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WATER SAMPLING

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WATER SAMPLING AND CHARACTERIZATION

Water Quality in Iraq is currently contending with increasing salinity and compositional alterations from changes in elemental concentrations due to pollutants. The development of agriculture throughout the Euphrates and Tigris watershed, both within and out with Iraq's borders, has manifested in a progressive increase in the salinity of the river waters. Regions are often punctuated by severe droughts, further aggravating the local water quality. A combination of other factors such as seawater ingress, local geological features, damming, drainage practices and land management has further contributed to rising salinity concentrations, while contaminants continue to prevail in the wake of economic development and increasing population. This situation requires frequent water sampling campaigns and characterization analysis. These need to be monitored every year to mitigate risk and variations that may have an effect on water quality and subsequent water injection performance for hydrocarbon recovery.

POFG (COREX) water injection compatibility evaluations assist operators in Iraq and these studies include core floods that are performed under realistic wellbore conditions. POFG (COREX) have a base in Basra, Iraq, that has local expertise and experience in sampling and characterizing water samples which creates data to generate a matrix of water compositions. Poor quality water can cause impairment by restricting flow to cause Formation Damage. Failure to address this can result in missed opportunities, as well as deferred and/or reduced production/injection. By simulating injection and performing desktop modelling studies, POFG (COREX) have been able to assess injection performance.

Currently, the standard corefloods performed by industry have been unrepresentative due to limitations, and do not address the near wellbore conditions properly. POFG (COREX) recently have introduced advanced coreflood simulations that more closely mimic the near wellbore for predicting well performance.

Various impairment mechanisms may occur that affect well injection performance, such as particle agglomeration/coalescence, scaling, corrosion and microbial activity are primary mechanisms responsible in the occurrence of Formation Damage endemic across industry. By considering the injection of commingled river /produced/ sea water or individually into the representative rock materials from the injection intervals, POFG (COREX) have been able to determine appropriate water quality for successful injection. These impairment mechanisms can significantly affect permeability, leading to loss of injection which require corrective measures and/or treatment operations.

POFG (COREX) offers internationally recognized Formation Damage assessment/evaluation strategies to improve well operations in the field. POFG (COREX) extensive in-house expertise and unique proprietary technology has been developed with a view to offering operators unparalleled support, ensuring targets are met quickly and within budget.

IMPROVED WATER QUALITY FOR INJECTION

Injection wells in reservoirs are frequently examined by near wellbore coreflood simulations to evaluate damaging mechanisms associated with well operations. In addition, injection plant design must incorporate the correct level of filtration to attain the required water quality for successful injection. Water characterisation of injection water and the native fluids is important in determining the nature of particles (silts, clays, scale, oil, plankton, corrosion, bacteria, etc.). These particles must be filtered and/or removed to prevent damage to the formation. To mitigate risk, representative water samples are collected to assess variations in water chemistry that may occur. POFG (COREX), Iraq, utilise their local expertise and experience through their base in Basra. Impairment to the near wellbore has to be avoided for successful water injection and the correct standard of quality needs to be determined for successful injection performance. If water quality standard for injection is not satisfactory, impairment can occur primarily where finer material and particles coagulate, flocculate and agglomerate to form larger particles during periods of reduced, or static, flow. This can then manifest in significant permeability alterations due to pore occlusions and blockages. In order to mitigate permeability reduction and alteration, water quality is evaluated with corefloods at near wellbore conditions. A range of relevant corefloods therefore need to be considered. These include:

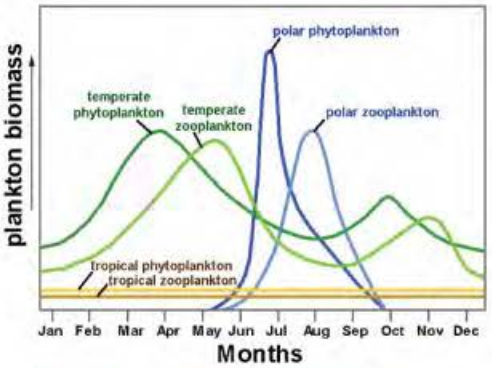
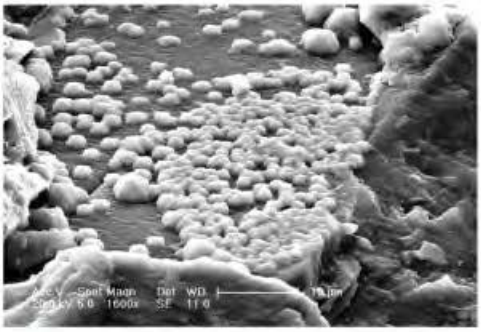


Figure 1. ***Seasonal Variations:*** Thorough water injection plant design must take into consideration planktonic growth seasons, important for selection of water samplers when looking at injection waters.

