

Water testing and analysis

A prime objective when testing a subsurface water zone is to establish the chemical and physical properties of the formation water and its associated gas

Firstly, it is a challenge to obtain unpolluted, representative formation water samples. During drilling and completion operations the zone close to the wellbore is invaded by drilling mud and brines. Therefore, the first produced water will be a mixture of mud/brine and formation water. The problem is determining when representative formation water is produced?

Secondly, the water samples collected should be analyzed as soon as possible because the properties of samples change with time. Changes occur in temperature, and pressure, gases evolve, pH changes and precipitations take place. These processes have an effect on important ions as well as some physical properties.

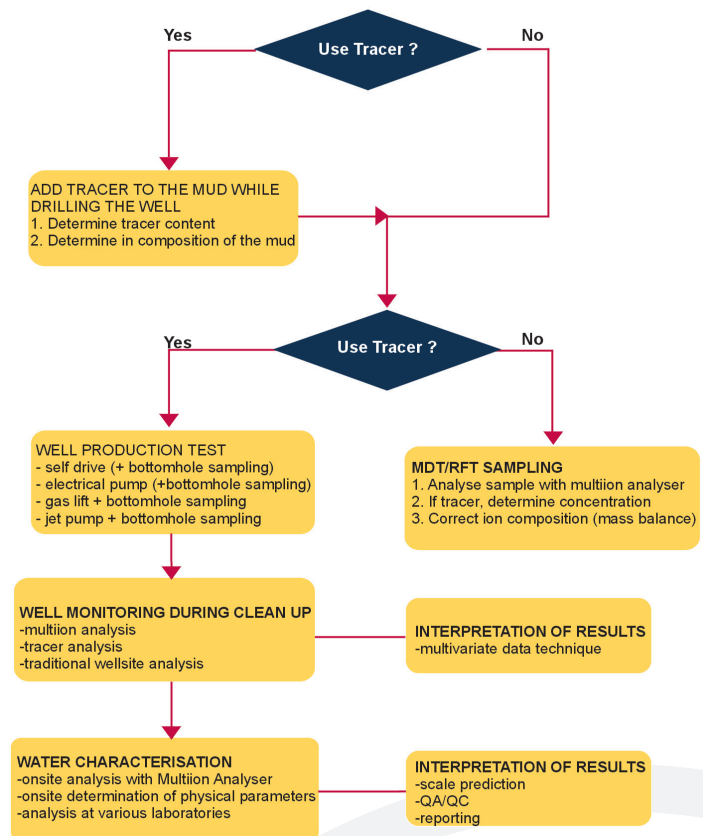
Thirdly, the samples should be treated and analyzed by experienced and qualified engineers using accepted methods and reliable instrumentation. Quality control and quality assurance throughout all stages of the test is required.

PRODUCING FORMATION WIRELINE SAMPLING

Reservoir fluids can be collected without producing the well to surface by the use of wireline formation samplers (WFS) such as the RDT & MDT tools. (reservoir description tool, MDT-modular dynamic tester).

As WFS water samples may be contaminated with mud filtrate or brine from the near wellbore area, only a limited amount of chemical information may be obtained from these samples. Mud contamination is often as high as 20-40% or more.

With the presence of a tracer in the mud it is possible to correct for mud contamination in the sample and adjust the analytical results. However, very often precipitation occurs when mudfiltrate (seawater based) mixes with the formation water. This cannot be quantified or corrected for. A full production test may be required to obtain a good characterization of the formation water.



PRODUCTION WELL TEST

Due to the high specific gravity of formation water, artificial lift is often required. Three techniques commonly used are:

- gas lift
- jet pump
- electrical pump

Gas lift

Injection of gas into the production tubing reduces the hydrostatic pressure of the fluid column and thus eases the flow.

The injection of nitrogen (N₂) or natural gas has serious drawbacks because it alters the chemistry. The added gas molecules tend to strip CO₂ and other inherent gas molecules from the water. This will result in a shift of the CO₂/ HCO₂ equilibrium and pH of the water.

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Bottom hole samplers are normally used in combination with gas lift to obtain water samples which are not affected by the lift gas.

Jet pump

The jet pump setup is similar to gas lift, except that the lift gas is replaced with driving water. The driving water is pumped down the annulus and into the production tubing through nozzles which create an upward venturi effect.

The disadvantage of a jet pump is that it involves introduction of another water (normally drillwater). The produced water at surface will thus be a mixture of driving water and formation water. The technique must be completed with bottom hole sampling to obtain a genuine sample of formation water. Precautions must be taken to avoid scaling in the pump.

Electrical pump

The subsurface electrical pump is the preferred method with respect to water chemistry. This method is robust and well proven. No other fluids are introduced, and clean up of the well can be monitored accurately at the surface.

Bottom Hole Sampling

The use of single phase bottom hole sampling is strongly recommended regardless of which method is used to produce the well. Single phase sampling ensures that the sample is collected, transferred and stored under pressure. Dissolved gases and ions that may otherwise precipitate out are kept in solution.

