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ORIGINAL ARTICLE

The integrated feasibility analysis of water reuse management in the petroleum exploration performances of unconventional shale reservoirs

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Abstract
Regarding the dramatic increase of water additional resource administration in numerous drilling industries' operational performances and oil/gas extractions, water supply plays a significant role in their performances as efficient as optimum operations, in respect of the way, this utilization is often invisible to the public eye. The necessity of water in a wide variety of drilling operation due to its vast applicant in several functions is widely reported in the literature that has been required to remain these procedures plateau. The objective of this comprehensive study is to conduct an investigation into the studied field and analyze the assessment of necessary water and produced water which is provided in the surface for reinjection procedures in the hydraulic fracturing and water injectivity; in respect of the way, petroleum and drilling industries will push themselves into limits to find suitable water sources from a local source to encapsulate their economic prosperities and virtually eliminate extra expenditures. In comparison to other industries and consumers, oil and gas development is not a significant water consumer, and its water demands can exert profound impacts on local water resources, and this is why it imposes particular challenges among water users in a vast majority of fields and areas in times of drought. Moreover, water has become an increasingly scarce and costly commodity over the past decades, and operators are being beneficially noted that awareness of recycling and reusing phenomenon that has treated effluent is both costs competent and socially responsible. Consequently, energy, environmental situation, and economic prosperity considerations should be analytically and preferably investigated to cover every eventuality and each possibility of disposal and water reuse options.

Keywords Drilling industries · Water reuse · Economic prosperity · Water treatment · Reuse options

Introduction

The volume of total freshwater consumption by individuals in the earth is only 2.5%, because most of it (97.5%) which is too salty for human use, that is to say, that just less than 1% of this fresh water is available for direct human consumption. Due to continual population growth, agricultural and industrial developments, and climate change effects, water resource scarcity has become a critical issue in many parts of the world (Arnell and Lloyd-Hughes 2014; Fischer et al. 2017; Freyman 2014; Gallegos et al. 2015; Pedro-Monzonís et al. 2015). The cost of rig water could be relatively inexpensive in those regions where there is abundant local access to rivers or lakes, and local regulations permit withdrawal, in respect of the way, petroleum operators are trying to achieve to cheap water which is dwindling and companies have to search further to access rig water (Kondash and Vengosh 2015; Nicot and Scanlon 2012; Nicot et al. 2014; Scanlon et al. 2014a, b). Water reuse offers an enormous chance for operators to access to independent sources of water which it is dependable on some occasions. Furthermore, it would be locally controlled and play a significant role in the environmentally friendly use. The proportionality of water resource distribution in each category is demonstrated in Figs. 1, 2, and 3. As can be seen in Fig. 1, the volume of fresh water is 1/32 of saline water in the earth, and this amount would be drastically decreased shortly due to the vast consumption of fresh water by individuals and numerous industries (Davarpanah et al. 2018).

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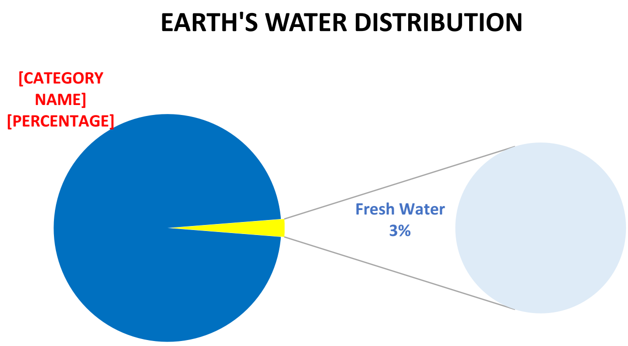

Fig. 1 Percentage of earth's water sources

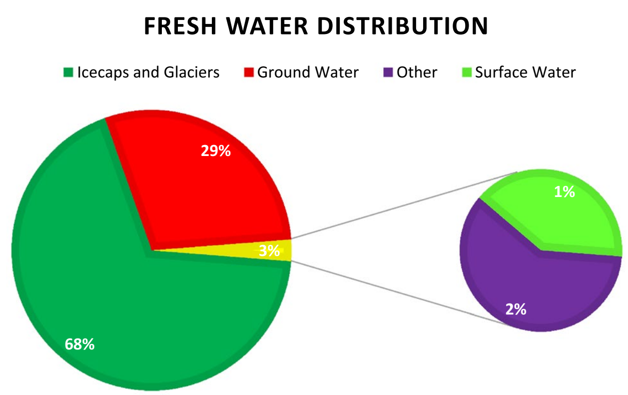

Fig. 2 Percentage of freshwater sources

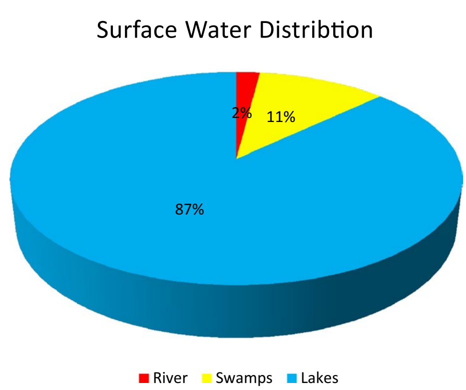

Fig. 3 Percentage of surface freshwater sources

The distribution of freshwater and surface fresh water is depicted in Figs. 2 and 3, respectively.

