

The Evaluation of Innovative Technologies for Application to Produced Formation Water Monitoring

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Abstract

Traditional methods for monitoring produced water are based on 'end of pipe' measurements and include either gravimetric analysis, Infra-Red absorption, or Gas Chromatography and Flame Ionisation Detection (GC-FID). However, despite these being well established and able to provide high precision datasets, the usefulness of the information generated from them is limited and each method has its own drawbacks. With this in mind, this study focusses on sheen detection through the use of a remote UV sensor as an alternative produced water monitoring method. In a laboratory environment, this alternative approach showed strong linear trends between sheen detection and the condensate concentration up to 10 minutes after the produced water sample had been created. Furthermore, statistically significant sheens, compared with seawater alone, were detected up to the 20-minute mark. Taking into consideration that produced water production is consistently occurring throughout oil and gas operations, this illustrates that sheen detection is a possible method for detecting the presence of produced water, as well as providing an insight into produced water dispersion and determining the condensate concentration. Hence, these results show that produced water monitoring through the use of remote UV sensors is suitable in laboratory environments.

1. Introduction

1.1. Produced Water

Produced water is derived from fresh and/or brine water that has been trapped, together with oil and gas, in porous sedimentary rock between layers of impermeable rock (Collins 1975). During oil and gas extraction, this entrained water is inevitably extracted (Veil et al. 2004), which is then separated from the oil and gas.

1.2. Produced Water Treatment

Even after the separation process, this water still invariably contains a range of substances, which are potentially harmful to the surrounding ecosystems if released into the ocean

(Bothamley 2004). Therefore, it is treated prior to release. Produced water treatment is designed to remove the most volatile hydrocarbons, along with any dispersed non-aqueous liquids, dispersed oil, suspended solids, scale and bacterial particles (Neff and Lee 2011). This process varies from place to place, though at Chevron's Wheatstone platform the treatment process involves the use of hydrocyclones, gas floatation units and absorption filtration media vessels (Van't Westeinde 2019).

1.3. Produced Water Monitoring

The treatment process, however, can never achieve 100 percent removal and, therefore, there are inevitably trace amounts of contaminants still present afterwards (Neff and Lee 2011). Hence, in order to guarantee that environmental regulations are met, it is essential that the concentrations of these trace contaminants are continually monitored.

Traditional methods for monitoring produced water are based on 'end of pipe' measurements and include either gravimetric analysis, Infra-Red absorption, or Gas Chromatography and Flame Ionisation Detection (GC-FID) (Neff and Lee 2011). Despite these methods being well established and able to provide high precision datasets, the information generated from them is only for a snapshot in time of a relatively localised area, hence limiting the usefulness of their results. Furthermore, each method has its own draw backs. Infra-Red absorption requires the use of chlorofluorocarbons and, due to their harmful effects to the environment, is being used less frequently, gravimetric analysis is prone to volatile losses, and GC-FID requires sophisticated equipment and skilled operators (Neff and Lee 2011).

1.4. Produced Water Monitoring using Remote Sensors

Due to a combination of temperature and low salinity, the produced water at the Wheatstone platform is strongly buoyant and will move towards the surface soon after being released. This results in it largely remaining in the upper water column and a surface plume forming (Chevron Australia 2016). Hence, with a surface plume forming, it is assumed that a sheen will also form.

With this in mind, and combined with their use to monitor oil spills being well documented, an emerging idea is the use of remote sensors for 'sheen detection'. A study on the application of remote sensors was conducted by Chevron (Haselwimmer 2018), with an additional study into the feasibility of using Ultra Violet (UV) sensors for produced water detection being conducted as well (Maroef 2019). This later study concluded that, in a laboratory environment, UV sensors are able to detect sheens at the hydrocarbon concentrations associated with produced water, however further analysis was recommended by the researcher.

1.5. Research Objectives

The primary objectives of this study are to expand upon the work of Maroef (2019) and investigate the threshold at which sheen detection begins as well as the relationship between condensate concentration and sheen detectability, in order to determine if sheen detection can provide an insight into the amount of condensate in the water. The secondary and tertiary objective are to determine the effect of time on sheen detection and to better understand the distribution of condensate throughout the water column through the use of a Total Petroleum Hydrocarbon (TPH) analysis, such to provide an insight into the appropriateness of UV sensors.

