

Region Midtjylland

## **Memo presenting surface tension measurements of Groyne 42 water samples**

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## 1 INTRODUCTION

This memo presents the results of surface tension measurements on the received water samples from Groyne 42 conducted at Section of Chemical Engineering, Aalborg University in Esbjerg. The measurements are conducted and used in the framework of the NorthPestClean project.

The surfactant Ecosurf EH-9 has been injected into Test Cell 2 (TC2) and the aim was to compare the surface tension of the water in this test cell to the reference Test Cell 3 (TC3) in order to assess the distribution of surfactant in TC2. Addition of surfactant to water will in general result in decrease of the surface tension of the solution, and a low and similar surface tension of the TC2 samples may indicate a uniform distribution in the test cell. However, the presence of large amounts of organics in the test cell and their dissolution in the water will also contribute to a lower surface tension compared to pure water, and the variations of aqueous concentrations of these organics can contribute to a non-uniform surface tension pattern in the test cell. Additionally, following initial distribution of the surfactant in the test cell, the surfactant distributed in the test cell may sorb to the sediment and/or react with the target compounds which could result in an increased surface tension over time.

## 2 PROCEDURE

The surfactant was injected into TC2 using recirculation between June 11 to June 17, 2013 at a target in situ concentration of 3 %. Sampling was performed by Region Midtjylland on July 1 2013. A total of 17 water samples from TC2 and TC3 were collected and measured for surface tension, see Table 1; however, the intended sample location well 6-1 could not be sampled. Sample locations are presented in Figure 2.1. The surface tension measurements were completed at room temperature (23 °C) using the pendent drop method with triplicate measurements performed for each sample.