Each year, the total volume of produced wastewater by petroleum industries are exceeded more than 800 billion gallons. These wastewater productions contain the large volumes generated wastewater over the life of the well and massive volumes of water which is urgently needed in hydraulic fracturing performances (Davarpanah and Nassabeh 2017a, b; Scanlon et al. 2013a, b; 2014a, b; 2015). Hydraulic fracturing is a controlled operation that pumps fluid and a propping agent through the wellbore to the target geological formation at high pressure in multiple intervals or stages, to create fractures in the formation and facilitate production of hydrocarbons. Hydraulic fracturing is a safe and proven way to develop natural gas and oil; it has been used throughout the oil and gas industry for about 60 years. Therefore, water usages and the water reuse in petroleum industries have become one of the significant concerns in petroleum exploration and production industries as an energy issue. Water exercise plays a dominant influence in the life cycle of petroleum industries as below:

- considered as the cooling equipment in mud circulation which helps to cool the drill bit and carries rock cutting out of the borehole;
- hydraulic fracturing;
- enhanced oil recovery techniques;
- water flooding;
- steam-assisted gravity drainage (SAGD) (Clark and Veil 2009; Holt et al. 2009).

Two of the main challenges of petroleum industries are providing the sufficient amount and appropriate quality of water and find novel solutions to properly manage the wastewater generation. Wastewater composition in most of the cases is being categorized as follows:

- high dissolved organic matter, including volatile compounds and hydrocarbons;
- high salt content (often > 35 g/L);
- metals (e.g., iron, manganese, calcium, magnesium, barium, etc.);
- dissolved gases (e.g., H_2S);
- naturally occurring radioactive material (NORM);
- high concentrations of suspended solids, oil, and grease(Chen and Carter 2016; Davarpanah and Nassabeh 2017a, b; Dubiel et al. 2012; Engle et al. 2014; Esser et al. 2015).

Waste management

There are four methodologies and techniques of waste management which are addressed to improve the quality of produced or injected water during drilling operations that have entailed reduce, recycle, reuse, and recover. Reduce is the generation of less waste through more efficient practices such as process modification, use of non-toxic additives, inventory control, and management. Recycle/reuse is to convert waste back into a product such as burning waste oil for energy, oily wastes for road construction and stabilization, recycling drilling muds, and recycling scrap metals. Recover is extracting materials or energy from waste such as recovery of oil from tank bottoms and sludges (Glassman et al. 2011). These four parameters are followed by waste treatment and disposal. The treatment utilizes techniques to minimize the amount and toxicity of waste to minimize the amount that has to be disposed of. For waste disposal, environmentally sound and approved methods should be used. Regarding local geology, there are million tons of in situ water which are produced by production operations on the surficial wellbore equipment and significant amount of these waters are separated by powerful equipment; however, these obtained water sources may contain chemical pollutants, heavy metals, oily particles, etc., which have potentially devastating effects on the environmental processes and they will not be capable for human treatments due to their toxic and detrimental effects. One of the primary reasons of this issue is that operators may add many chemicals to this fluid to make the process more productive. Another underlying assumption which is to be elaborated about this phenomenon would be natural salty water that is trapped in the rock matrixes. Thereby, a large volume of this water is transferred to the surface. The possibility of assessing the dire consequences of fossil and hydrocarbon fuel development on the water life cycle are being investigated and widely reviewed by numerous scientists and engineers to optimize the maximum water reuse in operations; these extensive studies include water management practices; recycling, treatment, disposal of wastewater, and the impacts on the watershed and surrounding environment. Reuse and recycling processes are practiced by petroleum companies; in such areas, there are restriction rules for disposal wells and freshwater is more expensive and harder to find (Kharaka et al. 1988).

Lots of water sources in petroleum industries include produced water, refinery wastewater, marketing terminal water, ground water, storm water, parking lot runoff, plenty of off-the-shelf treatments, and unlimited supply of applications. These steps are being illustrated graphically in the PFD diagram in Fig. 4.

Treatment challenges

Oil and gas wastewater treatment is considered as one of the leading pollution possibilities owing to including a broad variety mixture of salt and suspended solids in high concentrations, metals such as arsenic and barium, organics like hydrocarbon compounds, and potentially naturally occurring radioactive material. It is of paramount importance to clarify the hazardous risks of this toxicity appropriately and control their mobilization, and study their occurrence dispersion, their settlement time in the environment and their corrosive effects on the food chain. Some "light-treatment" techniques are widely administered in petroleum industries which most of these treatment methodologies have determined when wastewater treating is entirely variable, and its appropriate application is prohibitively expensive to construct, operate, and maintain. Thereby, a few acceptance standards due to how to identify what is in each waste stream and which adequate methods to clean this are being presented. One of the main steps in the rapid acceleration of water reuse is the advent of advanced membrane treatment methodologies, and their cost reductions are classified into four categories;

- membrane technologies include microfiltration (MF).
- ultrafiltration (UF).
- nanofiltration (NF).
- reverse osmosis (RO) (Orem et al. 2014).

