-65°C). In the heater treater emulsified oil is heated and small amounts of remaining gas are separated from the fluid after the primary separation. Emulsified oil is heated to 38°C andit then flows to the dehydrator where the dehydration process terminates.

The dehydrator is a vertical cylindrical tank with a volume of 1000 m^3 where the tertiary separation between the oil and the remaining water from the heater treater occurs. The emulsified oil flows to the lower part of the separator into the water zone of the dehydrator through a distributor in the form of an inverted funnel. It is at the top of the dehydrator that the heated oil emulsion is separated at atmospheric conditions.. The oil gradually emerges through the water towards the top of the dehydrator, where the release and separation of the remaining portion of the water occurs. The separated gas is discharged under a top compartment of the reservoir and is discharged into the atmosphere through the valves. Separated water from the bottom of the dehydrator goes to the water collecting reservoir which holds $10m^3$,and consequently pumped into the reservoir with a liquid hydrophobic filter.

Disposal of treated produced water in underground layers at depths of 1000 to 1100 m is carried with centrifugal pumps through the wells which are connected to the central system for water treatment.
The separated water in the reservoir with the hydrophobic filter is transferred to the water reservoirs R-5 and R-6 which are interconnected and each have a volume capacity of 25m3.

The injection process of the water from R-5 and R-6 into the non-productive layers at depths of 1000 m and 1100 m is carried out using centrifugal pumps through wells that are connected with the central system of water disposal.

Properties of the produced water in the Elemir oilfield are shown in Table 1.

Table 1: Properties of the produced water in the Elemir oilfield

Oil concentration	70.51 mg/l
Concentration of suspended solids	63.7 mg/l
Na^{+}	4410 mg/l
K^{+}	76 mg/l
Ca^{2+}	75.3 mg/l
Mg^{2+}	42 mg/l
Water hardness	20.16 dH
H_2S	2.76 mg/l
CO_2	90.64 mg/l
Fe	0.6 mg/l
pH	7.54
p - alkalinity (mol/HCl/m^3)	0
m - alkalinity (mol/HCl/m^3)	23
SO_4^{2-}	100.23 mg/l
Salinity (Cl^- calculated for NaCl	8067 g/l
Ba^{2+}	4 mg/l
Sr^{2+}	6.75 mg/l

Properties of treated water behind the free - water knockout (1), after the dehydrator (2), behind the water collecting reservoir (3) and behind the tank with a hydrophobic filter (3) are shown in Table 2.

Table 2. Properties of treated water behind the free - water knockout (1), after the dehydrator (2), behind the water collecting reservoir (3) and behind the reservoir with a hydrophobic filter (3).

	(1)	(2)	(3)	(4)
pH	7.58	7.32	7.26	7.23
p - alkalinity (mol/HCl/m^3)	0	0	0	0
m - alkalinity (mol/HCl/m^3)	29.8	24.5	24.49	24.58
Water hardness (dH)	19.93	29.78	30.32	28.96
Salinity (Cl calculated for NaCl) (g/l)	15.55	13.44	13.44	13.18
Ca^{2+} (mg/l)	81.1	126.2	124.08	121.9
Mg^{2+} (mg/l)	37.5	53	54	52
Fe^{3+} (mg/l)	0.9	0.9	0.76	0.36
Ba^{2+} (mg/l)	7.82	5.23	5.22	5.01
Sr^{2+} (mg/l)	18.08	28.7	29.3	28.8
SO_4^{2-} (mg/l)	7.92	36.25	38.44	20.9

The concentration of oil in water and concentration of suspended solids in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with a hydrophobic filter (4) are shown in Table 3.

Table 3. The concentration of oil in water and concentration of suspended solids in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with a hydrophobic filter (4).

	(1)	(2)	(3)	(4)
Concentration of oil in water (mg/l)	59.98	60.79	35.04	19.92
Concentration of suspended solids (mg/l)	76.9	69.7	85.4	130

The results of calculations for calcium carbonate in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with a hydrophobic filter (4) are shown in Table 4.

Table 4. The results of calculations for calcium carbonate in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with a hydrophobic filter (4).

	(1)		(2)		(3)		(4)	
Temperature (C)	Index	Quantity (mg/l)	Index	Quantity (mg/l)	Index	Quantity (mg/l)	Index	Quantity (mg/l)
20	0.824	170.19	0.683	242.29	0.63	237.19	0.583	216.99
30	1.003	180.93	0.861	266.17	0.808	264.47	0.761	245.54
40	1.182	188.14	1.04	282.4	0.987	283.05	0.94	265

The results of calculations for barium sulfate in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with hydrophobic filter (4) are shown in Table 5.

Table 5. The results of calculations for barium sulfate in water samples after the free - water knockout (1), behind the dehydrator (2), after the water collection reservoir (3), behind the reservoir with a hydrophobic filter (4).