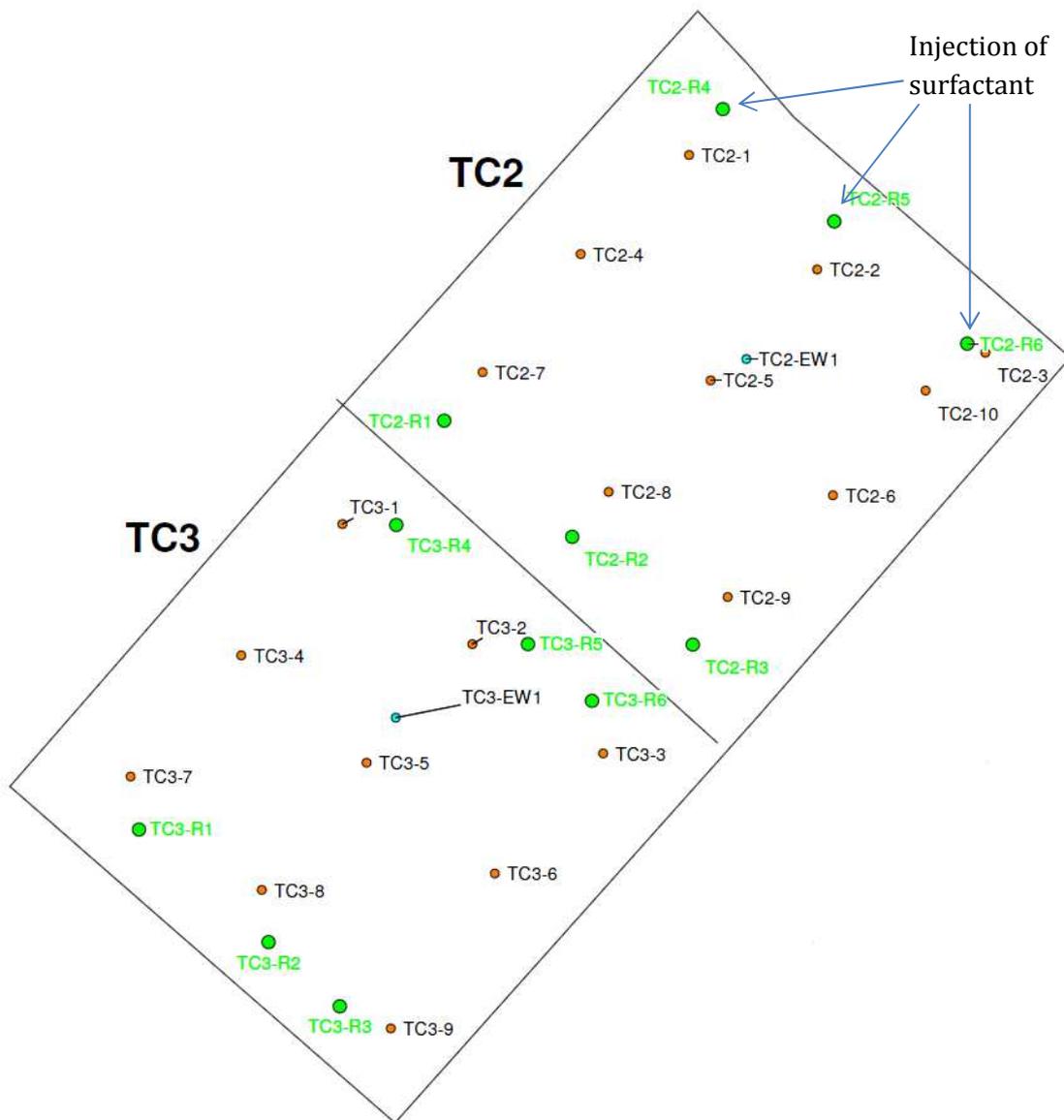


Figure 2-1: Overview of Test Cell 2 and 3 showing the sample locations.

ID	Test cell	Well	Screen*	Note
2-1-1	2	1	1	Ecosurf EH-9 added
2-1-2	2	1	2	Ecosurf EH-9 added
2-1-3	2	1	3	Ecosurf EH-9 added
2-5-1	2	5	1	No sample
2-5-2	2	5	2	Ecosurf EH-9 added
2-5-3	2	5	3	Ecosurf EH-9 added
2-6-1	2	6	1	Ecosurf EH-9 added
2-6-2	2	6	2	Ecosurf EH-9 added
2-6-3	2	6	3	Ecosurf EH-9 added
2-9-1	2	9	1	Ecosurf EH-9 added
2-9-2	2	9	2	Ecosurf EH-9 added
2-9-3	2	9	3	Ecosurf EH-9 added
3-8-1	3	8	1	Reference
3-8-2	3	8	2	Reference
3-8-3	3	8	3	Reference
3-9-1	3	9	1	Reference
3-9-2	3	9	2	Reference
3-9-3	3	9	3	Reference

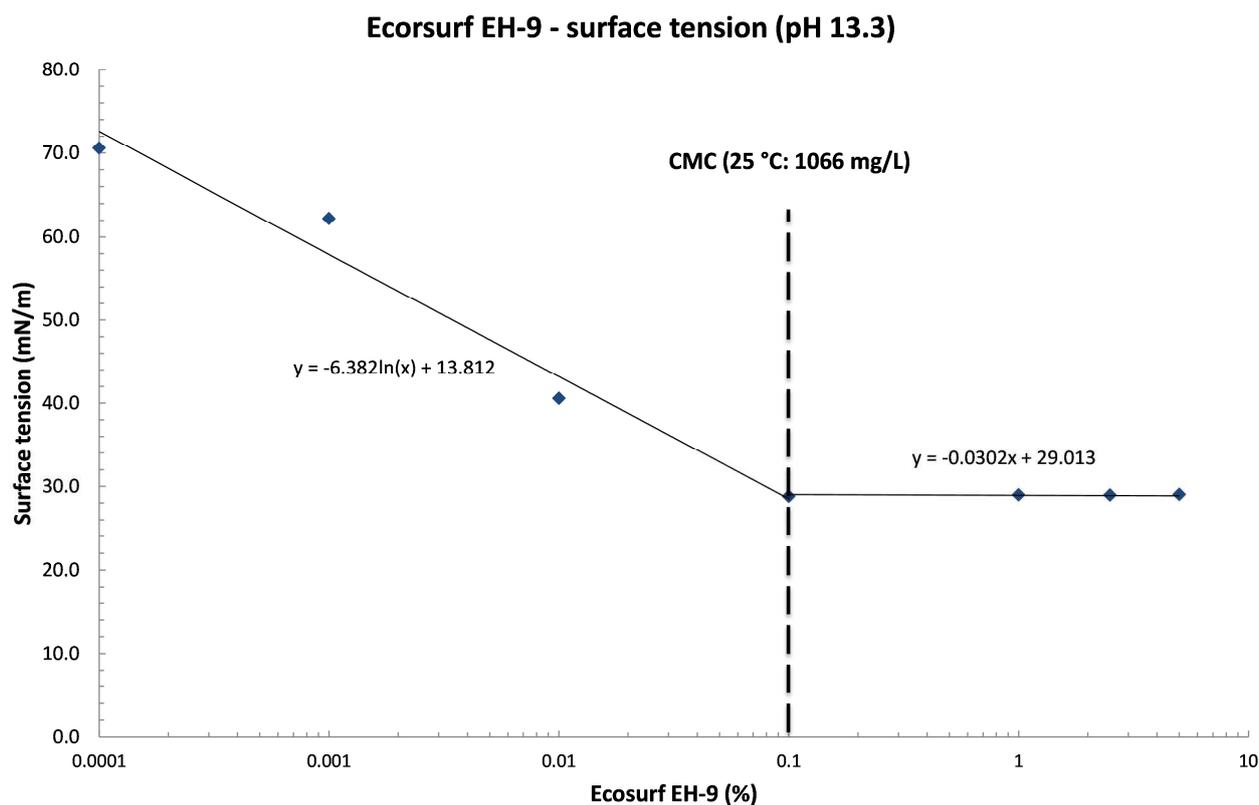
**Table 1: Overview of samples.** \* For each location there were three screens, a shallow (#1, screened 0.5 to 1 m below sea level [m bsl]), middle (#2, screened 1.5 to 2.0 m bsl) and deep (#3, screened from the silt layer and 0.5 m up).