Using MF or UF in municipal wastewater reuse, especially for RO pretreatment, started to multiply in the late 1990s. Nowadays, the integrated utilization of MF and UF with RO has widely available and has reached a standard

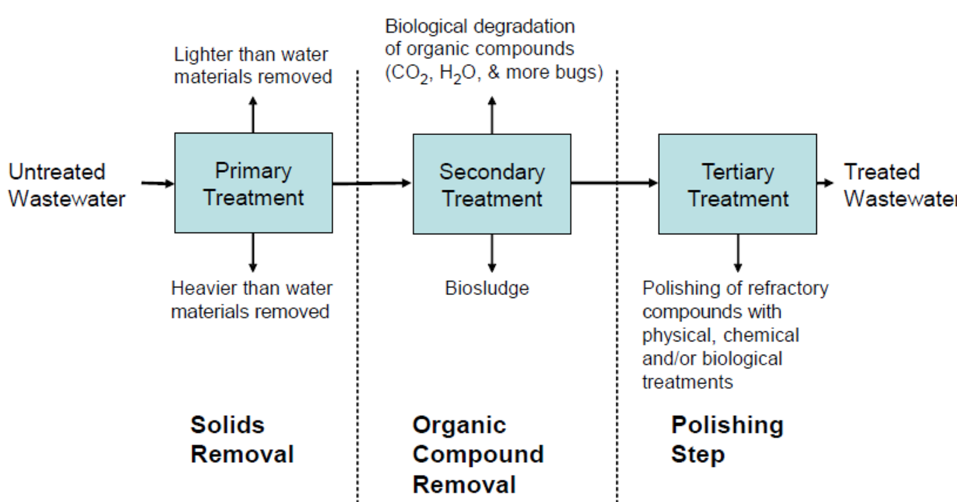

Fig. 4 Typical water treatment PFD (Kharaka et al. 1988)

in municipal advanced recycled water projects, especially for indirect potable water reuse cases where the recycled water is re-injected to the groundwater aquifer to augment the existing water sources. Historically, petrochemical plants and refineries have used RO as pretreatment for ion exchange demineralizers to produce pure water for boiler feed and process uses. Since 1999, more than ten UF systems have been installed as pretreatment for RO in petrol facilities for boiler feed-water demineralization. RO, in the form of VSEP (vibratory shear enhancing processing), has also been used in the full scale for removing selenium from stripped sour water to help a large refinery meet stringent discharge requirements. In addition, there are other types of preparing techniques for separating solids and other particles from water which are necessary to reuse it again in drilling and operational performances. These techniques are dilution, filtration, and centrifugation, liquid–liquid extraction (LLE), support-assisted liquid–liquid extraction (Al Dabaj et al. 2018), solid-phase extraction (Oetjen et al. 2017, 2018), and solid-phase micro-extraction (SPME). Dilution serves the purpose of two significant principles: lessen the sample viscosity which plays a vital role on the analysis of water injections and flow backs; in respect of the way, viscosity reduction causes the enhancement of re-productivity. Furthermore, dilution procedures altered the matrixes of the sample and prompted to have more compatibility with further analyzing. Filtration and centrifugation are other kinds of separation for virtually eliminating the particulate components to deal more compatibility with the analytical methodologies. Moreover, filtration processes would not have the ability of dissolved fractional component alteration (Ferrer and Thurman 2015; Mitra 2004; Oetjen et al. 2017, 2018; Rodriguez-Aller et al. 2016; Thurman et al. 2017).

Production from unconventional shale oil and gas plays

Accumulations of hydrocarbons such as oil and gas in natural conventional and unconventional reservoirs throughout the world which most of them were migrated from clean fine-grained, dark-gray, or black organic-rich sedimentary source rocks were referred to organic-rich shales. Over the past decades, organic-rich shale formations have been considered as the source rocks in petroleum reservoirs, that is to say, that, hydrocarbons originated and migrated into sandstone and limestone of various reservoir qualities, because unconventional reservoirs have low permeability than other reservoirs and have less economic volumes of oil and gas produced in oilfields. To produce commercial quantities from the unconventional reservoirs, a combination of increased oil and gas prices and improved technology of horizontal drilling and multi-stage fracturing are required (Rabbani et al. 2018; Rowan et al. 2015; Thacker et al. 2015).

Produced water reuse and recycling in some of the oilfields

Produced water in two of the Barnett shale reservoirs which are located in the northern portion of Pennsylvania is being studied, and their comparison between them is clarified as below to continue to minimize the amount of freshwater utilization in drilling and production operations; in respect of the way, it lessened the extra expenditures of freshwater supplements (Mantell 2011):

- Shale field-1 water reuse

In this field, produced water has generally had higher levels of TDS, low amounts of TSS, and moderate scaling tendency; that is to say, that, in this field, the volume of water reused and treated by membrane treatment techniques is relatively 8% of the total amount of water which is used for drilling and hydraulic fracturing operations. However, water reuse treatments play a significant role in production and drilling operations; logistical and economical performances impose specific restrictions in the administration of large volume of water reuse in this field (Jin et al. 2017; Mantell 2011).