2. Methodology

2.1. Step 1 – Pre-Laboratory Considerations

Artificial produced water samples were created in the laboratory, of varying condensate-in-water concentrations. A total of 7 concentrations were considered, with 8 samples made for each (Table 1). For each concentration, half of their samples were subjected to 60 minutes of imaging prior to TPH analysis, such to study the effects of concentration and time on sheen development and detectability. The other half underwent TPH analysis immediately after creation, such to compare the differences between the imaging and non-imaging samples, and thus provide an insight into evaporative losses during the imaging process.

Case ID	Condensate Added (μL)	Condensate Added (mg)	Seawater Added (L)	Oil-in-Water Concentration (mg/L)	Imaging Time (minutes)
A	0.0	0.0	0.4	0.00	60
B	1.0	0.78	0.4	1.95	60
C	2.0	1.56	0.4	3.90	60
D	3.0	2.34	0.4	5.85	60
E	4.0	3.12	0.4	7.80	60
F	5.0	3.90	0.4	9.75	60
G	10.0	7.80	0.4	19.50	60
H	0.0	0.00	0.4	0.00	0
I	1.0	0.78	0.4	1.95	0
J	2.0	1.56	0.4	3.90	0
K	3.0	2.34	0.4	5.85	0
L	4.0	3.12	0.4	7.80	0
M	5.0	3.90	0.4	9.75	0
N	10.0	7.80	0.4	19.50	0

Table 1 Experimental Cases Investigated

2.2. Step 2 – Sample Creation

Each sample consisted of 400 mL of seawater, with a micro-pipette being used to measure the required volume of condensate. The seawater and condensate used were taken from UWA's Watermans Bay facility and Chevron's Wheatstone platform, respectively. Clear, 800 mL glass jars with air-tight wooden lids were used to prepare the artificial samples in, with an IKA Mechanical Overhead Stirrer (RW 20 Digital package) with an R 3003 Spiral stirring piece used to create the sample.

2.3. Step 3 – Imaging

A PCO UV camera (Figure 1) and a 50 W TEATRO UV LED floodlight were used during the imaging process. The camera's lens was set to an 'f-stop' of 2.8 and the Camware software settings, as shown in Table 2, were selected.

Parameter	Setting
Exposure Time (ms)	85
Trigger Mode	Auto Sequence
Recording Mode	Sequence
Timestamp	Binary
Allocated # of Images	10

Table 2 Camera Software Settings



Figure 1 PCO Ultra Violet Camera Used

The camera (on its tripod) was situated 0.74 m from the sample, at an angle of 85° below the horizontal. The imaging process was conducted inside a single 210 L container, such that it was void of external light and the light source could be controlled throughout the trials. Furthermore, it was conducted on a black cloth, using amber-glass jars. This was done to prevent any light reflecting from the ground as well as to reduce glare caused by the clear-glass jars, hence improving the quality of the images produced.

Taking into consideration the time for oil droplets to rise from the bottom to the surface of the sample, it was decided that the majority would reach the surface by the 15-minute mark, with the vast majority reaching the surface by the 60-minute mark. Hence, 1-minute imaging intervals were conducted from the 5-minute to the 15-minute mark to provide an insight into the sheen formation during this period of time, with imaging being continued until the 60-minute mark at 10-minute intervals, after which it was concluded that sheen formation was no longer occurring.

2.4. Step 4 – TPH Analysis

Once the imaging process was complete, the sample was separated into top and bottom halves (200 mL each) with 15 mL of cyclohexane being added to each, such to extract the condensate from the seawater. Pasteur pipettes were then used to extract the cyclohexane-condensate layers. To perform the TPH analysis, an ERACHECK PRO machine was utilized. This machine is capable of measuring the concentration of condensate within cyclohexane, hence allowing for the concentration of condensate in the sample to be calculated.

2.5. Step 5 – Image Analysis

The image analysis was conducted using ImageJ, an open source Java-based imaging process program. It was used to perform a flat field correction on each of the images, threshold the images and then calculate the relative sheen intensity.

3. Results and Discussion (Imaging)

For each trial, the average relative sheen intensity (ARSI) was taken as the average of the 10 images' relative sheen intensities at each point in time. For each experimental condition, the overall mean relative sheen intensity (OMRSI) at each point in time was calculated as the average of its respective ARSIs.

Even after thresholding, there was still a very slight sheen detected in the Experiment A trials, despite no condensate being added. Therefore, any sheen being produced here was attributed to reflection from the seawater. A two standard deviation increase was applied to each OMRSI

from Experiment A, with the largest value of these taken as the ‘background sheen’. Hence, OMRSIs were required to be greater than this in order to be considered a sheen associated with the presence of condensate.

The OMRSIs obtained indicate that the UV sensor is able to detect a sheen greater than the ‘background sheen’ at least 50-minutes after the condensate has reached the surface of the sample.

