

Improving Scale Management Using ESEM Bulk Scale Analysis

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ABSTRACT

Scale deposition in oil and gas wells is a major issue in the oil and gas industry as it reduces hydrocarbon production, restricts well access to production logging tools and, in addition, causes safety issues due to blocking and ineffective operation of chokes and valves. Scale is predominantly controlled with chemical scale inhibitors and the most common methods to control scale deposition are through continuous injection and scale squeeze treatments although some non-chemical methods can be applied.

The performance of continuous injection and scale squeeze treatments is traditionally monitored by the analysis of scaling ion and residual inhibitor concentrations (RSI) in collected produced water samples in conjunction with other parameters such as productivity index (PI) and temperatures and pressures throughout the whole production system. However, these methods are not always sufficient to identify the onset of scale formation and there can be some uncertainty as to whether the produced water is fully protected.

It is therefore desirable to have an alternative to more conventional monitoring methods to assess the actual scaling regime of produced brine samples. This can be achieved by analyzing suspended bulk scale solids using Environmental Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis (ESEM/EDX).

ESEM bulk scale analysis can measure particle size, identify morphology and the chemical composition of any bulk scale produced. The method provides accurate statistics of the amount of the different types of scale, which can both be an early warning indicator as well as a key parameter for trending over time together with other relevant parameters such as scaling ions, RSI and PI. In addition, machine learning has been applied to images of representative scale particles to classify them as either transported (pre-formed)/modified by the selected scale control process or actively growing.

The intelligent investigation of particle morphology provides a further understanding of the mechanisms of inhibition and enables a prediction of the % efficiency of scale inhibition. Therefore, ESEM bulk scale analysis offers a more direct approach to monitoring the scaling regime of produced brines and can identify if scale prevention is needed and indeed, whether any applied chemical or non-chemical treatments are effective. Specific field examples are provided in this paper where the technique was used to reduce chemical costs and improve the performance of scale squeeze treatments in terms of placement and longevity.

This paper discusses how ESEM bulk scale analysis can improve scale management in a variety of production scenarios and demonstrates how the technique can provide a more direct monitoring tool enabling meaningful trend observations and better reactions and decisions to be made to reduce environmental impact factors and contribute towards net zero.

Key words: Scale Management, Bulk Scale Analysis, Environmental Scanning Electron Microscopy and Energy Dispersive X-Ray Analysis (ESEM/EDX)

INTRODUCTION

Inorganic scale deposition is a major issue for the oil and gas industry as it can block perforations, production tubing, valves, chokes and prevent topside heat exchangers and fluid separation equipment from functioning effectively.

Inorganic scales such as calcium carbonate and calcium, strontium and barium sulphate are typically prevented by the application of chemical scale inhibitors which act by nucleation inhibition, crystal growth retardation and dispersion mechanisms although non-chemical methods can also be applied¹. Indeed, the most common forms of scale prevention are via continuous scale inhibitor injection (topside, downhole and gas lift) and downhole scale squeeze treatments.

For both continuous injection and scale squeeze treatments it is necessary to determine the minimum inhibitor concentration (MIC) of the selected chemical in the laboratory using a variety of techniques including static jar, dynamic scale loop or kinetic turbidity tests². For cost effective continuous injection and scale squeeze longevity it is desirable to have the MIC as low as possible as this lowers chemical injection rates and, in the case of scale squeeze treatments, allows for higher water volumes to be produced before the scale inhibitor residual levels drop below MIC and become insufficient to provide adequate scale control.

Although the MIC determined in the laboratory is designed to mimic the field conditions as close as possible, there is still a level of uncertainty associated as to how the laboratory MIC may translate to field application; it is often difficult to correlate traditional ion and scale inhibitor residual data to determine if the produced water is fully inhibited.

An alternative method to determine the actual scaling potential of produced brine samples and to provide a more realistic scale risk in the field compared to theoretical risks of scale prediction is to analyze suspended bulk scale solids by ESEM/EDX. This method can identify the amount and type of relevant bulk scale as well as the degree of scale inhibitor interaction with the scale produced. Hence, it presents a more direct method of monitoring the scaling regime and can aid to identify a lower and more accurate field MIC for both continuous injection and scale squeeze treatments by supplementing traditional ion and scale inhibitor residual data³.