- **Raw injection/filtered water, to examine whether significant damaging mechanisms are associated with the candidate injection fluids**
- **Evaluation of candidate additives to the injection water, such as scale inhibitors, drag reducers and biocides**
- **Fractional flow of candidate injection/formation waters, for example various ratios of produced water for re-injection and formation brine**
- **Microbial formation damage associated with injection operations**

Gypsum: COREX in-house Scanning Electron Microscopy (SEM) photographs above show a variety of scale types



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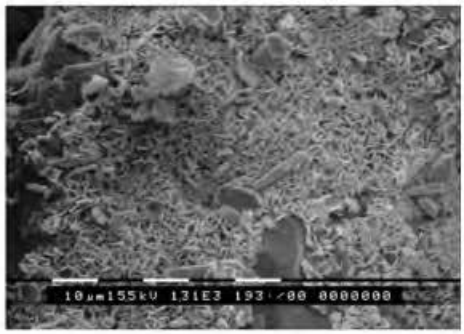

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Water quality is therefore an important consideration in the design and implementation of cost and time-effective reservoir maintenance, and maximised hydrocarbon recovery operations. The bespoke services offered by COREX UK Ltd (POFG) is of significant benefit to industry in sustaining and improving well inflow/outflow through effective controls. These control measures reduce risk and enhancing hydrocarbon recovery, whilst also ensuring the longevity of the well. Correct water injection/filtration control strategies is therefore central to this success.

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Further information is also available on our website: ***www.corex.co.uk***

MICROBIAL INHIBITION/PREVENTION

Wellbore operations may have associated risks from bacteria/microbial activity within the near wellbore area. Those bacteria/microbes may reside with rock/fluid and/or fluid/fluid interfaces or within individual phases (resident pore fluids, introduced and near wellbore altered fluids).

Microbial growth and activity may reduce well inflow. These mechanisms restrict pores and reduce the open flow area causing impairment (e.g., bacterial plugging of pores, biopolymer plugging of pores, scaling, precipitates etc).

Souring of reservoir oil may result from sulfate-reducing bacterial activity to cause health and safety and facilities concerns. POFG (COREX) use reservoir simulators to produce models of souring phenomena. Standard industry practice is to use microbial evaluations for topside evaluations, however correct procedure should not be limited to topside evaluations only. Isolated topside evaluations alone are not sufficient to mitigate risk of microbial activity and growth in the well. Operators now realise that in order to reduce uncertainty, they should also consider rock/fluid interactions in the near-wellbore. In-house research by POFG (COREX) experts las led to the development of new, custom-designed scopes on bespoke coreflood systems which are used to investigate these microbial rock/fluid interactions. Microbial activity and growth (indigenous or introduced) may reduce well inflow, and should be predicted and controlled for improved well performance.

- Identify what the problem is, and where it lies. Initial screening of reservoir core, oil, formation water, drilling & completion fluids, and other injection fluids for the presence of bacteria/microbes. Determine if bacteria are native (autochthonous) or introduced (allochthonous) and their type/species and living conditions.
- Understand the consequences of the problem. If the potential for bacterial activity is identified, simulations can then be performed to identify the consequences. Assessments can initially include or exclude any vendor optimized treatments and the scope can range from fluid incubation tests to full near wellbore conditions simulations of the operational sequence. Potential risks may include H2S generation, pore blocking bacterial-biopolymer-insoluble metal sulfides.
- Evaluate solutions to eliminate the problem. If we can establish the conditions that bacteria cause damage and expected mechanisms, it is possible to evaluate additional or adjusted treatments proposed by chemical vendors.
- Deploy selected treatments to eliminate the problem. The QA/QC cycle continues at this point by checking again whether the vendor adjusted treatments are fit for purpose by performing near wellbore coreflood simulations to avoid risk.

