Oil & Gas Authority

SNS Salting Study

Impact of Salt Deposition on Production Losses

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Images on front cover courtesy of Perenco UK , Neptune and TNO.

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1. Executive summary

Gas fields in the Southern North Sea (SNS) are currently experiencing production losses due to salt deposition. Halite precipitation occurs in the SNS due a number of reasons, including high salinity in formation water, methanol overdosing, excessive drawdown, pressure depletion and changes in reservoir conditions.

In 2017, the Oil and Gas Authority (OGA) carried out a study to quantify the impact of salt deposition on production losses, with participation from seven Southern North Sea operators who have either direct experience of salting and salt management, or anticipate salt formation and deposition at a future point in the lifecycle of their facilities.

The study evaluated the extent of self-scaling salt deposition across the SNS, the effectiveness of current treatment options and methods of mitigation. The study also established a view on production losses in the SNS due to salting.

The study identified that at least one fifth of all producing fields in the SNS are likely to be affected by salt deposition with a diverse range of salt mitigation measures adopted, but with limited consistency of approach across operators.

Based on the OGA's 2016 UKCS Stewardship Survey, SNS production efficiency (PE) is estimated at 64%. This is the lowest across the UKCS. The OGA estimates daily production loss totalling 130 mmscf/d attributable to salting, equivalent to 20% of the SNS's total production losses.

At least
1 in 5
SNS producing fields are likely to be affected by salt deposition

PE in the SNS is the
worst
in the UKCS, with
20%
of production losses attributable to salting

Figure 1: Illustration of salt build-up and blockages in topsides gas flowlines and processing equipment. Images courtesy of Perenco UK.

2. Background

Production wells in gas reservoirs can experience rapid performance decline as recovery progresses. In many cases, this behaviour may be attributed to halite precipitation in the near well bore area around the perforated pay zone, but it can also deposit within the wellbore, tubing or within the process plant.

Salt deposition is a problem encountered in a number of UKCS SNS gas fields as well as similar reservoirs across the North Sea. Salt deposition gives rise to a reduction in well deliverability and flow rates and in extreme cases blockages.

The OGA study evaluated the extent of self-scaling salt deposition in UKCS SNS gas fields, including predictive techniques, monitoring and surveillance of the wellbore for salt deposition, options for mitigation and removal and possible further study.

Salt in this context refers to sodium chloride (although other salts such as calcium chloride may be present). Elsewhere, in HPHT reservoirs, other self-scaling salts, for example zinc sulphide, may form but such scales were not investigated in the OGA study.

Salt deposition is relatively common and is believed to be a problem for at least 20% of the SNS gas fields in the UKCS. Despite the prevalence of salting, there are significant gaps in the industry's ability to predict the propensity of salting and potential for formation damage. Technology for the removal of salt in UKCS SNS wells relies mainly on intermittent water washing, although capillary strings are being used in some wells. There appears to be useful opportunities to encourage the sharing of industry experience, knowledge and best practice in dealing with salt deposition and also to promote or sponsor research into salt deposition.

Salt is predominantly sodium chloride (NaCl) and its formation is a self-scaling phenomenon, in contrast to typical scale formation which usually occurs when different waters mix. Its formation is more commonly a problem in gas wells.

There are two main mechanisms of salt deposition in hydrocarbon producing wells:

1. The first is due to gas stripping fresh water from the produced formation water at reduced pressures which increases brine salinity. In this case, salt deposition is normally experienced in gas wells with a low formation water to gas (WGR) ratio (at the same magnitude as water content in the reservoir gas, e.g. < 5 stb/MMscf). Salt drop-out most likely occurs in the formation, near the wellbore and at the wellbore.

   Wells affected by salting can experience a 'saw-tooth shape' in their production profile and a dramatic reduction in the well productivity caused by salt induced formation damage and formation of the bridge plugs in the completion. Water samples collected from topsides can be of low salinity (e.g. < 10,000 mg/l total dissolved salts) due to dilution by the condensed water from the produced gas, and sometimes only condensed water.