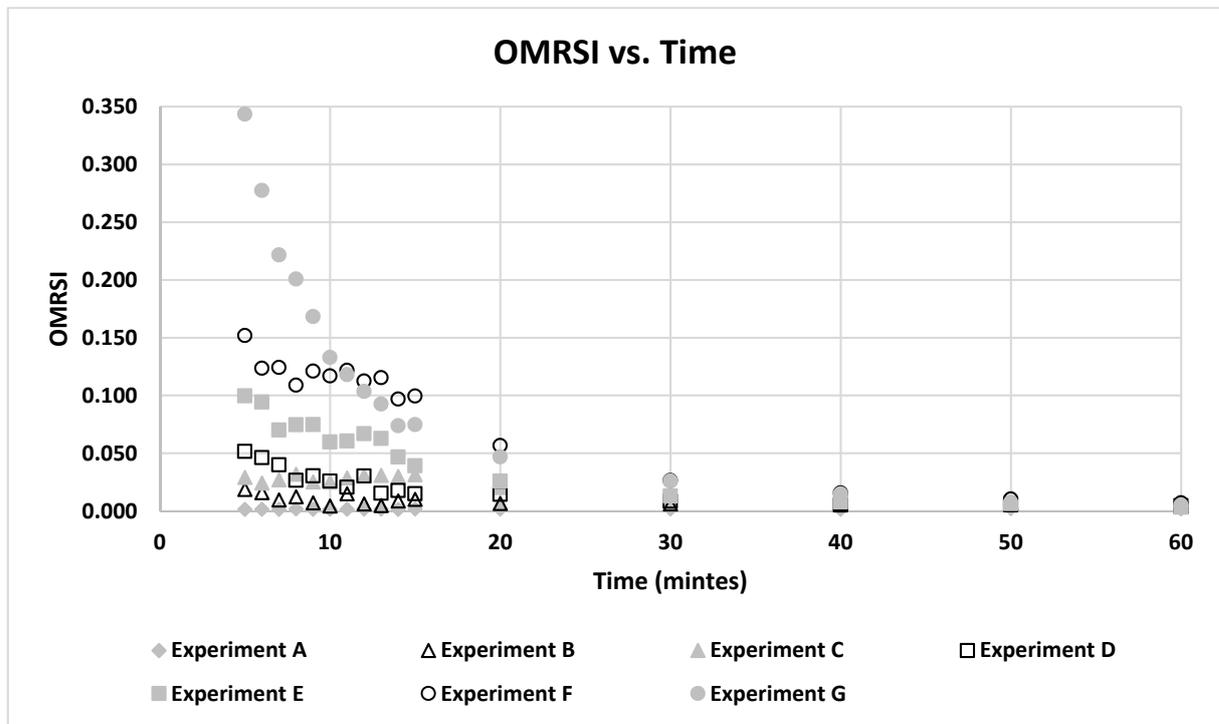


Figure 2 Overall Mean Relative Sheen Intensity vs. Time

As seen in Figure 2, the OMRSI decreases at a decaying rate, with it decreasing rapidly initially before approaching a plateau over time. This would indicate that within the first 5-minutes, the majority of sheen formation has occurred and that, after this, evaporation is the dominating factor. Furthermore, with there being differing quantities of condensate between experiments as well as condensate decreasing over time, this would explain the differing decay rates between experiments.

4. Conclusion and Future Work

The detection threshold at which the UV sensor was unable to detect a statistically significant sheen at the 5-minute mark was not found. However, it is clear that, with an increase in concentration, there is an increase in the sheen produced, particularly within the first 10 minutes of imaging. Furthermore, at the 5-minute mark, the OMRSIs detected by the UV sensor were statistically significant compared with each other. Therefore, in a laboratory environment, it is possible to use a UV camera to provide an insight into the oil-in-water concentration at the 5-minute mark.

However, sheen detectability decreased at a decaying rate over time, with it initially decreasing rapidly before approaching a plateau over time. This resulted in the sheen detected quickly

being no longer statistically significant between experiments after the 20-minute mark. Hence, for the concentrations investigated in this study, the use of UV sensors for determining the concentration based on sheen detectability over time periods much greater than 20-minutes is not suitable.

Taking into consideration that the produced water treatment process is constantly operating during the oil and gas process at the Wheatstone platform, produced water production is likely to be constant. With this in mind, it is likely that any condensate lost to evaporation will be replaced by new produced water rising to the surface. Hence, if this were to be the case, issues associated with sheen detection reducing over time in the laboratory may not be an issue in the real world.

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