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PHYSICOCHEMICAL CHARACTERIZATION AND ANALYSIS OF INJECTION WATER QUALITY DURING WATERFLOODING AT OFFSHORE PETROLEUM FACILITIES

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ABSTRACT

In this research, we study the physicochemical characterization of the injection water during water flooding and the changes in the water quality during its transportation from the Main injection pump (MIP) to the Well Head (WH) at the offshore platform in Mumbai High offshore field, India. The distance between the main injection pump and the well head is approximately 15 kilometers, connected by a subsea pipeline, which is long enough to degrade the quality of injection water during its transport. Physicochemical parameters such as pH, turbidity, cations, anions, filterability, iron content, Total suspended solids (TSS), Total dissolved solids (TDS) were determined from the industrial laboratory investigations. Cerini plots were graphed to determine the relative quality of water at MIP and injector. The result indicates the addition of solid content in the water during travel to wellhead. There is also a reduction in filterability from 6.45L/30 min to 3.43L/30 min. There has been increase in iron content from 0.01 mg/L to 6.85 mg/L. The research showed that there was deterioration in the quality of injection water during the transportation through the pipeline. An injection water treatment plant was recommended at the Mumbai High offshore platform after this study.

Key words: Physicochemical characterization, Water flooding, Offshore, Platform, Water quality.

INTRODUCTION

The objective of this study is to analyze and monitor water quality at various points in the injection system and identify the cause for water quality changes, if any, during its

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transportation at the offshore platform in Mumbai High offshore field, India (Fig. 1). Water quality is of paramount significance in the water flood projects as required measure of water is important to be injected in the reservoir to get coveted advantages of oil recovery[2]. Low quality water prompts plugging of the injector wells and equipment corrosion. The injection water should be free of un-dissolved solids, it should be chemically stable and should not react with compounds and elements present in the injection system and the reservoir. Water flooding is the most usual method of secondary recovery. The ultimate recovery by water injection is obtained in the range of 20-40 %, though in the few cases, the recovery may be significantly higher or lower[1].

Amid the beginning of water flooding, just the amount (not the quality) of the water was given significance[3]. Be that as it may, it was soon identified that higher injection pressures were required to keep up reasonable injection rates and corrosion issues mounted. The practices of water treating have enhanced extraordinarily as the water flood process has developed a point that is substantiated in the literature by the numerous commitments on this subject. At the point when the source of water is known, water examination is necessary to answer few questions that would pose solution of research problem. Compatibility of the reservoir water with the injection water needs to be checked. We need to test whether a closed or open injection facility would be the most appropriate; and the type of treatment that is important to have good quality water for the subsurface reservoir and to minimize wear and tear of equipment by corrosion.

Physicochemical characterization of injection water

Water analysis of the injection water show concentrations of the major constituents present in it. It helps in the analyzing potential danger that may occur during injection, e.g. formation of scales or the corrosions products. The substances which are commonly dissolved in the water are discussed in this article.

The cations that are mostly found in Indian offshore waters are sodium, potassium, calcium, magnesium, iron, manganese, barium, strontium, aluminium while chloride, sulphate, carbonate, bicarbonate, hydroxide are ordinarily dissolved anions. Oxygen, hydrogen sulphide, carbon dioxide are the gases dissolved in the injection water. Presence of charged ions allows the injection water to become electrically conductive, salt (NaCl) in the solution also increase water viscosity, density and surface tension. To eliminate the loss of dissolved gases through changes in temperature and pressure, testing of such gases were carried out in the field soon after a water sample is taken. Aerobic, anaerobic, fungal, and algal growths will cause reservoir and equipment plugging and corrosion. Special attention and control are required for Sulphate reducing bacteria (SRB). The presence of the sulphate ion is essential to the growth and reproduction of these particular bacteria. Sulphate, in turn, causes reservoir pore plugging. The reaction of the sulphate ion with the SRB forms the sulfide ion which then reacts with iron. Iron sulfide is serious plugging agent and H_2S is an extremely corrosive agent.