2. The second mechanism of salt deposition is due to halite solubility reduction at a reduced temperature and pressure. For this condition to apply, salt deposition is normally experienced in gas wells with a high WGR (e.g. WGR > 20 stb/MMscf). Water samples collected from topsides will show high salinity or will be saturated with halite. Salt drop-out in this scenario is expected in the upper completion and surface facilities.

Salt deposition usually occurs in mature, depleted gas fields, though can also occur in the early life of some wells. The solubility of water in natural gas increases at lower pressures and gas can become under-saturated with respect to water after pressure drops, as occurs when gas flows into a well. Such salting is observed in gas fields across the UK and Dutch sectors of the SNS.

3. Production losses due to salt formation

The OGA has estimated the impact of salting on recoverable reserves using a representative sample of wells known to be affected by salting.

Well histories (including decline curves and P/Z plots), have been obtained from operators which highlight the key events in the lifecycle of a well. These have been used to compare recoverable reserves both pre- and post- salt deposition and in turn provide an estimate of potential production losses.

Using the above approach across the currently affected SNS well stock, the OGA has estimated some 96 bcf of losses due to salting over a two year period, equivalent to 130 mmscf/d or 20% of the SNS's production losses in 2016.

From the study undertaken by the OGA, there is evidence that some SNS operators may underestimate the impact of their production losses attributable to salting, with the majority estimating the impact of salting to be less than a 10% contributor to their losses.

Production efficiency returns to the OGA (ref: OGA publication UKCS Production Efficiency in 2016), currently provide limited insight into the extent of losses due to salting, beyond the bespoke analysis undertaken by the OGA as part of the 2017 study.

There is an opportunity to therefore improve the approach taken to production loss measurement in the UKCS by aligning with that of EBN in the Dutch sector. This could provide a more comprehensive data set and insight into the magnitude of salting losses across the SNS and therefore the level of effort required to mitigate such losses.

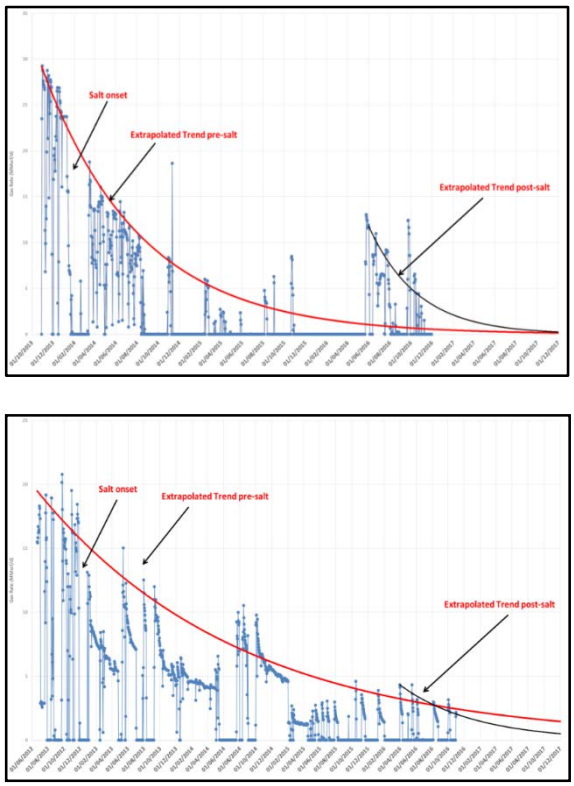


Figure 2: Well histories both pre- and post- salt deposition have been used to provide an estimate of potential production losses.

4. Operator salt management strategies

The OGA study involved a series of structured interviews with a selected number of SNS operators with known salt management issues and challenges. The following table seeks to summarise some of the findings from those interviews, including the level of consistency and approach to the management of salt. It is evident from the table that there are a diverse number of approaches to the management of salt across the SNS, along with a common request for support and the establishment of a forum for the dissemination of best practice on the subject.