- Shale field-2 water reuse

In this field, produced water has generally had lower levels of TDS, moderate amounts of TSS, and low scaling tendency; that is to say, that, in this field, the volume of water reused and treated by membrane treatment techniques is relatively 8% of the total amount of water which is used for drilling and hydraulic fracturing operations with water reuse production with a target goal of 23% reuse in the play. Regarding low levels of TSS, it does not urgently need of specific filtration before reuse operation. In comparison to the previous category, logistical and economical performances impose particular restrictions in the administration of large volume of water reuse in this field (Horner et al. 2016; Mantell 2011).

Total dissolved solids (TDS) are being used for the following purposes:

- It is used as a measurement of inorganic salts, organic matter, and other dissolved materials in water.
- It is used as a secondary drinking water contaminant.
- It can cause some operational problems for drinking water systems.

- It can cause toxicity to aquatic life through increases in salinity, changes in the ionic composition of the water, and the toxicity of individual ions.
- Significant sources of TDS are being found in:
- steel industry;
- pharmaceutical manufacturing;
- mining operations;
- oil and gas extraction;
- some power plants;
- landfills;
- food processing facilities (Wilson and VanBriesen 2012).

Although there are numerous studies and research activities which are widely reported in the literature to emphasize the importance of flow-back waters, in this comprehensive study, the author is tried to investigate the water treatment of shale reservoirs and how to provide sufficient water utilization for each well by the optimization of each procedure. Furthermore, by serving the purpose of water reuse in drilling and exploration industries, the administration of fresh water is virtually reduced and subsequently will help to the water scarcity in the world.

Methodology and application of produced water reuse

Studied field

The vertical wells to be drilled were exploration wells in the southwest Iran's oilfield which is called South-Aban oilfield that could provide information on potential reservoirs and lithological data of the field. This oilfield unit distributed into the Asmari, Pabdeh, Gorpey, Ilam, and Sarvak formations which are located in the Cheshmeh-Khosh operational field. No offset data were available on the well, and the nearest well information was 80 km away. Geologist forecast from this well required drilling through reactive shales in the member. It produces a smaller volume of produced water initially (compared to the other significant plays) and has inferior quality produced water. It has had higher levels of TDS and high amounts of TSS, and produced water has high scaling tendency. In this field, low produced water volumes, poor produced water quality, and the resulting economics have prevented successful reuse of produced water. However, due to the large volumes of higher quality drilling wastewater generated during the drilling process, it is actively exploring options to reuse this wastewater in subsequent drilling and fracturing operations.

Well performance

The studied field entails seven production wells which three of them are located in the gas shale layer (well-05–07), and other wells are drilled horizontally on the oil shale layers. The reason for drilling the wells in the horizontal form is that high potentiality of wells for hydraulic fracturing regarding the high connectivity of the fractures and cracks has successfully operated. The production performance for each well is schematically demonstrated in Figs. 5, 6, and 7 to espouse the importance of productivity rate for each well.

As it is evident from Fig. 5, well-04 has the maximum oil production rate rather than other wells and well-05–07 due to its original properties (gas shale reservoirs) does not produce any oil during the production operation. Moreover, as it is shown clearly in Fig. 6, water production has a similar decline pattern as oil production; in respect of the way, the volume of water production has decreased gradually.

As it is clarified in Fig. 7, due to the more production of gas volume in the gas shale wells, this amount of gas has increased dramatically in the first stages of production.

