Analyses and Treatment of Oil Field Formation Water of Upper Assam Basin (India)

Tapan Jyoti Gogoi and Subrata Borgohain Gogoi

Abstract

Formation water constitutes the biggest oil by-product of oil exploration and production industries, which disturbs the ecological balance. In view of the above, this study is an attempt to examine the physical and chemical parameters of formation water and to determine the scaling potential of untreated and treated formation water by Ryznar stability index and Langelier saturation index calculators. Ten samples of crude oil containing more than 70% formation water are collected from the wellheads of ten production wells of the Upper Assam Basin. Analyses of the parameters of the separated formation water from crude oil are found to be outside the permissible range set by the Central Pollution Control Board of India which gives us a clear view that the untreated water cannot be discharged to the environment until proper treatment is done. The formation water samples are treated in a parallel flow hollow fiber membrane module by micro-filtration, ultra-filtration and nano-filtration membranes in sequence. The parameters of the treated samples by nano-filtration are found to be within the range set by the Central Pollution Control Board of India, therefore, it can be disposed of without affecting the environment. The scaling potentials are evaluated by Ryznar stability index and Langelier saturation index calculators of the untreated and treated formation water. The untreated water sample forms heavy scales than the treated ones.

Keywords

Formation water • Parameters • Membranes
Scaling

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1 Introduction

The focus in the oil industry is to carry out exploration and exploitation and to develop hydrocarbon prospects and commercially produce oil and natural gas in an environmentally harmonious manner. It produces around 77 billion barrels of water per annum globally which contains inorganic salts, organic compounds, total dissolved solids, suspended solid—with a presence of bacteria and microbes, oil and grease and heavy metals [6]. Oil wells in some oil fields of the Upper Assam Basin are producing 98% formation water (FW) and 2% crude oil [5]. The most efficient way of handling this large quantity of formation water is to use it in a water injection plant for reservoir pressure maintenance or re-inject it in disposal wells after treatment. The water quality parameters set by the Pollution Control Board of India can be achieved efficiently through membrane processes which is an economically viable physical process. The primary objective of this paper is to treat the contaminated formation water by membrane filtration to remove the major pollutants, so as to dispose of the treated water without affecting the environment along with determining the scaling potential using Ryznar stability index and Langelier saturation index calculators.

2 Materials and Methods

Materials: Ten samples of FW were taken for analysis along with potassium hydroxide, ethanol, petroleum ether, ethylene di-amine tetra acetic acid (EDTA) disodium salt di hydrate, erichrome black T, potassium chloride, sodium chloride, calcium carbonate, lithium carbonate, hydrochloric acid, phenolphthalein, toluene and filter paper were used.
Methods: The pH, conductivity, salinity, TDS, turbidity and DO were analyzed in a water analyzer (Systronics 371). The BOD was tested in a BOD incubator (Velp scientifica). The Na, Li, Ca were determined in a flame photometer

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(Systronics 128), while Al, B, P, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Mn, Mg, Ni, Pb, Sr, Te, Zn, Ti were determined in an atomic adsorption spectrometer (AAnalyst 200) and induced coupled plasma optical emission spectrometer (Optima 2100DV). The membrane treatment was done in a hollow fiber membrane module set up with microfiltration (MF), ultrafiltration (UF) and nano-filtration (NF) membranes. While the scaling effect on the membranes were evaluated in RI and LSI calculators.

3 Results

3.1 Results of Water Cut Analysis

See Table 1.

3.2 Results of Physic-Chemical Analysis

See Figs. 1, 2, 3, 4, 5, 6, 7 and 8.

4 Discussion

Table 1 shows the water cut analysis of the FW which gives us an apparent view of the presence of a high quantity of water along with crude oil due to ageing of the oil fields of the Upper Assam Basin. Figures 1, 2, 3, 4, 5, 6, 7 and 8 show the results of the physicochemical analysis. This provides a comparison between untreated FW and stages of filtration in MF, UF and NF membranes. It gives us a clear view that the pore size is inversely proportional to the removal of contaminants. NF membrane provides maximum removal of contaminants and its water is considered for disposal as all the parameters are within the range set by the Central Pollution Control Board of India.

