PHYSICO – CHEMICAL STUDY OF PRODUCED WATER AND ITS CORROSION EFFECTS ON LOW CARBON STEEL

Kehinde J. Awatefe, Christopher A. Idibie and Abosede O. James

Department of Chemistry, College of Education, Agbor, Delta State, Nigeria
Department of Chemical Sciences, Edwin Clark University Kiagbodo, Delta State, Nigeria
Department of Pure and Industrial Chemistry, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria

DOI: https://doi.org/10.32553/ijesar.v5i1.159

Abstract
The Physico-chemical analysis of produced water and the corrosion effect on low carbon steel has been studied. Discharge of produced water from oil wells formation unto surface environment were analyzed for ph, turbidity, electrical conductivity, salinity, total dissolved solid (TDS), dissolved oxygen (DO), total iron, carbonate, nitrate and sulphate content values, in comparison with Department of Petroleum Resources (DPR) standards. The corrosion effects of the produced water were then investigated using the weight loss methods. Result obtained of the physico-chemical analysis were: pH (5.4); turbidity (82 UTU) conductivity (8290 Ns/Cm), salinity (2394 Mg/L), TDS (1:28 Mg/L), DO (5.64Mg/L), total iron concentration (1.28 Mg/L), carbonate (180 Mg/L), nitrate (42.74 Mg/L), and sulphate (nil); while the corrosion rate (MPY) measured in hours of 120, 240, 360, 480, 720 respectively, corresponds to 0.078, 0.154, 0.204, 0.346, 0.353 and 0.371 values in MPY respectively. The produced water, was however, found to be of higher concentration of effluents when compared to DPR standard. It can be concluded that the corrosion of the metal coupon was due to the presence of high chemical matters in the produced water samples. Therefore, produced water should be treated and disposed in accordance with regulatory requirements and best practices.

Keywords: Corrosion, Produced Water, Rock, Environment, Dissolved Oxygen.

INTRODUCTION
The production and export of oil and gas play a dominant role in Nigeria’s economy and account for about 90 percent of her gross earnings (Okoko and Nna, 1998). The improvement and sustenance of this key section of the nation’s economy led to the discovery and investment in new oil fields.

Produced water is generated at the drilling and production phases of wells. It is an extricate part of hydrocarbon recovery process. It accompanies crude oil and gas from drilling wells. Produced water is mostly composed of reservoir fluids, dissolved and suspended solids, metallic salts and heavy metals. In some instances produced water could leach radioactive elements from geological formations and transported to the surface (Khatib and Verbeek, 2002).

Produced water, if discharged into environment can have negative effects. This could in the long-term lead to adverse impact on soils, surface and ground water in the discharged area (Ashim, 1998). Salt water accompanying oil production is a potential source of pollution in the petroleum
industry and hence, the management of produced water is a challenge for matured field sand for the development of remote fields (Barley, 2000). Although, the physico-chemical characteristics of produced water may vary from one formation to another, but its properties have been reported to be responsible for failure of most drilling operations (Nelson, 1985).

Water samples that tend to corrode metals or materials that are in contact with it are termed corrosive. Corrosiveness is a measure of corrosion damage at specific concentrations of the corrosion agents in water (Jones, 1988). Blake (1980), ascertained that water can be corrosive if it has (i) a low pH value (high acidity), (ii) high free carbon dioxide, (iii) absence of temporary hardness (low alkalinity). Corrosive properties of produced water form the basis for this study. This paper presents a study on the corrosive tendencies of produced water by carrying an intensive chemical analysis and corrosive aggressiveness of samples of produced water from the oil wells in Azuzuama, Bayelsa State, during drilling.

**Materials and Methods**

Produced water sample used for this study were collected during the drilling campaign in Azuzuama field, within the month of October, 2005. Azuzuama field is located in Southern Ijaw Local Government Area of Bayelsa State. It is located within the coordinates of 10°50.16700E and 15°000.325000N in the lower plains of the lower Niger delta of Nigeria.

Produced water was collected at a depth interval of 50cm starting at depth of 200cm till 350cm. At the required depth of 200cm, 250cm, 300cm and 350cm, produced water samples were collected in one (1) litre plastics containers. The plastics containers were pretreated by washing each with dilute Hydrochloric acid and dried (DPR, 2002). At the collection point and depth, each plastic container was rinsed twice with relevant samples and filled to the brim. Samples were identified by labels on the containers.