Operator	Salt Management Strategy	Salt Prediction Analysis	Monitoring		Surveillance		Mitigation				
			Daily PVT	PW salinity check	Investigate productivity step change	Well intervention / Wireline survey	Manual dilute methanol wash	Manual fresh water wash	Remote wash including foaming skids	Wireline / Coiled Tubing intervention	Continuous fresh water injection
A			●		●		●	●			
B			●		●	●		●			
C			●		●			●			
D			●		●			●			
E			●		●	●		●	●	●	
F			●	●	●	●		●			
G	●	●	●	●	●	●				●	●

Figure 3: Approach to salt management by SNS operators included within the OGA study

5. Salt prediction, monitoring and surveillance

Drawing on the insights from the OGA study, produced water salinity is the leading cause of salt precipitation, with deposition occurring as pressure and temperature reduces in the well bore, as shown in Figure 4.

Building on this, more than half of the wells reviewed in the study affected by salting in the UKCS were associated with Permian age fields, followed closely by Carboniferous age fields. Carboniferous fields however typically have higher salt concentrations in formation water compared to Permian and Triassic fields.

The OGA study identified limited evidence of predictive analysis or techniques to identify the onset of salting and furthermore halite deposition envelopes. This is despite the availability of proprietary software tools. Similarly, very few operators were found to have a good understanding of formation water composition, nor did they carry out regular sampling and analysis of produced water fluids in support of their predictive analysis.

Well performance (rate, temperature and pressure) was found to be the primary means by which operators diagnose potential salting issues downhole and at surface, as shown in Figure 5. Thereafter, wireline camera surveys and sampling surveys were found to be undertaken on an infrequent basis and consistent with the intrusive nature of such activities.

There is a clear opportunity for SNS operators to improve the management of gas fields with salt issues by using established techniques and software to predict the onset of salt deposition. Improvements in the regularity and frequency of produced water sampling for salinity is another key measure and typically impacted by the more limited access to “not normally attended installations” (NPAIs), which are commonplace in the SNS.

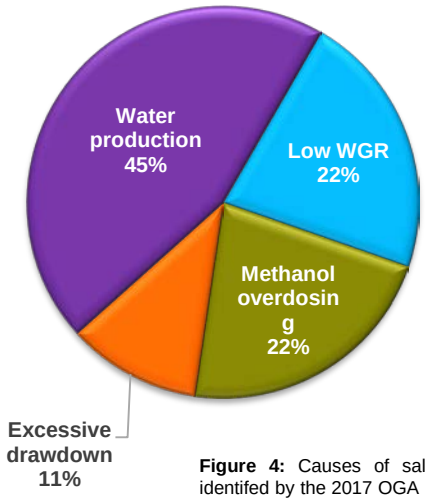


Figure 4: Causes of salt formation as identifed by the 2017 OGA salting study

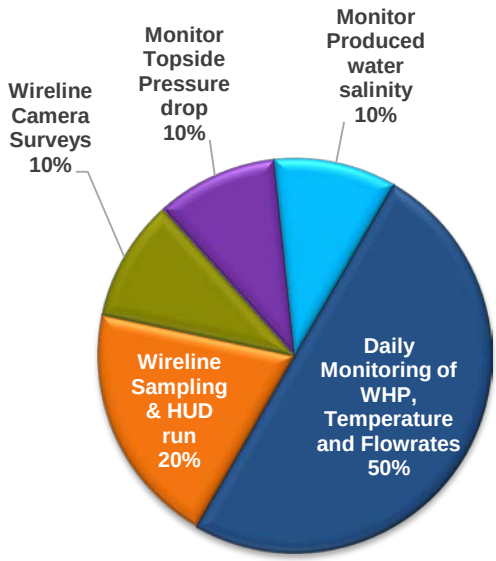


Figure 5: Monitoring and surveillance techniques as identifed by the 2017 OGA salting study

6. Salt mitigation

Though water washing is the most common method of salt removal, there are a range of approaches adopted by operators, from bullhead batch washing through to continuous down hole capillary washing, as shown in Figure 6). A summary is provided below:

- **Manual Washes.** Treatments requiring manual intervention can often be delayed due to the availability of fresh water for subsequent treatment of the wellbore but also the ability to access SNS NPAIs
- **Remote Water Wash Skid Installation.** Wells which have been proven to have significant salt problems have had specialist water wash skids installed to allow regular washes to be conducted without the need for access to NPAIs
- **Trickle washes.** Pumping water downhole whilst a well is shut-in but with the sub-surface safety valve (SSSV) open. Due to the prolonged period during which the tubing is exposed to a flow of water, this is considered to have the greatest effect when there is salt deposition at multiple points within the tubing
- **Batch and fall wash.** The wash is performed with the well shut in and the SSSV closed. Once a given volume of water has been pumped, the SSSV is opened and the water dropped as a slug. This technique is believed to be best utilised when there is a “salt bridge” formed in the lower completion
- **Continuous downhole capillary wash.** Small bore capillaries are installed as part of the completion and facilitate continuous water wash of the well bore. Installation of a permanent capillary must ideally be planned along with the completion of the well
- **Gargling.** Gargling is the process of opening the well on a limited choke whilst performing a water wash soak. This is intended to encourage the dissolving of a potential salt bridge
- **Use of Potassium Chloride (KCl).** A 3% KCl solution is used in some wells as the wash water, in order to limit clay swelling (particularly where Smectite rich clays are present) and associated formation damage

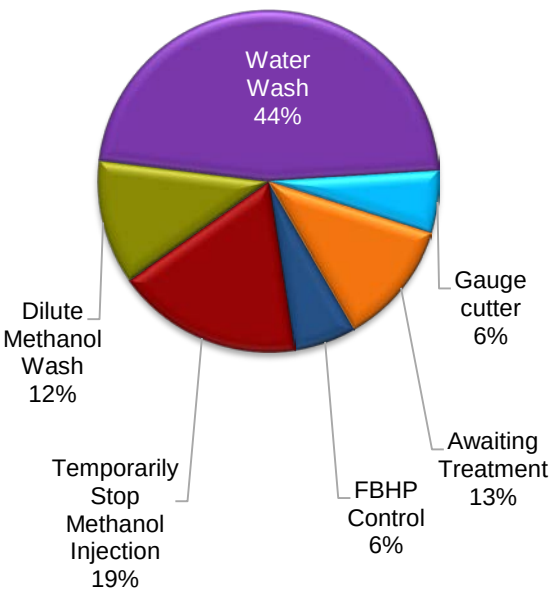
Consistent with common practice, the OGA study identified that water washing accounted for almost half of the salt removal interventions carried out in the SNS, with a success rate of approximately 70% reported by operators.

This was followed by temporarily stopping the injection of methanol (demonstrated to be 100% effective in Permian wells), followed by dilute methanol washing (found to be 100% effective in Carboniferous wells).

Wireline interventions, including the use of bailers and gauge cutters were noted to have limited application but used to recover salt samples and remove salt plugs within the wellbore. The approach clearly becomes prohibitive for subsea wells or dry wells with limited remaining economic life.

The 2017 OGA study identified little evidence of consistency and best practice amongst the SNS operators, with a number calling for the establishment of a forum for the dissemination of lessons learned and best practice in the UKCS.

Figure 6: Salt mitigation approaches and techniques as dentifed by the 2017 OGA salting study



7. EBN and TNO led initiatives

Both EBN and TNO place significant emphasis on salt / halite management within the Dutch sector. Similar to the UKCS, EBN observes significant production losses associated with salting amongst its production operators. Regional work by EBN also suggests that UKCS production losses due to salting are underestimated; application of the same EBN criteria could be applied to UK SNS gas fields to provide a further estimate of the likely number of fields affected and losses at stake.

In recognition of the importance of salt management, both EBN and TNO lead on a number of initiatives.

- **SNS Gas Well Salt Precipitation Forum:** EBN hosts an annual Salt Precipitation Forum which consists of a series of presentations from operators but also contractors, vendors and academic speakers to provide a balanced view of topics. Feedback from the Forum suggests that there is an ongoing role for the OGA, either to present UKCS insights and findings or furthermore to promote collaboration between the UKCS and Dutch Sector on salt management initiatives and data gathering.