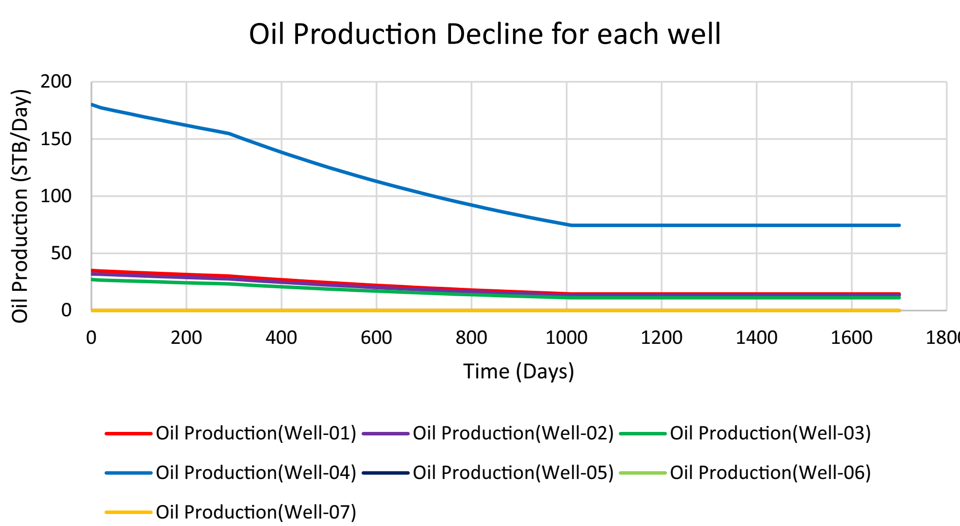

Fig. 5 Oil production rate for each well

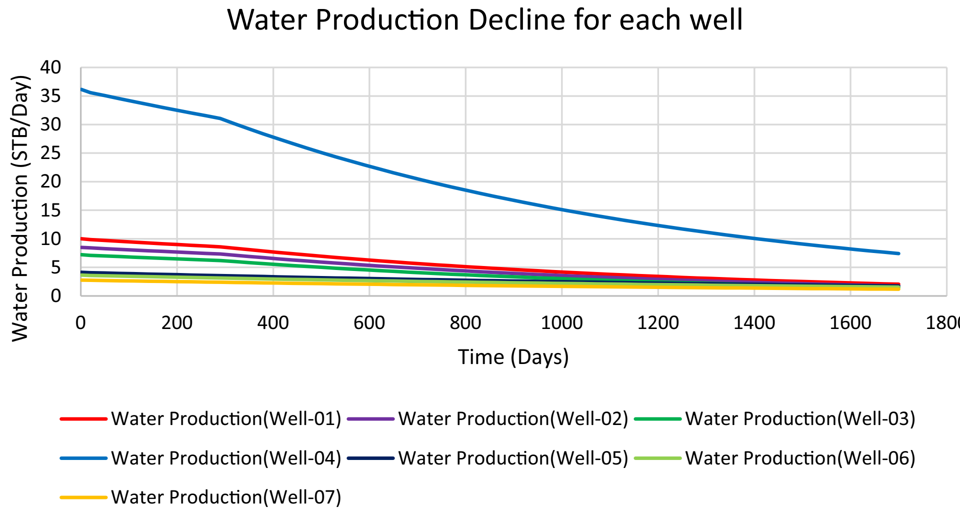

Fig. 6 Water production rate for each well

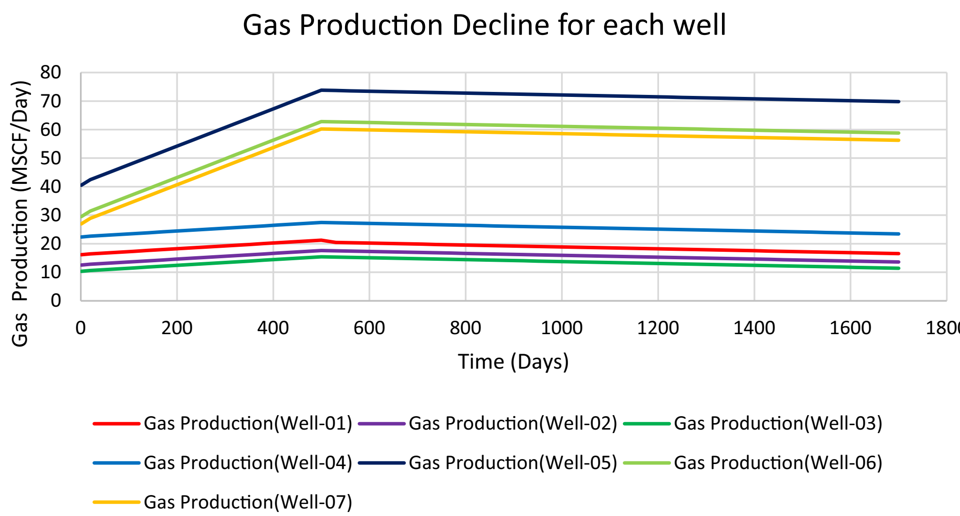

Fig. 7 Gas production rate for each well

Since then, this volume has reached approximately a plateau in the next steps.

Furthermore, regarding the constant water production of the wells in shale reservoirs, it is a common reason for unconventional reservoirs than conventional reservoirs that has a gradual rise in the water production. Therefore, the water cut fraction for each well is being depicted in Fig. 8. As can be seen in Fig. 8, bypassing the production time, the fraction of water cut in all the wells has an approximate constant value and those wells that are drilled in the oil shale layers are more than wells which are drilled in gas shale layers. This phenomenon might be related to the miscibility of oil and water which enables the water phase to mobilize to the surface with oil in the solution phase.

Reservoir and rock properties

The reservoir and rock properties of each well such as average permeability, porosity distribution, and the gas volume in gas cap are being statistically explained in the ordinary format in Table 1. As it is clarified in Table 1, porosity varies approximately between 5.48 and 9.13 in this field; in respect of the way, it changes a little in some parts of the field. Moreover, the range of permeability which is obtained by production logging tools is relatively 8.03–12.37 for oil shale reservoirs and 3.89–5.34 for gas shale reservoirs. In this field, oil saturation is assumed an average constant amount (approximately 0.42) and water saturation is averagely about 0.254.

Utilization of water in the development of shale reservoir of the field

Water is considered as the fundamentally vital components in the construction of shale reservoirs. Some of the utilization of water in drilling and exploration industries are: the administration of clay and water to carry the cuttings to the surface equipment, function as a lubricant for drilling