PVT analysis of the single phase water sample will generate accurate gas/water-ratios, formation volume factors and compositional analysis of the associated gas.

WELL MONITORING

During a Well Test or Drill Stem Test (DST) large changes in the properties and appearance of the produced fluid are observed. After a period of clean-up production a relatively constant level in fluid properties signals that clean, representative formation water is produced to surface. A comprehensive sampling program is then initiated.

Three different techniques are commonly used, alone or in combination, to monitor the well flow composition in order to determine when clean, uncontaminated formation water is produced. These techniques are:

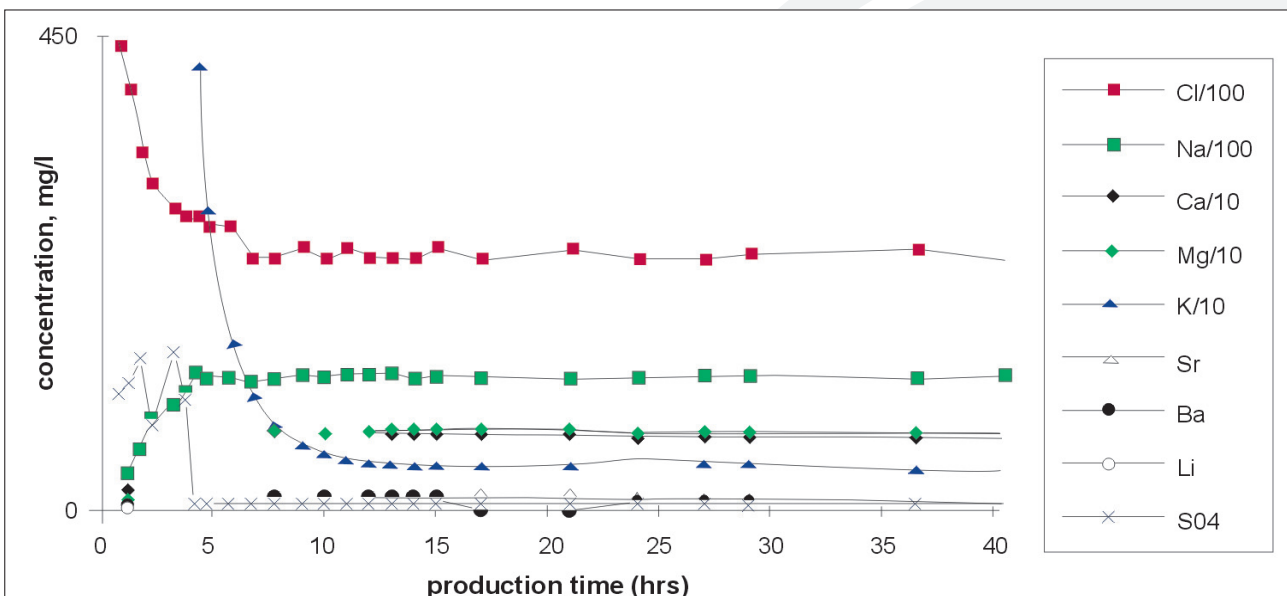
- a) Traditional well site analyses
- b) Ion tracking using "Multi Ion Analyzer"
- c) Tracer techniques

Traditional well site analyses

The traditional well site surveillance analyses include the following :

- i Chloride
- ii Barium / Strontium
- iii Sulphate
- iv pH
- v Alkalinity
- vi Density
- vii Conductivity / resistivity

These determinations are quick and easy to perform and give an approximation of the water characteristics.





Water testing and analysis

Ion tracking using the Multi-Ion Analyzer.

The Multiion Analyzer represents a major breakthrough in onsite water analysis technology. The Multiion Analyzer, which is based on ion chromatography principle, can determine all the major ions in formation waters except bicarbonate and organic acids (these are both determined by separate titrations). In one sample injection the following ions are determined:

Lithium, Li+	Strontium, Sr ²⁺
Sodium, Na+	Barium, Ba ²⁺
Potassium, K+	Chloride, Cl ⁻
Calcium, Ca ²⁺	Bromide, Br ⁻
Magnesium, Mg ²⁺	Sulphate, SO ₄ ²⁻

In addition, pH and conductivity are also determined.

The Multiion Analyzer has a number of features which makes it superior in its field:

- concentration determination of the most significant ions in formation waters (fingerprint analysis).
- analysis can be performed with the same accuracy and precision as that obtained using standard onshore methods (ICP-AES, AAS etc).
- as measurements are carried out on-site there is minimal delay between sampling and analysis and therefore negligible deterioration of samples.
- all ions are analyzed simultaneously from one 2mL injection of sample.
- the analysis time is short, less than one hour, which makes it possible to continuously follow the variations in well flow composition. In offshore operations decisions can be made earlier and rig time may be saved.

In summary the Multiion Analyser provides a means for:

- continuous well stream monitoring;
- immediate well stream diagnosis, allowing for process intervention in terms of chemical treatment;
- improved control of process flow variables; and
- economic savings, due to reduced laboratory expenses and sample transportation.