To demonstrate the influence of surfactant concentration on the surface tension, the decay of the surface tension of drinking water with 0.34 M NaOH with increasing Ecosurf EH-9 concentrations were also evaluated to understand the range of surface tension values to be anticipated in the test cell.

### 3 RESULTS

#### 3.1 SURFACE TENSION VS. ECOSURF EH-9 CONCENTRATION

In Figure 1, the surface tension with increasing concentration of Ecosurf EH-9 is presented; results are the average of triplicate measurements.



**Figure 3-1: The evolution in surface tension of 0.34 M NaOH and Ecosurf EH-9 solutions of increasing concentration.**

Plotted versus the logarithmic surfactant concentration, the evolution in surface tension followed the expected linear decay down to a lower limit obtained when CMC is reached and micelles are formed in growing numbers. CMC for Ecosurf EH-9 is, as found in the MSDS for the product, 1066 mg/L at 25 °C, which fits reasonably with the experimental findings. The surface tension of the Ecosurf EH-9 formulation in drinking water with 0.34 M NaOH above the CMC was found to be 29 mN/m. Notably, this surface tension was observed for Ecosurf EH-9 a concentration of 3% that was the target Ecosurf EH-9 concentration for TC2.

### 3.2 SURFACE TENSION OF GROUYNE 42 SAMPLES

In Figure 2, the surface tension measurements of the Groyne 42 samples of TC2 and TC3 are presented (results are the average of triplicate measurements), the results are tabulated in Appendix 1 For each monitoring well.