Produced water samples were analyzed for the following physico-chemical properties: pH, turbidity, salinity, total dissolved solids (TDS), [iron content], dissolved oxygen (DO), electrical conductivity, total iron, carbonate, nitrate and sulphate. These parameters were chosen because they are good environmental indicators for corrosion risk assessment (DPR, 2002). The pH, turbidity, salinity, total dissolved solids, dissolved oxygen and electrical conductivity were determined using multi-parameter water quality monitor. At the determination of any of these parameters, the instruments were properly checked and calibrated before and after use. Nitrate, carbonate and sulphate were determined using Brucine colorimeter technique. Total iron in the sample was determined using Atomic Absorption Spectrophotometer (AAS) of Perkin-Elmer Model 3110. All methods of analyses were consistent with APHA (1990) and DPR (2002).

For the corrosion testing of samples, sheets of low carbon steel (0.1-0.2 percent carbon content and, density 7.82g/cm³) were obtained from a corrosion company in Port Harcourt. These sheets were cold cut to the dimension 4 x 4 x 1cm. The cold-cut technique was used to maintain the integrity of the steel to avoid the probable effect of heat-affected zone (HAZ) on corrosion. Each coupon was perforated with hole of the same diameter at the side to allow the passage of a thread. The average weight of the coupons ranged from 20.000g to 20.224g. Six pieces of coupons were prepared for the study. The coupons were surfaced finished by scrubbing the sand paper, sterilized by digging in absolute ethanol and, decreased by washing in acetone. Coupons were dried in an oven at a temperature of 60°C for 15 minutes. They were allowed to cool in the desiccator. The methods of coupons preparation were as reported (Avwiri and Tay, 1999).

Produced water sample used for the corrosion testing was formed by bulking produced water samples collected at the various depths. Physico-chemical characteristics of the bulk produced
water were also determined. The coupons were immersed in a beaker containing the water samples.

Weighed coupons were immersed in the test solution for 30 days. A coupon was withdrawn every 5 days for re-weighing. Corrosion rates were determined using the conventional weight-loss method (Bradford, 1993) as stated in Equation (1)

\[ R = \frac{KW}{ATD} \]

where:

\( R \) = Corrosion rate in mils per year (mpy)
\( W \) = Weight loss in grams
\( A \) = Original surface area of coupon
\( T \) = Exposure time (hours)
\( D \) = Density of coupons

\( K \) = constant \( (3.45 \times 10^6) \)

\[ W = W_o - W_t \]

where;

\( W_o \) = original weight of coupon before testing
\( W_t \) = weight of coupon before testing

\[ A = 2 (LW + LH + WH) \]

where:

\( L \) = Length of the coupon
\( H \) = Height of the coupon

Results and Discussion

Results of the physico-chemical analyses of produced water samples and corrosion testing of the composite produced water samples are presented in Tables 1 and 2 respectively.

Table 1: Physico-chemical parameters of produced water

<table>
<thead>
<tr>
<th>Parameter/Units</th>
<th>Sample concentration</th>
<th>Composite sample average result</th>
<th>DPR limit for produced water discharged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>200 ML 250 ML 300 ML 350ML</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>5.3 5.3 5.4 5.3</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Turbidity (UTU)</td>
<td>84 80 70 76</td>
<td>82</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Cond.(NS/cm)</td>
<td>7800 9000 9020 9100</td>
<td>8920</td>
<td>-</td>
</tr>
<tr>
<td>Salinity as Chloride (mg/l)</td>
<td>23.43 23.6 24.07 25.13</td>
<td>23.94</td>
<td>600</td>
</tr>
<tr>
<td>Dissolved Oxygen (mg/L)</td>
<td>5.30 5.34 5.50 6.4</td>
<td>5.64</td>
<td></td>
</tr>
<tr>
<td>Total Dissolved solids (mg/L)</td>
<td>1.02 1.26 1.34 1.39</td>
<td>1.28</td>
<td>1.0</td>
</tr>
<tr>
<td>Carbonate (mg/L)</td>
<td>186 175 160 140</td>
<td>180</td>
<td>200</td>
</tr>
<tr>
<td>Nitrate (mg/L)</td>
<td>42.68 42.29 43.10 43.35</td>
<td>42.74</td>
<td>10</td>
</tr>
<tr>
<td>Sulphate (mg/L)</td>
<td>Nil  Nil  Nil  Nil</td>
<td>Nil</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 2: Corrosion rates for low carbon steel in composite produced water sample