The Multiion Analyzer is a product of a research project at Petrotech in conjunction with national research institutions and sponsored by several major oil companies.

Tracer application

The use of a tracer is an important tool in water tests in order to verify when the produced water is representative. The tracer acts as a label in the mud which makes it easy to identify. Tracer techniques are normally used in combination with ion pattern analysis (Multiion Analyzer) and are strongly recommended when sampling is performed with WFS tools.

A number of different tracers are available which include both radioactive- and chemical. The most common radioactive type is tritiated water (H₃O). Among the chemical tracers Petrotech has



obtained good results with Thiocyanate (SCN⁻) in brines and water based mud.

When drilling through the water zone the level of tracer in the mud is monitored continuously and maintained at a fixed concentration, normally around 400 mg/L when thiocyanate is used.

When the formation water is produced to surface the process of cleaning up the well can be closely monitored by the decrease in tracer content. The concentration of thiocyanate in the produced water corresponds to a fraction of mudfiltrate which can be determined quite accurately.

The tracer technique together with Multiion analysis ensures that sufficient clean up is provided to obtain good water samples as well as minimizing the rig time.

Prior to offshore water tests it is very important that samples are collected of any mud or brines involved in the operations. In particular fluids which might come in contact with the formation water should be sampled and analyzed.

USE OF TRACER

Action 1

The tracer chemical (thiocyanate) is added to the mud process under controlled conditions to maintain a concentration of approximately 400 mg/L in the return mud to the pits. The concentration must be measured frequently when drilling through the actual zone of interest.

Action 2

The Multiion system is used to measure the ion concentration of the mud filtrate from the pit.

Action 3

The WFS chamber is run in hole and the sampling process- is initiated. When the WFS tool is returned to surface one chamber is opened and sampled. The sample is analysed for thiocyanate, cation, anions, pH, conductivity and bicarbonate. From the detailed analysis Expro performs a quantitative interpretation of the water phase and a mass balance calculation.

Each of the three techniques, traditional wellsite analysis, Multiion Analyzer and tracer application can be used individually. However, by performing two or three techniques in parallel, consistency of results will provide added confidence as to the quality of the data.

Water testing and analysis

Multivariate data analysis (MVDA)

Decisions based on the variation of concentration of only one variable have resulted in erroneous conclusions about when representative formation water is produced.

By considering a greater number of variables, i.e. by analysing samples for a greater number of anions/cations with the Multiion Analyzer it is possible to arrive at a more reliable decisions. A MVDA computer program is used to interpret the analytical data in order to identify trends.

SAMPLING AND ANALYSIS

When it has been decided that the well is producing pure formation water a comprehensive sampling program for onshore laboratory analysis is initiated.

The sampling program normally consists of 3 sets of water samples plus one backup. One set consists of:

- raw untreated water (no preservation)
- raw water preserved with nitric acid (prevents precipitations)
- filtered produced water (no preservation)
- filtered water with acid preservation
- the above filters for solid characterization
- raw untreated water to be frozen immediately for preservation
- raw water preserved with mercury chloride

Expro can offer a wide range of chemical and physical water analysis. Listed below are some of the most common analyses performed on formation water:

INORGANIC ANALYSIS:

- basic ion composition (Multiion Analysis)*
- thiocyanate (tracer)*
- 27-element analysis
- heavy metals analysis
- isotope ratio $87\text{Sr}/86\text{Sr}$
- radioactive isotope analysis
- dissolved iron*
- sulphide content*
- dissolved oxygen*
- dissolved carbon dioxide*
- organic components
- organic acids
- total organic carbon (TOC)
- aromatics
- oil in water*

PHYSICAL PROPERTIES:

- pH*
- alkalinity*
- density*
- conductivity/resistivity*
- temperature*
- turbidity*

- suspended solids
- particle count*
- particle size distribution*
- particle analysis (SEM/EDX, XRF)
- bacteria (SRB,GAB)
- compatibility test (jar test).

PVT-ANALYSIS:

- gas/water ratio
- saturation pressure
- formation volume factor
- composition of associated gas
- pH in water in equilibrium with associated gas

* Analysis performed onsite.

SCALE PREDICTION

The chemical and reservoir data gathered during a water test can serve as useful input for the computer program MultiScale. This multiphase PC based program, can simulate situations where there are mixtures of different water types, changes in pressure or changes in temperature and will ultimately predict the corresponding scale formation characteristics.

The following types of scale are predicted:

- calcite (CaCO_3)
- siderite (FeCO_3)
- gypsum ($\text{CaCO}_3 \times 2\text{H}_2\text{O}$)
- strontium sulphate (SrSO_4)
- barium sulphate (BaSO_4)
- halite (NaCl)
- marcasite (FeS_2)

The program development performed by the Technical University of Trondheim has been supported by Statoil and Hydro. The program is marketed and distributed worldwide by Expro.



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