Sulfates are of most interest from a deposition standpoint. Three generalizations may be made with regard to this class of substances. An abnormally low or zero sulfate value in brine suggests the possibility of the presence of barium and strontium. It requires practice and experience to evaluate low-sulfate-content water. In general, high-sulfate water should not be mixed with water containing appreciable amounts of barium or strontium. High sulphate brine indicates that there is a possibility of exceeding the calcium sulfate solubility. The solubility of $SrSO_4$ or $CaSO_4$ is governed by the limiting factor of either SO_4 or Ca or Sr and the ionic strength or foreign salt concentration of the brine. Chlorides are the primary indication of the salinity of injection water, or the ionic strength of brine, or the presence of fresh water. Chloride tests can be useful in tracing the progress of a waterflood.

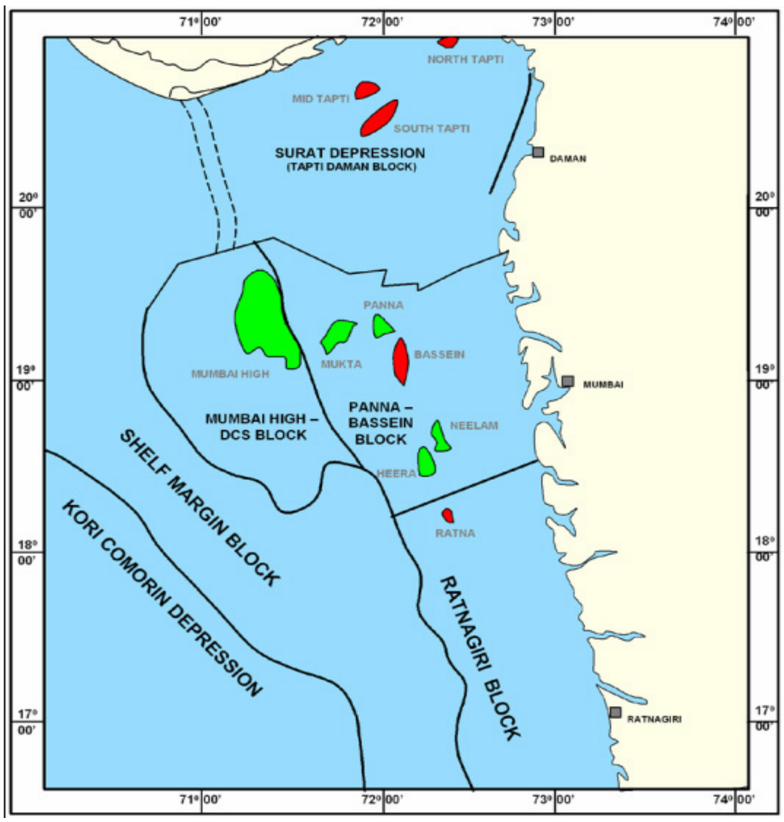

Fig. 1: Mumbai high offshore facility location, India

The Millipore filter test has been developed to provide a means of measuring suspended material under injection system conditions. This test is conducted with the mixed esters of cellulose and a uniform pore size of, generally, 0.45µm opening. The filter diameter may be of several sizes; however, 90-mm diameter filters are recommended because a greater volume of throughput water can be handled, thus giving a more representative test for the system being examined. A small stream of water is taken, through suitable connections and the test apparatus (shown in Fig. 2), from the selected point in a system. The test apparatus that holds the filter will trap all the suspended material flowing through the sample line. The water effluent that passes through the filter is measured and recorded, for use in the later analysis, as volume throughput in milliliters of water.

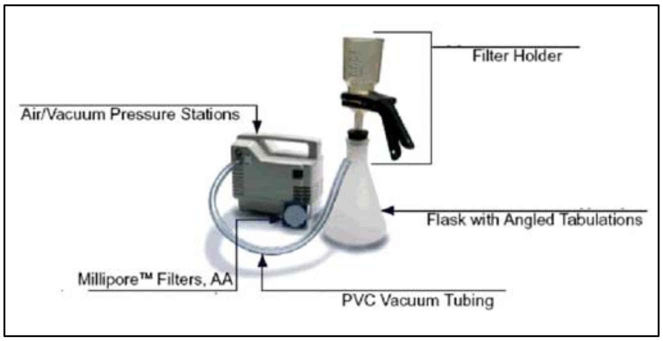

Fig. 2: Millipore filterability test setup

The physicochemical parameters of source and injection water are analysed and the results are as shown below (Table 1).