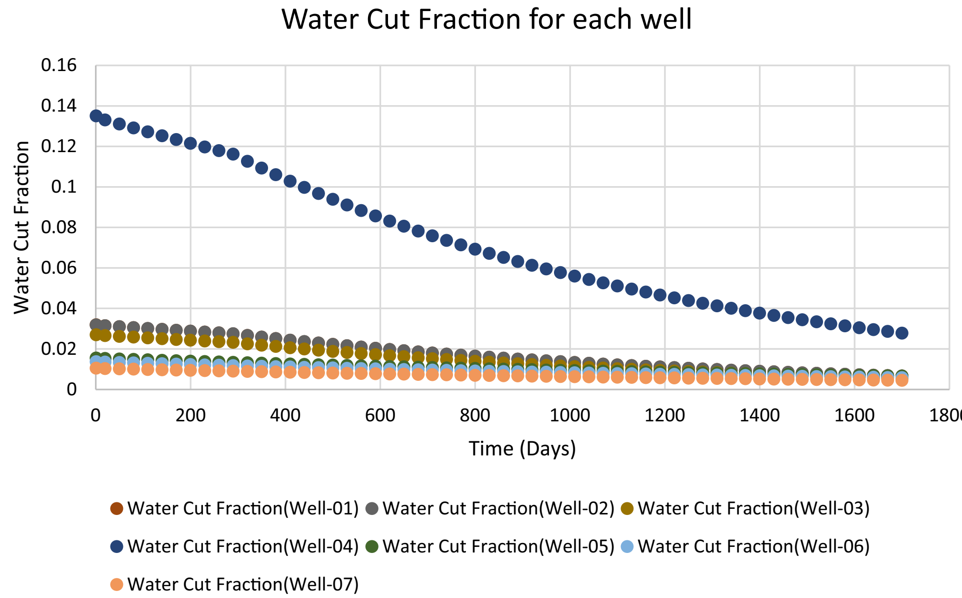

Fig. 8 Water cut percentage for each well

Table 1 Rock and reservoir characteristics

Well no.	Porosity %	Average permeability mD	Gas volume in gas cap MMCSF
Well-01	8.65–9.13	12.37	835
Well-02	7.98–8.34	11.52	920
Well-03	8.12–8.57	13.69	960
Well-04	6.42–7.09	8.03	714
Well-05	6.84–7.03	5.34	6151
Well-06	5.76–6.16	4.27	8000
Well-07	5.48–5.97	3.89	9835

Table 2 Relatively estimated water volume for each well

Well no.	Well type	Average water use (million gallons)
Well-01	Oil shale	4.80
Well-02	Oil shale	6.40
Well-03	Oil shale	5.90
Well-04	Oil shale	10.84
Well-05	Gas shale	3.3
Well-06	Gas shale	4.5
Well-07	Gas shale	5.4

bit and other parts of drilling facilities; and, in hydraulic fracturing, the mixture of water and sand is administered. The total of water volume which is required for drilling a shale well is approximately 65,000–600,000 gallons. In Table 1, the relatively estimated water volume for each of the shale wells is explained statistically. Furthermore, the uses of water volume in each procedure are described in Table 2.

As can be seen in Table 3, the most volume of consumed water is spent in the hydraulic fracturing procedures. In addition, lubrication processes and drilling operations are played the least significant role in water consumptions.

Produced water management

Produced water has been exerted a profound impact in the environmental and economic prosperity of shale oil and gas operation and its vital development strategies; in respect of the way, it acts as the byproduct energy in the development of oil and gas reservoirs. Hence, water production should be significantly performed to be brilliantly succeeded in developmental plans. The feasibility of produced water reuse is utterly dependent on three central phenomena. First and the most important one is the volume of the produced water generated. It should be noted that the initial amount of water generated is being added to these measurements and it considered as the only first few weeks after simulation processes, because it significantly affected the calculations. Since then, the proportionality of time with the quantity of produced water is of great importance to measure the rate of water production and how it would be declined in the extended durations. For example, such wells with a large volume of produced water at the preliminary stages of operations would be elected for reuse treatments regarding their capability of transportation to the store locations. The last significant factor to have a steep rise in economic prosperity is the continuous production volume of water which helps to remain tanks and trucks movable all over the oilfield unit. These three substantial factors would make

Table 3 Uses of water volume in each procedure

Well no.	Water use in hydraulic fracturing (million gallons)	Water use in lubrication processes (million gallons)	Water use in the drilling operations[a] (million gallons)
Well-01	4.455	0.145	0.200
Well-02	5.984	0.212	0.204
Well-03	5.540	0.185	0.175
Well-04	13.651	1.234	0.286
Well-05	2.720	0.216	0.364
Well-06	3.860	0.300	0.340
Well-07	4.910	0.197	0.293

[a]Drilling operations entail all the activities such as making water-based muds, carrying cuttings to the surface, etc

a breakthrough in the independence of water sources from alternative sources and give petroleum industries the chance to schedule a wide range of hydraulic fracturing and proper drilling operations simultaneously due to virtually eliminate the vast sums of money and time to provide water for their performances. In addition to these crucial parameters, long-term produced water production is of paramount importance, in respect of the way, those wells that produce vast quantity of produced water for long time duration periods will be urgently needed a disposal or reuse management selection in the nearest areas to the field to retain the economic viability of the operation.

Techniques for managing the produced water from oilfields

Energy and appropriate, necessary equipment exercise a dominant influence on the control of water composition impurities such as large quantity of natural salts, minerals, and toxic heavy metals which they are an internal part of produced water and lead to reduce the quality of water at surficial wellbore facilities. Therefore, administer the proper policies to impart the best quality of produced water exert a considerable influence on the drilling and production operations and lessen the inefficiency of current methodologies by applying the high quality of water. To achieve this goal, two recent and practical techniques are operated in oilfield units to directly affect the key parameters such as energy, environmental, and economic issues.