- **Innovation Programme in Upstream Gas.** This TNO led programme of work has already initiated a number of projects with industry and academia to address salting issues. This multi-year programme is part funded by industry but also the Dutch government. Partners include EBN, Engie E&P, Total, Oranje Nassau Energie and Wintershall.

The programme includes the development of a model that predicts salt precipitation behaviour in the near well bore / perforation region as well as the development of remediation strategies, such as wash water frequency and volumes. The programme also includes the real time monitoring of salt precipitation, and the development and trialling of salt crystal growth inhibitors.

The OGA has established relationships with both EBN and TNO and therefore has an opportunity to promote synergies between the UKCS and the Dutch sector on salt / halite management issues.

Figure 7: Effects of novel crystal growth inhibitors on halite deposition in porous media and control without inhibitor (bottom). Images courtesy of TNO.

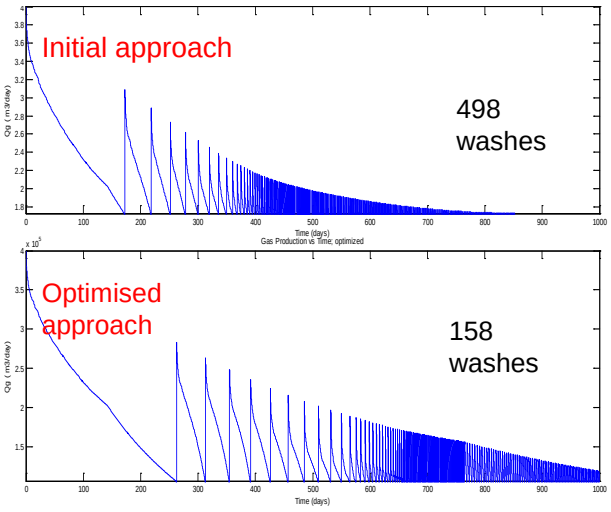


Figure 8: Use of predictive modelling to optimise the frequency and volume of wash water in gas wells. Images courtesy of TNO.

8. Recommendations for further work

The OGA will maintain an active role in the monitoring of salting and halite management issues across the SNS, particularly whilst this continues to represent a significant proportion of the SNS's production losses.

Based on the feedback received from the various participants in the 2017 OGA study, as well as the OGA's broader considerations on the subject, the following actions and recommendations are being progressed:

1. The EEEGR Southern North Sea Rejuvenation Special Interest Group will seek to engage relevant SNS operators in a collaborative effort on salt management and furthermore establish a Salting Work Group

2. The EEEGR Salting Work Group will seek to develop industry best practice, from inhibition and prediction through to mitigation and intervention as part of its terms of reference

3. The EEEGR Salting Work Group will seek to identify potential JIPs and / or deployment of technologies in support of salt management, including access to existing programmes of work currently being progressed by TNO

4. The OGA will raise the profile of production losses due to salting and salt management practices with SNS operators both for new developments as well as existing developments through the OGA's Asset Stewardship process

5. The OGA will identify any additional data requirements from operators in support of improved salt management and seek to access such data through the Asset Stewardship process and / or the annual Stewardship Survey

6. The OGA will seek to promote cross border collaboration with TNO and EBN; including data sharing opportunities where possible, sharing of best practice and lessons learned

Glossary

EBN	Energie Beheer Nederland
EEEGR	East of England Energy Group
FBHP	Flowing Bottom Hole Pressure
HUD	Hold up Depth
HPHT	High Pressure & High Temperature
JIP	Joint Industry Project
NPAI	Not Permanently Attended Installation
OGA	Oil & Gas Authority
PVT	Pressure, Volume and Temperature
PW	Produced Water
SNS	Southern North Sea
TNO	The Netherlands Organisation for applied scientific research
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
WGR	Water Gas Ratio
WHP	Well Head Pressure

Oil & Gas Authority

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