Table 1: Physicochemical parameters of source water (MIP) and injection water (WH)

S. No.	Parameter	Source water (MIP)	Well head injection water (WH)	Unit
1	pH	7.46	7.43	-
2	Turbidity	0.2	11.6	NTU
3	Filterability	6.45	3.43	L/30 min
4	TSS	0.3	3.8	ppm
5	Chloride	19880	20590	mg/L
6	Calcium	481.2	441.1	mg/L

Cont…

S. No.	Parameter	Source water (MIP)	Well head injection water (WH)	Unit
7	Magnesium	1372	1445.5	mg/L
8	Carbonate	Not present	Not present	mg/L
9	Bi-carbonate	244	213.5	mg/L
10	Sulphate	3300	3450	mg/L
11	Sodium	11413.52	11841.25	mg/L
12	Salinity	32603.2	33767.6	mg/L
13	DO	nil	1.2	ppm
14	Iron	0.01	6.85	mg/L
15	TDS	36690.72	37981.35	mg/L

Water quality rating

The most widely used method to compare relative water quality of injection water is a filtration rate test using porous plastic membrane as the standard test medium. The method consist of passing a measured volume of injection water through a membrane filter disc under constant pressure and measuring the flow rate at selected volume intervals. A graphical plot of flow rate and water throughput volume produces curves whose slope is indicative of test filter plugging rate. By using a pre weighted membrane disc the amount of solids retained from the volume of water filtered can be determined. Quantitative determination of solids present in the water is the essential for comparison of quality of various waters. The water quality rating considers both concentration and relative plugging capability of the solids present in the injection water, thus provides numerical values to plugging capability of water.

First, Empirical Slope Number (ESN), a dimensionless number, is determined by Eqs (1):

$$ESN = \log \frac{Qa}{Qb}\left(\frac{2500}{CVb - CVa}\right) \quad \ldots(1)$$

Where Qa, Qb - Filtrate rate (mL/sec) at data points a and b, respectively.

CVa, CVb - Cumulative volume of water filtered (mL) at data points a and b, respectively

Secondly, we determine the total weight of the suspended solids (TSS) by Eqs. (2) in order to find out the Relative Plugging Index (RPI). The RPI and the TDS range are given in Table 2.

$$RPI = ESN + TSS \qquad \ldots(2)$$

Table 2: RPI and its relative TDS range

RPI	TDS Range (mg/L)
<4	Excellent
4-12	Good to Fair
12-20	Questionable
>20	Poor

Source water (MIP), Mumbai high field, India

The source water was analysed for its physico-chemical parameters. The pH value was found to be 7.46. Filterability was 6.850 L/30min. There was no presence of Carbonate and dissolved oxygen.

Table 3: Filtration experiment and relative plugging index calculations for MIP water

Data point of the plot	Cumulative volume filtered (mL)	Vol. of water filtered (mL)	Cumulative time (min)	Time difference (sec)	Filtration rate (mL/sec)
1	4500	500	06:43	87	5.74
2	6600	200	23:33	176	1.12

$$ESN = \log \frac{Qa}{Qb}\left(\frac{2500}{CVb - CVa}\right)$$

Substituting,

$$ESN = \log \frac{5.74}{1.12}\left(\frac{2500}{6600 - 4500}\right)$$

ESN = 0.84 and RPI = ESN + TSS

RPI = 0.84 + 0.3

RPI = 1.14

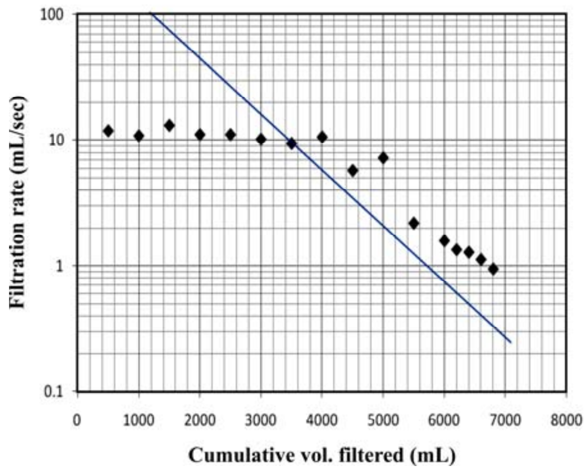

Fig. 3: Cerini plot of MIP water

Fig. 4: Physical appearance of the residue (MIP water filtration)

Well head injection water (WH), Mumbai high field, India

The well head injection water was analyzed for its physicochemical parameters. The pH value was 7.43. Filterability was found to be 3.43L/30 min. There was no presence of Carbonate. Presence of dissolved oxygen in well head water indicates the intrusion of oxygen in the injection system (most likely through pump leakage).