The untreated FW has a high value of pH which affects its chemical properties. The conductivity of pure water is 0.35 mS/cm which is well below the conductivity of FW due to the presence of ions in it [3]. The removal of total dissolved solids is a challenge given the sheer number of ion particles that are smaller than 2 μm and range from <2000 to>150,000 ppm [1]. The complete removal of all total dissolved solids from water can only be achieved through MF, UF and NF membranes together in a sequence. The conductive ions basically come from inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds. The presence of suspended solid may damage the formation by plugging the pores while injecting FW through the injection wells. The FW was found to be highly saline and rich in dissolved minerals. The main contributing ions are Na, Mg, Ca, K, chloride, sulphate, bicarbonate and bromine. The hardness was predominantly caused by divalent cation such as Ca, Mg, Al, Ba, Fe, Mn, Sr and Zn. Alkalinity was primarily due to hydroxide, carbonate and bicarbonate contents. The oil and grease was present in FW in the form of free oil, dispersed oil and emulsified oil. These have to be completely removed from FW as it contains harmful constituents which are not suitable for disposal into the environment. The principle behind the separation of oil and grease from FW is Stokes law [7]. BOD measures, the quantity of oxygen used by microorganisms in the oxidation of organic matter which is must be as low as possible so that the aquatic animals are provided with adequate oxygen. The hydrocarbons are directly related with environmental pollution and biological toxicity problems where the metallic elements are human carcinogens which may induce multiple organ damage even at lower levels of exposure [2, 8]. By calculating the scaling effect, it was found that all the RI values remained around 6 and the LSI values remained

Table 1 Table of water cut analysis

Sl. No.	Sample ID	Geologic formation/depth (m)	Reservoir pressure (kg/cm^2)	Reservoir temperature (°C)	Water cut i.e. water in crude oil (%)
1	1	Barail (2950)	190	82	86
2	2	Barail (3100)	200	88	91
3	3	Barail (2800)	240	85	73
4	4	Barail (3100)	180	89	82
5	5	Barail (3350)	240	89	89
6	6	Barail (2900)	250	83	76
7	7	Barail (2850)	230	81	77
8	8	Barail (3100)	220	86	95
9	9	Barail (3300)	180	90	90
10	10	Barail (3200)	210	87	83