In this paper the use of ESEM/EDX monitoring in several North Sea fields to provide an improved understanding of the field scale risk will be described, which not only enabled improvements in scale squeeze performance but also allowed safe operation of wells considered to be at risk until retreated.

ESEM/EDX

Scanning Electron Microscopy techniques are very wide-spread analytical techniques for the investigation of surfaces. This is particularly true for SEM/EDX and ESEM/EDX. The advantage of ESEM compared to an ordinary SEM microscope is that it can examine wet samples directly and is capable to construct clear images at very high magnification without the need for a low vacuum associated with SEM technology. A typical ESEM/EDX microscope schematic is shown in Figure 1.

In this method the specimen of interest is bombarded by high energy electrons, see Figure 2. When an electron hits the sample of interest it will generate both secondary and back scattered electrons and X-rays.

All the emitted radiation is detected and used to provide information on the sample. The intensity of the secondary electrons is largely governed by the surface topography of the sample. An image of the sample surface can thus be constructed by measuring secondary electron intensity as a function of the position of the scanning primary electron beam. High spatial resolution is possible because the primary electron beam can be focused to a very small spot (<10 nm).

The intensity of backscattered electrons can be correlated to the atomic number of the element within the sampling volume. Hence, some qualitative elemental information can also be obtained. In addition to low energy secondary and back scattered electrons, X-rays are generated by primary electron bombardment, see Figure 2. The analysis of characteristic X-rays (EDX) emitted from the sample gives quantitative elemental information and by repeating thousands of counts the ratio between the elements present can also be given.

ESEM/EDX is considered a relatively rapid and inexpensive approach to surface analysis which is why it suitable for Bulk Scale Analysis (BSA).