<table>
<thead>
<tr>
<th>( W_o ) (g)</th>
<th>( W_t ) (g)</th>
<th>( W=W_o-W_t ) (g)</th>
<th>Exposure time (hrs)</th>
<th>Corrosion rate (mpy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.034</td>
<td>20.033</td>
<td>0.001</td>
<td>120</td>
<td>0.077</td>
</tr>
<tr>
<td>20.178</td>
<td>20.174</td>
<td>0.004</td>
<td>240</td>
<td>0.153</td>
</tr>
<tr>
<td>20.001</td>
<td>19.993</td>
<td>0.008</td>
<td>360</td>
<td>0.204</td>
</tr>
<tr>
<td>20.000</td>
<td>19.982</td>
<td>0.018</td>
<td>480</td>
<td>0.345</td>
</tr>
<tr>
<td>20.224</td>
<td>20.201</td>
<td>0.023</td>
<td>600</td>
<td>0.352</td>
</tr>
<tr>
<td>20.000</td>
<td>19.971</td>
<td>0.029</td>
<td>720</td>
<td>0.370</td>
</tr>
</tbody>
</table>
From the obtained results, the pH values of the water samples ranged from 5.3 to 5.4 and depicted an acidic medium. Braford (1993) suggested that acidic environment with pH < 6 are more corrosive than pH from 6-8 or alkaline pH < 8. The acidity of the water sample may have resulted from corrosive gas such as carbon dioxide, that have entered the system through chemical decomposition of calcium carbonate and which was converted into carbonic acid (Stott and Herbert, 1986).

The carbonate (CO₃) concentrations for the water sample were low (140 - 186 mg/l), however that for sulphate (SO₄) was nil. The low concentration of CO₃ and nil concentration of SO₄ could have resulted from scale precipitation down hole. Scales are deposits that precipitate directly from the water in petroleum production operations. Scales commonly encountered in oil and gas production operations are calcium sulphate, Barium sulphate, calcium carbonate and strontium sulphate (Jones. 1988).

The nitrate and total dissolved solids (iron concentrations) ranged from 42.68 - 43.35 mg/l and 1.02 – 1.39 mg/L respectively. The iron content of the water samples indicates the problem of iron, oxidation. This is further collaborated with the high level of dissolved oxygen (5.3 - 6.4mg/L) present in the water samples.

High concentration of salinity that was measured as chloride concentration (23.43 - 25.13 mg/l) could have been created by the contact of the water sample with the minerals present in the rock.

The variations of produced water samples collected at various depths against pH, carbonate, salinity, conductivity, turbidity, and total iron concentrations are presented in Table 1 respectively. The table reveals that produced water becomes more acidic (decreasing pH values) with increasing depth. This agrees with previous report for corrosive environment (Ovri, 1998). Table 1 also illustrates the relationship between carbonate concentrations of produced water samples with increasing depth down hole. Carbonate concentration decreases with increasing depth. The relationship between salinity concentrations of produced water with increasing depth were also compared as shown in Table 1. That is, as the depth increases salinity increases. The relationship of conductivity of produced water samples with increasing depth, were compared, and as depth increases, the conductivity of samples also increases. However, the turbidity decreases with increasing depth. The relationship between the concentrations of iron in the produced water samples with depth were compared, and it shows a corresponding increase in iron content of produced water samples with increase in depth.

Table 2 shows the relationship between weight – loss in grammes and time in hours. The table indicates the relationship between the two variables. Where W is weight-loss in grammes and t is the time of exposure in hours. Table 2 also shows the influence of produced water on the corrosion of low carbon steel. The corrosion is attributed to the presence of corrosive elements especially hydrogen ions which accelerated the corrosion process. The corrosive action on the low carbon steel suggests a high degree of aggressiveness of the produced water. This is consistent with previous report for steel in acidic environment (Ovri, 1998), Besides, Table 2 also shows the relationship between corrosion rates and exposure time up to 480 hours. However, it was observed that the corrosion rate was beginning to slow down as from 600 hours. This illustrates the typical behavior of a metal that demonstrates passivity effects. The behavior of the low carbon steel can be conveniently divided into two regions, active and passive. In the active region, the behavior of this material is identical to that of a normal metal. From 480 hours, the passive region begins. The decrease in corrosion rates could be attributed to the formation of a surface film or protective film. The passivity displayed is due to the formation of
protective oxide film on the coupon surface and this lowers corrosion rates (Evans, 1968).

A similar observation has been made for metals such as iron, nickel, silicon, chromium, titanium and alloys containing these metals (Bradford, 1993).

Finally, Table 2 also reveals the relationship between corrosion rates and weight loss. It indicates a general increase in weight loss with increase in corrosion rates. This increase corresponds with the general rule guiding chemical reactions (Sherwood, 1971).

Conclusion

The study shows that produced water samples collected from Azuzuama field are acidic (average pH of 5.3). Also, the corrosion rates of carbon steel were enhanced by the phenomenon of produced water. It is therefore, recommended that produced water be treated and disposed in accordance with regulatory requirements and best practices.

References