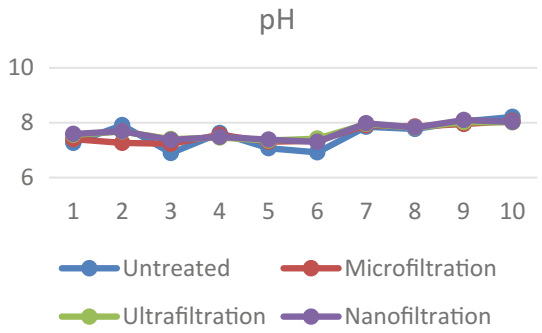

Fig. 1 Comparison of pH after stages of membrane treatment

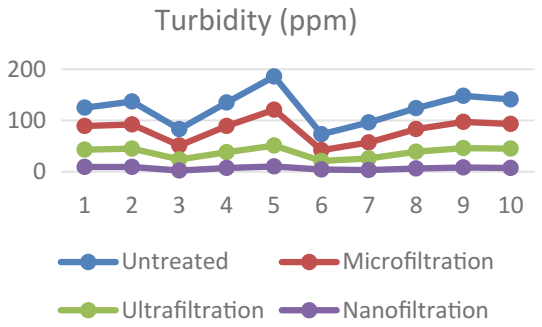

Fig. 2 Comparison of turbidity after stages of membrane treatment

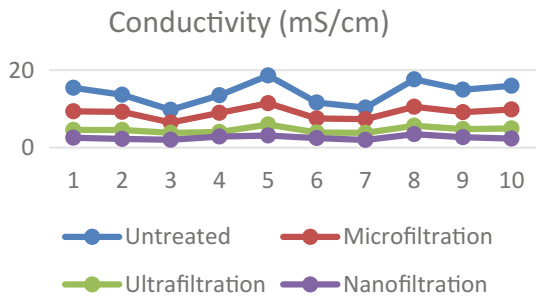

Fig. 3 Comparison of conductivity after stages of membrane treatment

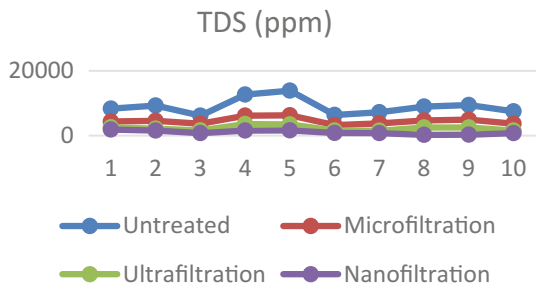

Fig. 4 Comparison of TDS after stages of membrane treatment

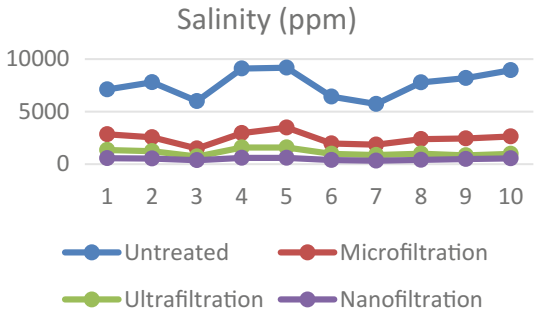

Fig. 5 Comparison of salinity after stages of membrane treatment

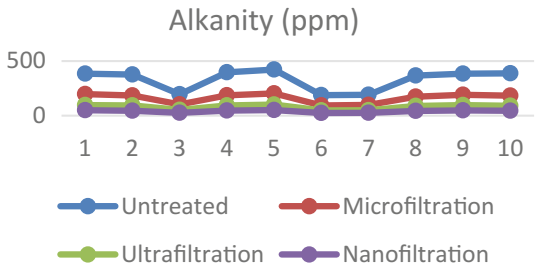

Fig. 6 Comparison of alkalinity after stages of membrane treatment

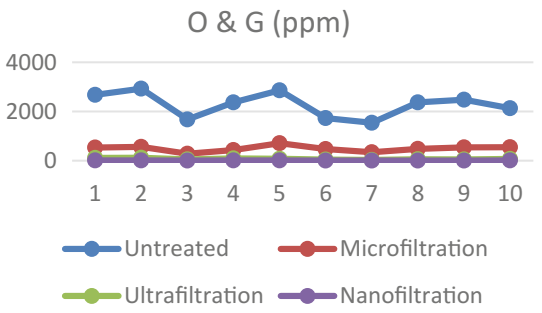

Fig. 7 Comparison of O&G after stages of membrane treatment

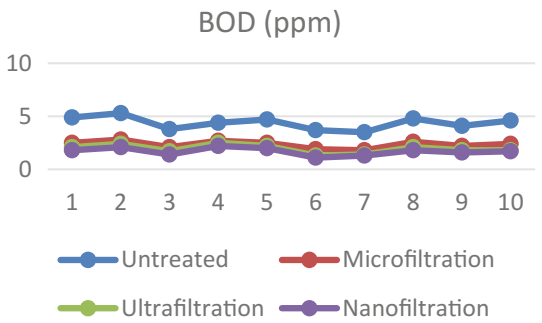

Fig. 8 Comparison of BOD after stages of membrane treatment

Table 2 Membranes with average pore diameters

Sl. No.	Membrane	Molecular weight cut-off (MWCO) (kDa)	Average pore diameter (μm)
1	MF	–	0.2
2	UF	44	12.9
3	NF	400	1.04

around 0.5, which shows that the untreated FW forms a heavy scale whereas the treated water shows a light scale, while scaling indicates the presence of $CaSO_4$, $BaSO_4$ and $SrSO_4$ [4].

5 Conclusions

This paper reveals the effect of untreated FW on the ecosystem. It affects the soil and water bodies if requisite treatment is not done by oil and gas industries. The FW reduces dissolved oxygen concentration and leads to the formation of sludge in the environment which damages the aquatic biota.

Table 2 gives us an idea about the average pore diameter and molecular weight cut-off of the MF, UF and NF membranes with which the FW is being treated. The average pore diameter which remains uniform throughout the whole membrane. After consecutively treating with all the membranes, it was found that all the parameters were within range set by Central pollution control board of India. He presence of $CaSO_4$, $BaSO_4$ and $SrSO_4$ in FW lead to the occurrence of scales on filter membranes. The scaling effect of on the membranes were evaluated in RI and LSI calculators. Heavy scales formation was observed during untreated FW filtration process, while light scale formation was observed during untreated FW filtration process.

References

1. Arthur, J.D., Langhus, B.G., Patel, C.: Technical summary of oil & gas produced water treatment technologies (Mar 2005)
2. Gakwisiri, C., Raut, N., Al-Saadi, A., Al-Aisri, S., Al-Ajmi, A.: A critical review of removal of zinc from wastewater. In: Proceedings of the World Congress on Engineering 2012, vol. I, July 2012
3. Gogoi, S.B., Sen, R.K., Rajbongshi, A., Hazarika K.: Characterization of oil field produced waters of Upper Assam Basin, India. Int. J. New Technol. Sci. Eng. **2**(1) (2015). ISSN 2349-0780
4. McCartney, R.A.: Conditions under which anhydrite precipitation can occur in oil reservoirs as a result of seawater injection (2008)
5. Neff, M.J., Lee, K., DeBlois, M.E.: Produced water: overview of composition, fates and effects (Jan 2011)
6. Rangarajan, T.D., Ali, H., Amr, H.: State of the art treatment of produced water (2016)
7. Rudolfs, W., Babbitt, H.E., Bloodgood, D.E., Edwards, C.P., Faber, H.A., Genter, A.L., Heukelekian, H., Miles, H.J., Mohlman, F.W., Ruchhoft, C.C., Sawyer, C.N., Setter, L.R., Van Kleech, L.W.: A critical review of the literature of 1945 on sewage and waste treatment and stream pollution (1946)
8. Tchounwou, B.P., Yedjou, C.G., Patlolla, A.K., Sutton, D.J.: Heavy metals toxicity and the environment (Aug 2012)