These methods entail conventional treatment and advanced treatment. The traditional treatment includes flocculation, coagulation, sedimentation, filtration, and lime softening water treatment processes. These treatment procedures are significantly impacted the water impurities suspended and colloidal solids, oil and grease, hardness compounds, and other non-dissolved parameters. Furthermore, these processes are much less energy intensive than the salt separation treatments. On the contrary, advanced treatment technology includes reverse osmosis membranes, thermal distillation, evaporation, and crystallization processes. These techniques are utilized to treat dissolved solids, primarily consisting of chlorides and salts, that is to say, that it contains dissolved barium, strontium, and some dissolved radionuclides on some occasions. As a matter of fact, these dissolved parameters are actively tricky, and energy consumed to treat and can only be separated with this advanced membrane and thermal technologies.

Results

According to the performed analysis and experimental evaluations, the utilization of water for hydraulic fracturing operations is higher than that for the conventional gas production but is in the low range of that for conventional oil production. The volume of water which is used for hydraulic fracturing procedures varies regarding the type of drilled wells such as some vertical vs. horizontal wells, length of laterals, and fracture fluid types. Furthermore, the possibility of water occurrence is utterly depended on the local sources of water supply. Produced water has entailed all sources of water such as returning water to the surface, flow back of injected water during the hydraulic fracturing performances as well as natural formation water. Although produced water is generated for the well lifespan, its volume might be efficiently altered by its mobilization on each. There are a wide range of quality for produced water which can also vary tremendously from brackish (not fresh, but less saline than seawater) to saline (similar salinity to seawater) to brine (which can have salinity levels multiple times higher than seawater). Furthermore, in this part of extensive study, two laboratory experimental field tests are being performed to enhance the oil and gas productivity; in respect of the way, for oil shale wells, two sets of experimental analysis (hydraulic fracturing and water injectivity) are operated on the cores which was taken from the wells 01–04; and for gas shale wells, only hydraulic fracturing is performed because of the proportionality of this technique rather than water injectivity. The results of these investigations are as below;

Experimental field application of hydraulic fracturing and water injectivity in oil shale wells

To investigate the water volume which is needed for water injectivity and hydraulic fracturing experiments and how this methodology would enhance the oil production, the oil production curves for each well, and the water volume which is required to be supplied from external resources are schematically depicted in Figs. 9 and 10. As it is evident from Fig. 9, water injection would enhance the oil production for a specific period, and then, it has decreased slightly. Moreover, hydraulic fracturing regarding the opening of fractures and cracks has caused to improve the oil volume production drastically in the first steps of fracturing procedures, and after that, by producing the specific oil volume, it lessened slightly; it is shown in Fig. 10.

The average rate of water production in each scenario and the required water volume for each well is statistically explained in Tables 4 and 5. It is a foregone conclusion that providing required water volume by the water produced water in the surface would significantly eliminate vast sums of expenditures in water supplementary and subsequently would be an accurate method of saving other water resources due to the water scarcest.

Experimental field application of hydraulic fracturing in gas shale wells

To investigate the water volume which is needed for hydraulic fracturing experiments and how this methodology would enhance the gas production, the gas production curves for each well and the water volume which is required to be supplied from external resources are schematically depicted in Fig. 11. As it is evident from Fig. 11, hydraulic fracturing regarding the opening of fractures and cracks has caused to improve the oil volume production drastically in the first steps of fracturing procedures, and after that, by producing the specific oil volume, it lessened slightly.

The average rate of water production in each scenario and the required water volume for each well is statistically explained in Table 6. It's a foregone conclusion that providing required water volume by the water produced water in the surface would significantly eliminate vast sums of expenditures in water supplementary and subsequently would be an accurate method of saving other water resources due to the water scarcest.

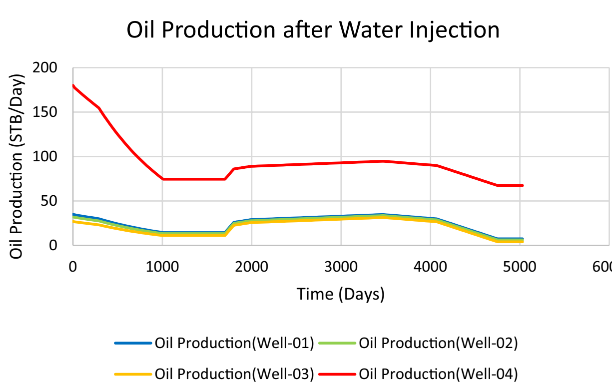

Fig. 9 Oil production after water injectivity

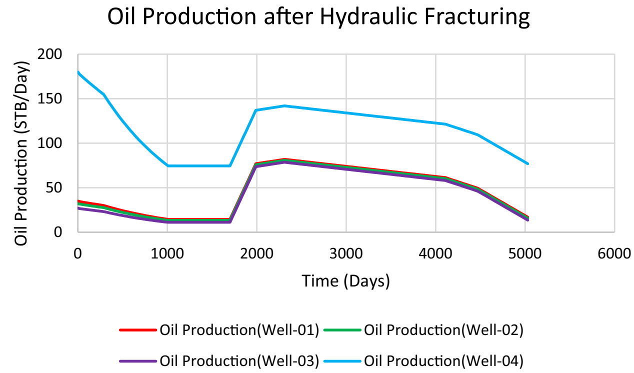

Fig. 10 Oil production after hydraulic fracturing

Discussion

However, numerous research studies (Oetjen et al. 2017, 2018; Thacker et al. 2015) have been widely reported in the literature about the different types of separation methods of particulate materials from flow-back water; it should be noted that this procedure needs to be more concentrated about the utilization of separation techniques and its optimum efficiency to investigate the significant principles such as high amount of TOC in water return and conductivity of particles such as ion particles that would be beneficial for petroleum industries. In addition, according to the results of this comprehensive study, it is noticeable that reinjection of produced water in the