COREX UK Ltd's (POFG) microbial assessment workflow incorporates diagnostic tools with expert interpretation to reduce uncertainty and provide more meaningful data to mitigate any associated risk for the field. Potential solutions may be either preventative or remedial treatments. Many treatments may be compared and then performance ranked.

EXAMPLE TESTS

- Temperature
- Conductivity / Resistivity resistivity
- Organic Components
- Oil In Water
- Nitrates
- Corrosion Assessments
- Corrosion Inhibitor Detection
- Raw Untreated Water (No Preservation)
- The Above Filters For Solid Characterization
- Microbial Content
- SEM/EDS of residues/sediment
- Cryogenic SEM/EDS of materials
- pH
- Density
- Dissolved Oxygen
- Aromatics
- Ion Elemental Composition
- Stack Screen Filtration
- Scale Flocculation Tests
- Raw Water Preserved With Nitric Acid (Prevents Precipitations)
- Raw Untreated Water To Be Frozen Immediately For Preservation
- Total Suspended Solids (TSS)
- Particle Size Distribution by Coulter Count Analysis
- Volatile Fatty Acids (VFA)
- Specific Gravity
- Dissolved Oxygen
- Dissolved H2S
- Organic Acids
- Alkalinity
- Dissolved Iron
- Scaling Evaluations (With/Without Inhibitors)
- Filtered Produced Water (No Preservation)
- Raw Water Preserved With Mercury Chloride
- Total Dissolved Solids (TDS)
- Water Quality Indices
- Souring Studies
- Turbidity
- Dissolved Carbon Dioxide
- Total Organic Carbon (TOC)
- Chloride Salinity
- Heavy Metals Analysis
- Fluid Compatibility Evaluations (Bottle Tests)
- Scale Tendency Predictions
- Filtered Water With Acid Preservation
- Sulphide Content
- Dissolved Organic Content (DOC)
- Particle Size Distribution by Laser Scattering by Mie and Fraunhoffer Theory
- Micro CT Scanning of residues 3D Model

SCALE, PRE AND POST TREATMENT PRODUCTION/INJECTION ASSESSMENTS

In water injection operations, compatible water selection is of paramount importance when considering scale formation. Incompatibility of water sources with formation water can often result in disastrous scale-formation that can lead to the termination of wells and, in some cases, entire fields. The formation of scale can significantly impair well inflow to reduce production/injection. A variety of scale-types can be encountered during wellbore operations. These scale types can arise from incompatibilities with comingling waters, pH alteration, pressure changes and temperature variations. During injection, the near-wellbore area is subject to high-flow velocities which can impart physical and chemical forces that may cause scaling. By properly accounting for the thermodynamic and kinetic interactions, it is possible to mitigate risk due to the propensity of scaling which causes impairment.

Scale prediction and the selection of an appropriate treatment to address scaling issues are therefore key to eliminating any potential impairment. Scale formation may occur from co-mingling/mixing of incompatible fluids (introduced or native pore fluids) or may occur from self-scaling of an individual fluid (e.g., alteration of water composition, pH alteration). Scale deposition causes Formation Damage by reducing the area open to flow.

Formation Damage can also occur due to any incompatibilities from scale treatment fluid/fluid and fluid/rock interactions and similarly from post treatment production/injection operations. After chemical vendors have optimized the scale treatment, fluids are supplied to COREX for independent scale assessment. These include:

- Scale prediction modelling
- Dynamic scale loop to determine the efficiency and minimum inhibitor concentration (MIC) of inhibitors
- Static incubation (jar tests) to determine the efficiency and MIC of inhibitors
- Treatment fluid production and injection coreflood simulations to examine compatibility, treatment life, including analysis of effluent to determine time taken to reach MIC
- Post treatment diagnostics on the actual core samples for reassurance or otherwise to reveal any impairment mechanisms or else to eliminate issues for improvements.
- Micro-CT; this type of analysis provides unprecedented insight with 3-dimensional alteration models of scale distributions and extent of change, thereby facilitating improved scale treatment solutions. These assessments are used to understand damaging mechanisms and interactions to circumvent any associated risk to successful scale treatment design. This is done by pinpointing where these changes have been distributed spatially within the near-wellbore, as well as the extent of alteration which has occurred.

Dynamic scale loop: Scale Inhibition: Dynamic scale loop to determine effectiveness of inhibitors and compatibility of comingling waters