	(1)		(2)		(3)		(4)	
Temperature (C)	Index	Quantity (mg\l)	Index	Quantity (mg\l)	Index	Quantity (mg\l)	Index	Quantity (mg\l)
20	0.061	1.07	0.566	6.28	0.591	6.42	0.316	4.04
30	-0.013	0	0.493	5.82	0.518	5.98	0.242	3.3
40	-0.079	0	0.427	5.34	0.452	5.53	0.176	2.54

DISCUSSION

The chemical composition of the water produced at the entrance of the treatment system is not uniform and varies inconsistently. The concentration of oil in water is lowest at the exit of the reservoir with hydrophobic filter. The concentration of suspended solids is approximately 130 mg/l. During the treatment process, the concentration of oil in water decreases while the amount of suspended solids increases. The pH of water during the treatment process is decreasing and the hardness is increasing which causes scale precipitation in the later stages of separation. The salinity of the water is decreasing during the water treatment process. Based on the determination of the corrosivity of water, the water behind the free-water knockout manifests itself as part of the unstable group. On the other hand, the samples at the other different sampling points of the systems show that they belong to a more aggressive group. The concentration of H2S ranges from 6.1mg/l to 9.95 mg/l. The CO_2 concentration ranges from 104.28mg/l to 156.64mg/l. The iron concentration is less than 1 mg/l and there is no considerable corrosion. All water samples show a tendency of calcium carbonate and barium sulfate precipitation at all tested temperatures, excluding samples after the free - water knockout. Calculations show that at 30 and 40 degrees, there is no precipitation of barium sulfate.

With an increasing separation temperature, affinity of water to precipitate calcium carbonate increases which results in the deposition of scale in the later separation stages.

A NEW MODEL FOR PRODUCED WATER TREATMENT

To meet the discharge criteria and additional volumes of water, it is necessary to:

- Remove the reservoir with hydrophobic filter,
- Add hydrocyclonedesander and deoiler to the produced water treatment system,
- Increase the pumping capacity from 360 m^3/day do 1000 m^3/day with new pumps,
- Increase the number of injection wells from three to six,
- Use scale and corrosion inhibitors and
- Install proper filters in the R5 and R6 reservoirs.

Proposed modification for water treatment system is shown in the Figure 3.

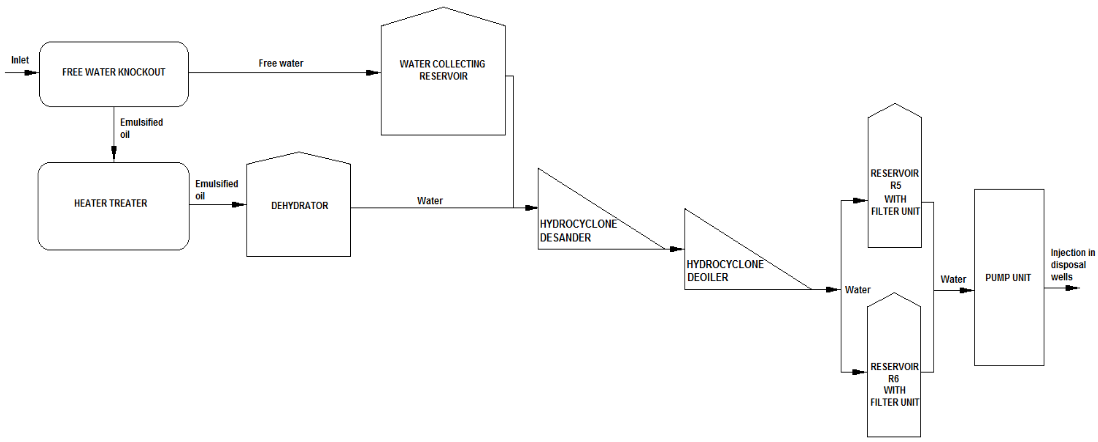

Figure 3. Proposed modification for water treatment system

CONCLUSION

Produced water treatment system in the Elemir was redesigned by removing the reservoir with hydrophobic filter and adding two hydrocyclones (desander and deoiler). Quantities of produced water required increasing of pumping capacity and also increasing the number of injection wells. Problems with suspended solids deposition was solved by adding two filter units and using scale and corrosion inhibitors. By adding of these devices, operating costs are increased, but that is the only way to deal with the current condition of the system.

Advantages of the new model:

- The requirements of increased fluid production in theElemir oil field are satisfied

- Solids in treatment systems of produced water are minimized by scale inhibitors and appropriate treatment before entering the pumping systems.
- Reducing the solids content enables a more efficient and longer pump operation and significantly lower injection pressures, which further minimizes energy consumption.
- Formation injectivity damage has been significantly reduced
- Environmentallyacceptable
- Possibility to handle more quantities of water in the future

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