Interpreting a Water Analyses

In order to develop information to aid in controlling scale problems, it is essential to have a basic understanding of oilfield water chemistry & water analysis.

The information obtained from a water analysis is used to predict the likelihood of scale deposition.

Using the water analysis & scale prediction calculations, we are able to predict the type & amount of scale that will be deposited under specific conditions.

A water analyses typically report the following constituents:

**Constituents of a Water Analysis**

<table>
<thead>
<tr>
<th>Cations</th>
<th>Anions</th>
<th>Field Gases</th>
<th>Other Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Bicarbonate</td>
<td>pH</td>
<td>Specific Gravity</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Sulfates</td>
<td>$H_2S$</td>
<td>Density</td>
</tr>
<tr>
<td>Barium</td>
<td>Chlorides</td>
<td>$CO_2$</td>
<td>Total Hardness</td>
</tr>
<tr>
<td>Strontium</td>
<td>O$_2$</td>
<td></td>
<td>Total Dissolved Solids (TDS)</td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
<td>Ionic Strength</td>
</tr>
</tbody>
</table>

Most of the components of a water analysis are reported in milligrams per liter (mg/l).
Sodium (Na)

Sodium is a calculated value in a water analysis.

It is used to adjust the cation-anion balance in the water analysis.

It is used in the determination of total dissolved solids & ionic strength, which is used for scaling tendency calculations.

Sodium can form sodium chloride (NaCl) which can precipitate as a salt scale.

Calcium (Ca)

Calcium content is used to calculate calcium carbonate & calcium sulfate scaling tendencies.

The calcium content of oilfield waters can range from a few hundred milligrams/liter (mg/l) to 50,000 mg/l.

The calcium ion is very important because it combines with bicarbonates, carbonates, & sulfates to form calcium carbonate & calcium sulfate scale.

High concentrations of calcium tend to precipitate treating chemicals such as water soluble corrosion inhibitors, scale inhibitors, and oxygen scavengers.

Magnesium (Mg)

Magnesium content is used to calculate scaling tendencies for calcium sulfate.

Magnesium content is also a factor in forming dolomite (a calcium-magnesium carbonate scale).
**Barium (Ba)**

Barium can react with sulfates to form barium sulfate scale.

Very small concentrations of barium can cause serious barium sulfate scaling problems because barium sulfate scale is not soluble in most oil field scale dissolving chemicals.

Barium content is used to calculate barium sulfate scaling tendencies.

*Barium content can range from very low (1 - 10 mg/l) to 1,000 -2,000 mg/l.*

**Strontium (Sr)**

Strontium is very similar to barium in chemical properties, and strontium sulfate scale is not soluble in most oil field scale dissolving chemicals.

Strontium content is used to calculate strontium sulfate scaling tendencies.

**Iron (Fe)**

The iron content of water can be used as a tool to monitor corrosion in some situations.

Iron content also can be used as an aid for monitoring acid treatments in a well.

Iron can be present as:

- ferric iron (Fe\(^{+++}\))
- or ferrous iron (Fe\(^{++}\))
Precipitate iron compounds can be a major cause of formation plugging.

**Chlorides (Cl)**

Chlorides are a measure of the salinity (salt content) of waters. The chlorides are an important factor in:

- calculating scaling tendencies for all of the oilfield scales
- & determining the origin of the water (the formation it comes from)

Chloride content is frequently used to identify casing leaks in oil and gas wells.

*The chloride content can range from about 100 mg/ to 300,000 mg/l.*

**Bicarbonate (HCO$_3^-$)**

Bicarbonate is very important in determining scaling tendencies for calcium carbonate.

Bicarbonates are unstable; therefore, the analysis should be performed in the field to obtain accurate information for scaling tendency calculations.

*Bicarbonate content can range from 0 to 10,000 mg/l.*

Bicarbonate is sometimes referred to as methyl orange or methyl purple alkalinity.
Carbonate (CO₃)

Carbonates are rarely present in produced waters because they exist only when the pH is above 8.3.

Carbonate is sometimes referred to as phenolphthalein alkalinity.

Sulfates (SO₄)

Sulfate concentration is used to calculate scaling tendencies for calcium sulfate, barium sulfate, & strontium sulfate.

Sulfates also are a food source for sulfate reducing bacteria

pH

*pH is very important in determining calcium carbonate scaling* tendencies & the corrosiveness of water.

The pH of oilfield waters is unstable; therefore, the analysis must be performed in the field to obtain accurate scaling tendencies, & to make accurate predictions about the corrosivity of the water.

pH is a measure of the acidity or alkalinity of water.

It is a number from 0 to 14.

A pH of 7 is neutral (distilled water has a pH of 7).

As the pH goes from 7 to 0 there is an increase in acidity of the water (15% hydrochloric acid has a pH of 0).

As the pH goes from 7 to 14 there is an increase in alkalinity of the water (15% sodium hydroxide) has a pH of 14.
pH is defined as the logarithm of the reciprocal of the hydrogen ion concentration.

It is a logarithmic scale, which means that pH unit change of 1 corresponds to a tenfold change in hydrogen ion concentration.

Oilfield waters typically have pH's from about 5.0 to 8.0.

Some waters such as in CO₂ floods can have pH's in the range of 4.0.

PH can be measured with:

- an instrument
- pH tests strips
- or it can be calculated from CO₂ concentrations

**Hydrogen Sulfide (H₂S)**

Hydrogen sulfide is a hazardous gas that occurs in some oilfield waters.

It usually is used to evaluate potential corrosion problems.

H₂S is also unstable & must be measured in the field to obtain an accurate analysis.