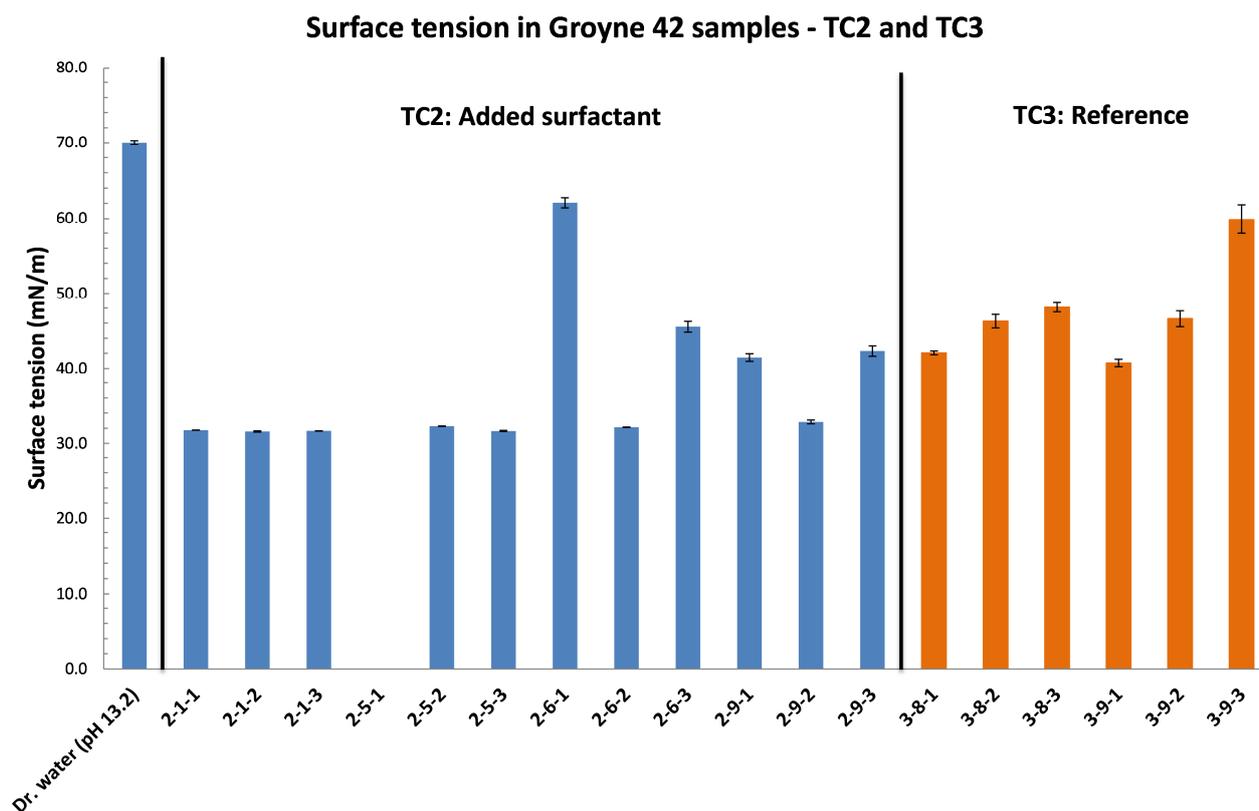


Figure 3-2: Surface tension of Groyne 42 samples of drinking water at 0.34 M, TC2 and TC3.

For the reference samples from TC3, the average surface tension was 47 mN/m and thus significantly lower than the approximate 71 mN/m of the 0.34 NaOH drinking water solution. This is likely due to the many organic compounds dissolved in the aqueous phase. For both well 3-8 and 3-9, surface tension increased from screen 1 to 3 with the highest value of 60 mN/m found in 3-9-3.

For TC2, the average surface tension was 38 mN/m, but there was substantial variation in the measurements. In all of the screens of wells 2-1 and 2-5, surface tension was around 32 mN/m, and thus close to the lower limit achievable with Ecosurf EH-9. Large variations were seen in well 2-6, with the highest value of 62 mN/m found in 2-6-1 and the lowest in 2-6-2 close to the limit. For 2-9, the pattern was similar with the lowest value seen in the middle filter. Of the locations sampled, well 2-1 is closest to an injection well, and well 2-5 is downgradient of the injection well that received the highest volume of surfactant solution (TC2-R5). Thus, the surface tension measurements suggest that while surfactant was delivered through much of the test cell, the delivery may have been most effective directly downgradient of injection wells, in the center of the test cell (downgradient of TC2-R5) and in the middle of the target depth interval (i.e., from 1.5 to 2.0 m bsl).

## 4 SUMMARY

Laboratory experiments using Ecosurf EH-9 in drinking water with 0.34 M NaOH showed that the surface tension decreased with increased Ecosurf EH-9 concentration to a lower limit of 29 mN/m, which was reached when the Ecosurf EH-9 concentration exceeded the CMC around 0.1% (1 g/L). Measurements of the Groyne 42 samples showed a higher surface tension in the reference TC3 (the

## Memo presenting surface tension measurements of Groyne 42 water samples

static test cell) compared to TC2 (the surfactant test cell), with a difference in average values of 9 mN/m. However, the average included some variation in each test cell. In TC2, the surface tension measurements were near 30 mN/m (i.e., surface tension above the CMC for Ecosurf EH-9) and suggest surfactant was delivered through much of the test cell with the delivery likely most effective directly downgradient of injection wells, in the center of the test cell (downgradient of TC2-R5) and in the middle of the target depth interval (i.e., from 1.5 to 2.0 m bsl).

## Appendix 1

### Surface tension data

ID	Test cell	Well	Filter	ST 1	ST 2	ST 3	Mean (mN/m)	std (mN/m)
2-1-1	2	1	1	31.76	31.74	31.75	31.75	0.01
2-1-2	2	1	2	31.47	31.68	31.60	31.58	0.09
2-1-3	2	1	3	31.62	31.65	31.67	31.65	0.02
2-5-1	2	5	1	-	-	-	-	-
2-5-2	2	5	2	32.22	32.29	32.28	32.26	0.03
2-5-3	2	5	3	31.60	31.73	31.58	31.64	0.07
2-6-1	2	6	1	61.13	62.54	62.56	62.08	0.67
2-6-2	2	6	2	32.09	32.16	32.14	32.13	0.03
2-6-3	2	6	3	44.66	46.40	45.50	45.52	0.71
2-9-1	2	9	1	41.04	42.16	41.16	41.45	0.50
2-9-2	2	9	2	33.18	32.58	32.74	32.83	0.25
2-9-3	2	9	3	41.34	42.86	42.71	42.30	0.68
3-8-1	3	8	1	41.83	41.94	42.40	42.06	0.25
3-8-2	3	8	2	45.08	47.25	46.43	46.25	0.89
3-8-3	3	8	3	47.22	48.55	48.51	48.09	0.62
3-9-1	3	9	1	40.42	40.34	41.44	40.73	0.50
3-9-2	3	9	2	47.57	45.13	47.05	46.58	1.05
3-9-3	3	9	3	58.42	58.65	62.60	59.89	1.92