# Produced Water Remote Monitoring

Alexander Tan

Professor Charitha Pattiaratchi
Oceans Graduate School & The UWA Oceans Institute
The University of Western Australia

Tim Robertson
CEED Client: Chevron

**Abstract**

*There is opportunity to improve the management of Produced Formation Water discharges from offshore oil and gas facilities through remote monitoring. As a global leader, Chevron seeks to pave the way through the investigation of the latest sensor technology to accomplish this. Remote monitoring has the potential to remedy drawbacks of current processes such as the reliance on end of pipe wet chemistry data and intensive vessel-based campaigns. These methods carry high-risk and are financially demanding. With developments in sensor technology, there is significant potential to refine and build both feasibility and robustness into Produced Formation Water monitoring processes.*

*This project investigates the performance and limitations of in-situ fluorometers through bench-testing and field-testing. Five in-situ fluorometers on the market have been considered. Parameters, particularly sensitivity and lower limits of detection, will be investigated with samples including Produced Formation Water sourced from Chevron facilities.*

*Outputs of the project include a bench-testing and field-testing report in addition to a final detailed report that contrasts the performance of the sensors. The conclusions will evaluate the feasibility of the sensors for field implementation.*

## 1. Introduction

The current methods for monitoring Produced Formation Water (PFW) have limitations including, but not limited to, costly and high-risk vessel-based field campaigns, use of chemical additives, and a lack of access to real-time data (Kato et al., 2017). Methods rely heavily on "end of pipe" wet chemistry data which are resource intensive to process, and numerical modelling which is extrapolatory in nature for ongoing operations and relies upon field validation via vessel campaign. An alternative remote monitoring process has the potential to significantly cut back on these costs and resources. However, there is limited literature and industry examples available at present to support large scale implementation. The potential benefits of remote sensor technologies in the market at present have prompted this project. In order to be applicable in offshore oil and gas (O&G) operations, further research and testing into the capabilities and compatibilities of in-situ fluorometers is required. The adoption of remote monitoring methods has the potential to address the aforementioned issues as well as better evaluate plume propagation and monitor impacts.

Remote monitoring sensor technologies potentially provide an opportunity to more efficiently conduct data collection, enabling better evaluation of hydrocarbon plumes as they propagate away from the point of discharge. The majority of these sensors are submersible and utilise fluorometry in determining various hydrocarbon concentrations, and are as such, classified in-situ fluorometers. The capabilities and limitations of many of these sensors including, but not limited to, the Sea-Bird Scientific SeaOWL UV-A, Turner C3 Submersible Fluorometer, Chelsea Technologies UviLux Fluorometer, and TriOS EnviroFlu-HC were investigated by an EU Horizon 2020 funded group known as the GRACE Project (Pärt & Kõuts, 2016).

In collaboration with research organisations such as UWA, Chevron seeks to evaluate the latest sensor technology with a view to incorporate in-situ fluorometers to PFW analysis processes. This project has multiple drivers beyond financial including seeking to improve environmental outcomes via direct measurement in the marine environment, rather than relying upon end of pipe data, and predictive models to extrapolate. There is potential to improve the safety of the process and minimise the risk to employees through remote sensor operation. Further, reducing the need for vessel operations aligns with initiatives such as the Paris Agreement (Rogelj, et al., 2016) which are motivating resource industry leaders to adopt lower carbon emission methods.

# 2. Project Execution and Experimental Design

## 2.1 Experimental Design

The practical component of the project is being executed in three phases, calibrations, preliminary testing, and trials. With each sensor having unique methods of calibration and accommodating software, each sensor required initial setup and familiarisation took time.

The second phase involved conducting preliminary tests for each sensor to ensure that each could perform adequately under a common experimental setup to control the trials as much as possible. These tests included analysing interferences on sensor performance and are detailed as follows:

- Container edge effects - Sensors are tested at various distances from the edge of a black plastic container. Following this, the minimum distance from the container bottom was determined by testing the sensors at various distances from the bottom. The minimum distance is deemed to be the point at which channel values plateau.
- Ambient light – Sensors are trialled in three different environments, enclosed with no light, laboratory lighting, and outside under sunlight.
- Solution movement – Magnetic stirrers are utilised in samples to maintain a degree of solution homogeneity and investigate whether significant solution movement interferes with sensor readings.