Hydrogen sulfide dissolved in water concentrations can range from 0 mg/l to 1200 mg/l.

**Carbon dioxide (CO₂)**

Carbon dioxide is a gas that can be dissolved in oilfield waters.
It is unstable; therefore, the analysis must be performed in the field to obtain accurate results.

Carbon dioxide is very important in calcium carbonate scaling tendency calculations.

Carbon dioxide is frequently referred to as an acid gas, meaning that carbon dioxide concentrations can affect the pH of water.

_Dissolved carbon dioxide contents can typically range from 0 to 2,000 mg/l._

Carbon dioxide analysis in the gas phase of a system can also be an important tool in calculating scaling tendencies.

In this case CO$_2$ content is measured with an instrument design for measuring CO$_2$ in gas.

The CO$_2$ content in this situation is measure in mol %.

**Oxygen**

Dissolved oxygen contributes significantly to corrosion problems by enhancing the corrosion reactions and accelerating H$_2$S and CO$_2$ corrosion.

Oxygen reacts with hydrogen sulfide to form elemental sulfur which accelerates corrosion and plugging tendencies of the water.

It will react with dissolved iron to form insoluble iron oxide scales.

Oxygen facilitates the growth of aerobic bacteria.
**Oil Residual**

When produced water is injected into a subterranean formation, or disposed of in the ocean, oil content of the water becomes very important.

Overboard water discharge in the Gulf of Mexico requires that 29 mg/L or less oil residual be present in the water.

If exceeded, the producer can be financially penalized by government regulatory agencies.

Re-injection of produced water into a disposal well or drive reservoir requires that the oil content be low, but there are no regulatory standards sets.

Oil in water can decrease the injectivity by forming emulsion blocks, absorbing certain solids such as iron sulfide, & restricting flow.

If water is being injected into a formation that is water wet, with no initial oil saturation, oil in the water can become trapped in the pores of the formation rock around the well bore.

This creates an oil saturation, which can reduce injectivity.

**Organic Acids**

Sometimes substantial concentrations of organic acids (carboxylic acids) are present in produced waters.

These acids (especially acetate ions) will contribute to the total alkalinity.

There is evidence that if the organic acid anions are not subtracted from the total alkalinity, the Saturation Index for calcium carbonate will be more positive than it should be.
**Specific Gravity**

Specific gravity is the ratio of the weight of a given volume of water to the weight of an equal volume of distilled water.

By definition distilled water has a specific gravity of 1.000.

The specific gravity of oilfield waters ranges from 1.000 to about 1.400.

Specific gravity for oil field waters can be estimated using the chloride concentration such as in the following table.

<table>
<thead>
<tr>
<th>Chlorides</th>
<th>Specific Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 mg/l</td>
<td>1.01</td>
</tr>
<tr>
<td>20,000 mg/l</td>
<td>1.02</td>
</tr>
<tr>
<td>50,000 mg/l</td>
<td>1.05</td>
</tr>
<tr>
<td>100,000 mg/l</td>
<td>1.10</td>
</tr>
<tr>
<td>150,000 mg/l</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Specific Gravity = \[ \frac{\text{Density of Water Sample}}{\text{Density of Pure Water}} \]

In order to obtain an accurate specific gravity, the water must be tested with a hydrometer or other suitable method for determining specific gravity.
**Density**

Density for a water analysis is usually reported in pounds per gallon.

This is determined by multiplying the specific gravity of the water sample by 8.34, which is the weight in pounds of a gallon of distilled (pure) water.

**Total Hardness**

Total hardness is the sum of calcium & magnesium dissolved in water.

*It is used to determine the magnesium content of the water, & it is usually reported in mg/l of calcium carbonate.*

**Total Dissolved Solids (TDS)**

Total Dissolved Solids (TDS) is a summation of the mineral ions dissolved in water & reported as mg/l.

TDS is the sum of the mg/l of calcium, magnesium, barium, strontium, sulfate, bicarbonate, chlorides, and sodium.

**Ionic Strength**

Ionic strength is the summation of the concentration of all the components of a water analysis.

Ionic strength is reported in moles per liter.

*Ionic strength is used in scaling tendency calculations for all of the oil field scales.*
**Temperature**

Temperature is used in the scaling tendency calculations. Temperature will affect the scaling tendencies for all of the oilfield scales. Temperature has a very pronounced effect on calcium carbonate scaling tendencies. Generally, continuous increases in temperature result in an increase in calcium carbonate scaling tendencies. Scaling tendencies for other scales will increase with increases in temperature to a certain point and then will decrease.

**Pressure**

Pressure is an important factor in calcium carbonate scaling tendency calculations. Pressure decreases greatly affect calcium carbonate scaling tendencies. Carbonate scaling is highly dependent on pH. Pressure decreases usually mean a corresponding decrease in solubility of the acid gases CO₂ & H₂S in water, resulting in an increase of pH.

**Resistivity**

Resistivity of oilfield water is a measure of the resistance of the water to an electric current. The resistance to flow of electricity through water is a function of the number of ions dissolved in the water.
Distilled water (no dissolved ions) will not conduct electric current (has high resistivity).

The lower the resistivity, the higher the dissolved ion content of the water.

Resistivity is used by geologists to identify formations.

Resistivity information is also used in cathodic protection systems for casing in oil wells.

The resistivity is measured in ohm-meters.

**Conductivity**

Conductivity is the reciprocal of the Resistivity.

Conductivity is usually expressed as micromhos/cm.

\[
\text{Conductivity (micromho/cm) } = \frac{1000}{\text{Resistivity (ohm meter)}}
\]