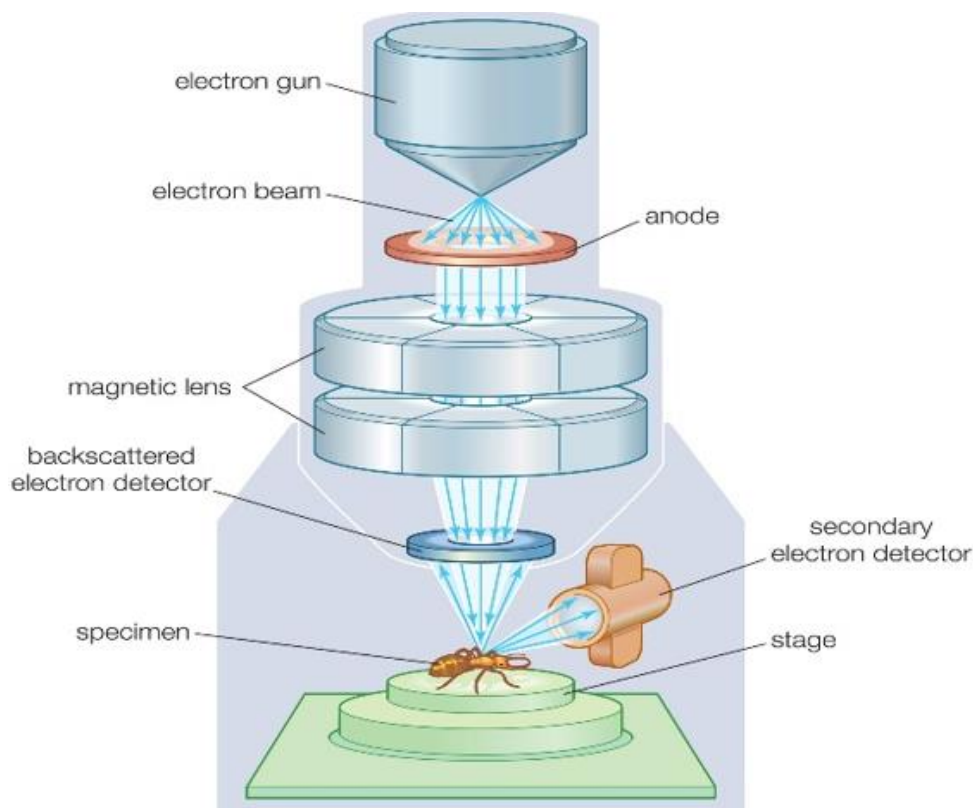


Figure 1: ESEM/EDX Microscope

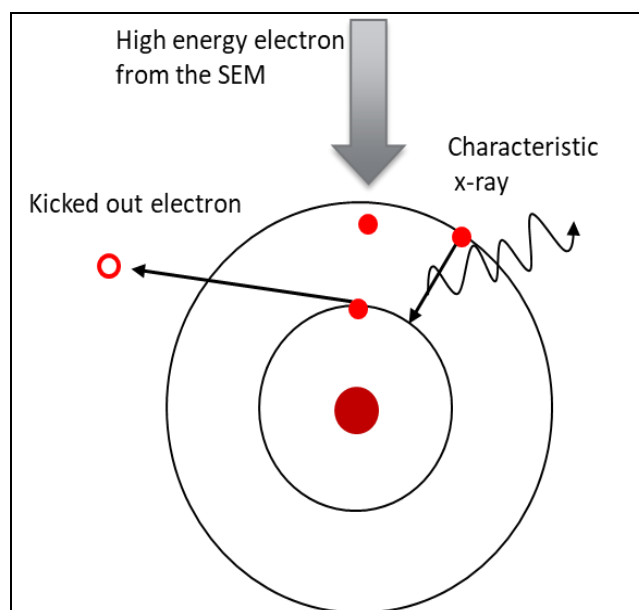


Figure 2: Principle of EDX

ESEM/EDX for BSA

ESEM/EDX has been used for investigating scale in produced water for the last 15-20 years and it is an especially good technique for detecting scale particles forming in the production tubing which tend to get build up over time, compared to scale particles in the reservoir, see Figure 3. Both high magnification images for morphology and estimation of the amount of scale on a filter sample can be produced and usually, the term % coverage is used for quantification of scale, expressed as the ratio between the sum of the area of the bright spots and the total investigated area.

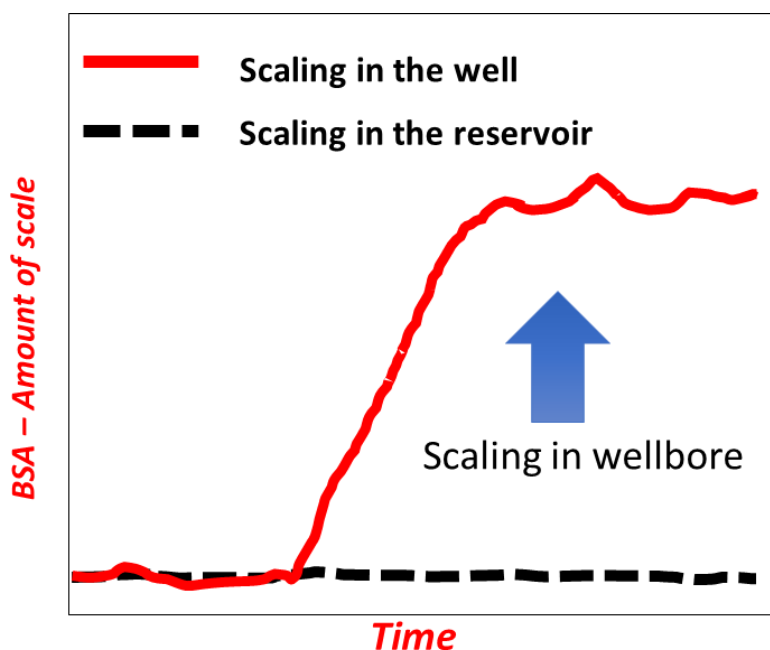


Figure 3: BSA Monitoring of Scale Particles in the Well vs Reservoir