Additionally, the sample was tested to investigate appropriate handling and storing methods. The sample stability was tested over time by taking measurements at fixed intervals over one week. PFW samples are also tested at a variety of temperatures using the sensors to determine if temperature control is required.

In the final experimental phase, a range of PFW dilutions are trialled, particularly at the low concentration range. Trials are conducted with five replicas to gauge the reliability of results and average performance. The range of samples is being informed by previous studies and cross-referenced with the stated specifications of the sensors. The limit of detection and reliability for each sensor to detect changes TPH concentration is also being investigated. The necessary blanks with distilled water in addition to dilutions with other influences of either chlorophyll or seawater are also tested. Introducing chlorophyll and seawater allows for the samples to better resemble water conditions near offshore facilities and assess the robustness of the sensors in the presence of background interference from non-target constituents.

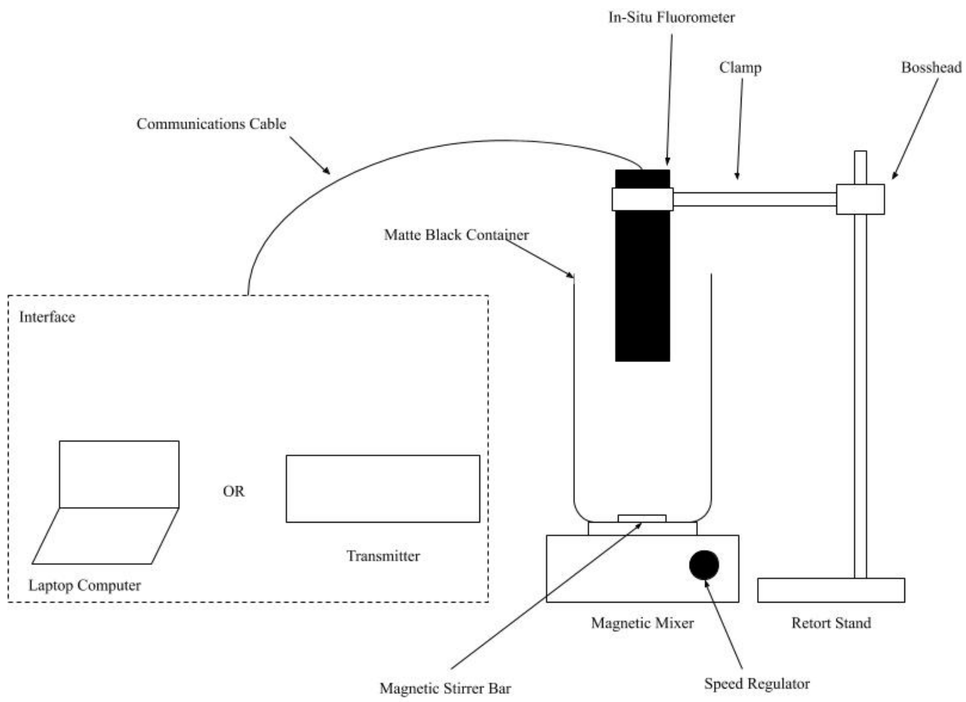


**Figure 1** Experimental apparatus for Produced Formation Water trials.

Figure 1 captures the general experimental apparatus for the sample trials. The sample is hosted on a magnetic stirrer device in a matte black cylindrical container. The sensor is held above by clamps and a retort stand whilst connected to the required interface. Sensors are submerged approximately 2cm during testing.

## 2.2 Feasibility Study

Should the results of bench-testing be sufficient to warrant a field-test, research into the feasibility of implementing the sensors will be conducted. This will include a literature review into unmanned or remote operable technologies that are able to host the sensors.

# 3. Results and Discussion

Three sensors have been analysed to date for user friendliness and compatibility in regard to setup processes, build robustness, data processing. These sensors will be designated sensors A, B, and C. Further, preliminary tests were conducted on each sensor to determine their sensitivity to potential physical interferences in the bench-testing space.

## 3.1 Setup

Sensor A and B require installation of drivers and software. Following this the parameters such as the bitrate need to be set. The communication cables and separate power cables are then attached. Sensor C is available with a transmitter. The transmitter is an external unit that can process the data in an already pre-set interface.