Table 4: Filtration experiment and relative plugging index calculations for WH water

Data point of the plot	Cumulative volume filtered (mL)	Vol. of water filtered (mL)	Cumulative time (min)	Time difference (sec)	Filtration rate (mL/sec)
1	1500	500	04:43	208	2.40
2	3200	200	24:04	156	1.28

$$ESN = \log \frac{Qa}{Qb}\left(\frac{2500}{CVb - CVa}\right)$$

Substituting,

$$ESN = \log \frac{2.40}{1.28}\left(\frac{2500}{3200 - 1500}\right)$$

ESN = 0.39 and

RPI = ESN + TSS

RPI = 0.39+3.8

RPI = 4.19

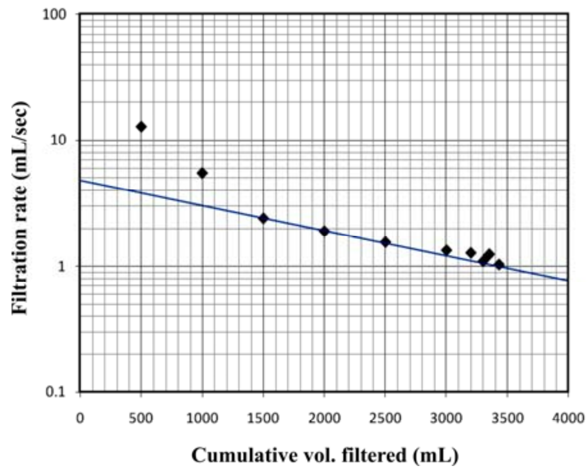

Fig. 5: Cerini plot of well head injection water

Fig. 6: Physical appearance of the residue (well head water filtration)

RESULTS AND DISCUSSION

In this study, the physicochemical parameters of injection water at Main Injection Pump (MIP) and Well Head (WH) locations of the Mumbai High Indian offshore platforms have been analyzed, monitored and an attempt has been made to identify the causes for the change in its quality. The quality of water was rated using the Relative Plugging Index (RPI) parameter.

From this work, it was found that the quality of the injection water was excellent both in terms of turbidity and RPI at MIP but was found to deteriorate during its transportation through pipeline from Main Injection Pump (MIP) to Well Head (WH). The increase in iron content in the well head sample was observed which appears to be main cause for deterioration in injection water quality. The presence of iron is indication of occurrence of corrosion in the pipeline which is contributing to the TSS in the injection water at the Well Head (WH).

A perusal of the results shows that the turbidity and the TSS value of injecting water have increased during flow from MIP to WH. This indicates the addition of solid content in the water during travel to wellhead. The reduction in filterability from 6.45L/30min to 3.43L/30min also indicates above observation. There was deterioration in the quality of injection water during the transportation through the pipeline. There has been increase in iron content from 0.01 mg/L to 6.85 mg/L leading to increase in RPI value. The RPI of the source water and the injection well head water was 1.14 and 4.19 respectively. The quality of the injection water at both the sampling points was found excellent (RPI<4). Although the water quality is excellent, deterioration during its transportation through pipeline was observed. Comparing the slopes of Cerini plots (Fig. 3 and Fig. 5), we conclude that the filtration rate of the injection water has reduced at the Well Head (WH). The increase in iron content appears to be main cause for deterioration in injection water quality.

The presence of iron is indication of occurrence of corrosion in the pipeline which is contributing to the TSS in the injection water. The presence of dissolved oxygen in well head water indicates the intrusion of oxygen in the injection system (most likely through pump leakage).

There is deterioration in the quality of injection water during the transportation of water through the pipeline. Corrosion is found to be the main reason for the quality degradation. An injection water treatment plant was recommended at the offshore platform after this study. These conclusions derived from the above can pave way for inventing new methods, designing and planning new strategies for offshore field development.

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