Table 4 Required and produced water in water injectivity

Well no.	Average required water volume for injectivity (million gallons)	Average produced water in the surface (million gallons)
Well-01	3.951	1.684
Well-02	4.625	1.8547
Well-03	3.684	1.4235
Well-04	11.284	5.7342

Table 5 Required and produced water for hydraulic fracturing

Well no.	Average required water volume for hydraulic fracturing (million gallons)	Average produced water in the surface (million gallons)
Well-01	4.455	2.6431
Well-02	5.984	3.1462
Well-03	5.540	2.9345
Well-04	13.651	7.7461

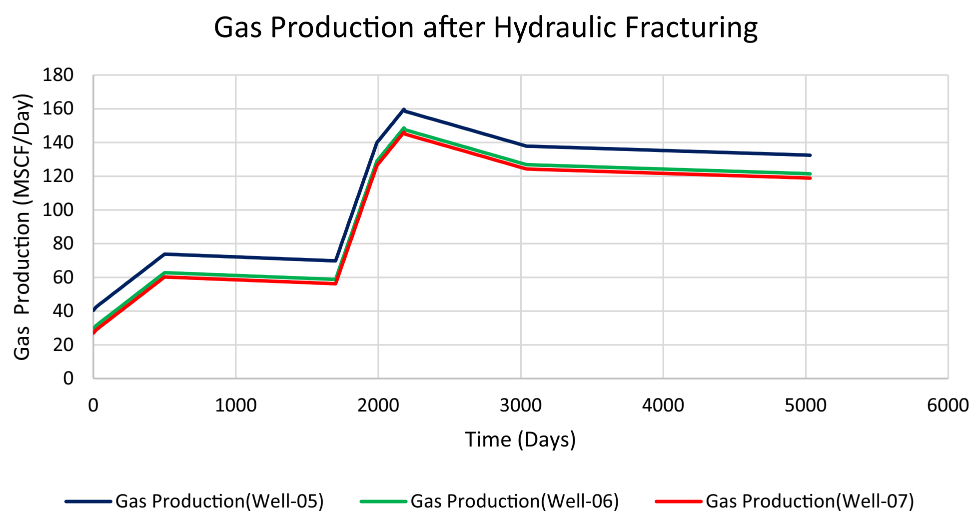

Fig. 11 Gas production after hydraulic fracturing

Table 6 Required and produced water for hydraulic fracturing

Well no.	Average required water volume for hydraulic fracturing (million gallons)	Average produced water in the surface (million gallons)
Well-01	2.720	1.3451
Well-02	3.860	2.0132
Well-03	4.910	2.7651
Well-04	2.720	1.2914

surface in both water injectivity and hydraulic fracturing techniques would be considered as the substantial methodologies to decrease the urgent needs of water volume from other resources and might virtually eliminate the unnecessary expenses like transferring of water from considerable distances. Although the stunning range of research enhancement and substantial technology development has concentrated on treatment methodologies to illustrate and investigate the optimum quality of water produced by removing unnecessary internal materials thereby, it would be beneficial for further procedures and operations. These alternative elections contain water reuse in oil and gas operations, municipal, agricultural, and industrial processes. The Lower amount of dissolved solids produced water must be under 30,000 ppm TDS which may be feasible to treat in other activities outside of oil and gas operations. Higher dissolved solid produced waters contain more than 30,000 ppm TDS, and this is why the high salinity content that is kept in solution with water should be virtually eliminated.

Conclusion

Reinjection of water produced in the water injectivity and hydraulic fracturing techniques is considered as the principal efficient way to reduce the urgent need for water resources dramatically. The main conclusions which are being significantly reported in this comprehensive study are as the following statements:

- Due to the fact that water scarcest in the coming decades would be a significant concern for petroleum industries, providing a part volume of water which is needed for oil recovery enhancement would be a significant step to eliminate enormous expenses of water supplies.

- Regarding the results of this extensive study, it is clarified that hydraulic fracturing enhances the oil and gas production rather than water injectivity because of its efficient property to open the closed and dead-end pores and made a breakthrough in the first period of its process. Therefore, providing the supplementary water for this operational performance is a significant concern and reinjection of produced water on the surface would be a considerable assessment.
- Although both technologies for water treatment play a substantial role in every aspect of petroleum industries' operational performances, advanced treatment which is metamorphically called "the second level"; in respect of the way, it would be ensured that most of the non-dissolved parameters on the water produced are removed prior to the dissolved solids treatment process.
- The feasibility of produced water reuse is dependent on three primary factors: quantity, duration, and quality of produced water generated.

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