## 3.2 Build Robustness

Sensors A and C are of similar size and robust-type build. The electronics are completely contained in housing with dimensions of 28cm length by 6.3 cm diameter and 31cm length by 6.8cm diameter respectively. Sensor B is a much more compact unit and was not provided with a waterproof housing however, this option is available. It stands at 4.1cm height and 7.7cm diameter.

## 3.3 Data Processing

Sensor B differed from the other two with the software not being able to provide a live graphical representation of the data. The feed from the sensor was provided numerically at a refresh rate of approximately 1-2 seconds. In contrast the other two sensors were complimented with much more modern interfaces which provided graphical interpretations of data. The refresh rate of Sensor C however, did prove to be significantly slower than the other two sensors at approximately five seconds in the fastest case.

## 3.4 Initial Tests

The preliminary tests for each sensor are designed to determine whether each could perform adequately under the experimental setup allowing for as much experimental control as possible. These tests included analysing interferences on sensor performance and are detailed as follows:

- Container edge effects - Sensors are tested at various distances from the edge of a black plastic container. Following this, the minimum distance from the container bottom was determined by testing the sensors at various distances from the bottom. The minimum distance is deemed to be the point at which channel values plateau.
- Ambient light – Sensors are trialled in three different environments, enclosed with no light, laboratory lighting, and outside under sunlight.
- Solution movement – Magnetic stirrers are utilised in samples to maintain a degree of solution homogeneity and investigate whether significant solution movement interferes with sensor readings.

Additionally, the sample was tested to investigate appropriate handling and storing methods. The sample stability was tested over time by taking measurements at fixed intervals over one week. PFW samples are also tested at a variety of temperatures using the sensors to determine whether temperature control is required. The PFW samples showed negligible degeneration in quality over time, which is expected as the samples have been in storage for approximately one year prior.

The following table describes the performance of the available sensors in the preliminary tests.

| Sensor | Container Edge Effects | Ambient Light | Solution Movement |
|---|---|---|---|
| A | Negligible interference when perpendicular<br><br>Minimum measurement distance: 11cm | Negligible | Negligible |
| B | Negligible interference when perpendicular<br><br>Minimum measurement distance: 8cm | Negligible | Feed occasionally flatlines for a short period or until sensor is removed and submerged again. |
| C | Negligible interference when perpendicular<br><br>Minimum measurement distance: 10cm | Negligible | Experiences slight shift in feed of $\pm$(1-2) $\mu$g/L |

**Table 1.** Preliminary tests summary table

# 4. Conclusions and Future Work

The results of the preliminary tests have been deemed satisfactory to proceed with PFW trials. The performance of the sensors, particularly Sensor B, in regard to solution movement will continue to be analysed throughout the PFW trials utilising the results of the ERACheck Pro, an oil-in-water measurement device, as a point of reference.

Currently, PFW dilutions are being made and cross-checked with the ERACheck Pro. Refinements are being conducted to clarify the dilution methodology. Once the dilution methodology is satisfactory, first the distilled water and PFW trials will be conducted, followed by the seawater and PFW trials, with the chlorophyll spiked distilled water and PFW trials last. At the moment two in-situ fluorometers, Sensor D and E, are not available. Should these become available, calibrations and preliminary tests will also be conducted for these sensors.

Pending the results of the project, field test validation of those sensors which perform satisfactorily need to be conducted. Should time allow, small scale field-tests will be conducted, however, ultimately the goal is to have the sensors hosted in an unmanned vehicle that is capable of remote operation from an offshore facility.

# 5. Acknowledgements

Additional acknowledgements are extended to the following individuals external to the primary project team. Dr. Brendan Graham and Prof. Michael Johns for providing laboratory space and the ERACheck Pro for use. Dr. Graham's insights and experience with PFW samples has also been helpful in refining experimental methods. Fellow CEED scholar Michael Weir for his explanation of methods utilised in a similar project and insights into utilising the samples in bench-tests.

# 6. References

Kato et al. (2017). An autonomous underwater robot for tracking and monitoring of subsea plumes after oil spills and gas leaks from seafloor. *Journal of Loss Prevention in the Process Industries, 50*(B), 386-396.

Pärt, S., & Kõuts, T. (2016). *In-situ oil detection sensor – technology overview and experiment design.* Tallinn.

Rogelj, J., den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., . . . Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2°C. *Nature*, 631-639.