

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA17133

STSM title: Exploring the capabilities of microalgae water treatment for the elimination of hazardous pollutants in produced water from oil and gas extraction processes

STSM start and end date: 01/08/2019 to 01/11/2019

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PURPOSE OF THE STSM

Produced water (PW) is generated as byproduct from oil and gas extraction and is usually discharged untreated into water bodies. Many of the chemical pollutants occurring in PW can pose an environmental hazard, such as the high salinity, oil and grease, natural organic and inorganic compounds, chemical additives and natural radioactive materials from the shale formation. Therefore, PW is considered a source of environmental pollution and raises concern. In particular, scale inhibitors and surfactants have been detected at high concentration levels in PW. The development of water treatment processes for the removal of these contaminants is necessary to ensure a safe discharge and eventual water reuse. The use of low-cost and eco-friendly technologies may contribute to decrease the load of hazardous chemicals entering the environment whilst minimizing the energy consumption of the overall treatment. Among them, microalgae have proven to be effective for removal of a large variety of organic pollutants from wastewater. The main objective of this STSM was to explore the capabilities of microalgae to treat the PW generated from oil and gas extraction process as a cost-effective and environmentally friendly solution. This STSM was performed at the Norwegian Institute for Water Research (NIVA) in collaboration with the Institute for Energy Technology (IFE) and the STSM applicant institution, the Catalan Institute for Water Research (ICRA). This project was supervised by Dr. Carlos Escudero-Oñate (NIVA) and Dra. Laura Ferrando-Climent (IFE).

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMs

The removal and transformation of two scale/corrosion inhibitors and two surfactants have been studied in seawater (SW) and produced water (PW) using 10 different microalgae species as potentially eco-friendly water treatment: *Attheta septentrionalis*, *Dunaliella salina*, *Dunaliella tertiolecta*, *Emiliana huxleyi*, *Isochrysis galbana*, *Nannochloropsis oculata*, *Phaeodactylum tricorutum*, *Skeletonema marinoi*, *Rhodomonas salina*, *Tetraselmis suecica*.

1) Preliminary seawater (SW) experiments:

Preliminary experiments were carried out in batch trials to explore the elimination of the 4 target compounds individually, and to evaluate the different factors involved in their elimination such as hydrolysis, photodegradation, and biodegradation. The experiments were performed by using three different experimental approaches: with, and without microalgae, and a control batch without algae in darkness. The removal and transformation were tracked for 15 days. Samples were analyzed in a liquid-chromatography

system coupled to a high-resolution mass spectrometer (LC-Orbitrap-QExactive™) and the data collected was processed via a suspect screening approach using the Compound Discoverer 2.1 software. Having gathered all this information, a tentative transformation pathway was suggested for each target contaminant.

2) Produced water (PW) experiments:

Four algae (*D. salina*, *D. tertiolecta*, *T. suecica*, *I. galbana*) were observed capable to remove the target pollutants in the previous SW experiments and were therefore selected for further experiments in PW. The PW was collected from different offshore oil and gas extraction locations in Norway and spiked with a mix of the selected compounds (two scale/corrosion inhibitors and two surfactants). As in the case of the assays with SW, the time-course experiments were 15-days. The removal and generation of TPs will be investigated using a similar suspect screening approach to the one applied in the preliminary experiments (see previous section 1).

DESCRIPTION OF THE MAIN RESULTS OBTAINED

The main results obtained from the experiments carried out during STMS are the following:

1) Preliminary seawater (SW) experiments:

After 15-day treatments, 4 out of 10 microalgae were able to grow in presence of scale/corrosion inhibitors (*D. tertiolecta*, *I. galbana*, *T. suecica* and *D. salina*) and only one (*T. suecica*) was able to grow in the presence of surfactants. This indicates that most of these compounds were toxic to some of the microalgae species selected. A complete removal of the 2 surfactants was achieved after 144 h (12 days) of treatment with microalgae *T. suecica*. Nineteen TPs were identified from the two surfactants investigated and detected at a relative presence of 8% from the initial concentration of the parent compounds. Hydroxylation, further dehydration and dealkylation of the hydroxylated intermediates were the main transformation processes occurring during biodegradation and photodegradation processes. In the case of corrosion inhibitors, analytical constrains (low ionization of the molecules in the mass spectrometer) experienced during their analysis calls for another analytical strategy to be developed.

2) Produced water (PW) experiments:

In PW experiments, it was observed that the addition of nutrients to the spiked PW provoked an increase of cell concentration (3 folds larger than without adding nutrients). From the four selected microalgae (*D. tertiolecta*, *I. galbana*, *T. suecica* and *D. salina*), only 2 species were alive after 15-day treatments. The evaluation of the elimination of the target pollutants and the identification of the intermediates will be performed according to the intermediates elucidated in preliminary SW experiments.

The main research outcome of the STMS is the confirmation of the potential of microalgae to remove hazardous pollutants from produced water. This outcome allows a potential implementation of these natural based solutions in water treatment and reuse.

3) Main outcomes of the STSM:

Oral presentations carried out during the STSM:

A. Jaén-Gil , L. Ferrando-Climent, S. Rodríguez-Mozaz, D. Barceló, C. Escudero-Oñate. *Exploring the removal of scale and corrosion inhibitors in produced water and seawater: photodegradation and bioremoval*, Produced Water Middle East 2019; Muscat, (Oman), October 2019.

Manuscript in preparation carried out during and after the STSM:

A. Jaén-Gil , L. Ferrando-Climent, S. Rodríguez-Mozaz, I. Ferrer, D. Barceló, E. M. Thurman, C. Escudero-Oñate. *Alternative and eco-friendly microalgae water treatments for the elimination of hazardous pollutants in produced water generated from oil and gas extraction processes: photodegradation and bioremoval*, Journal of Hazardous Materials (planned submission date March 2020).

FUTURE COLLABORATIONS

This STMS has been largely successful in terms of present and future collaborations between the STMS applicant, and the three institutions involved: the Norwegian Institute for Water Research (NIVA), the Institute for Energy Technology (IFE) and the Catalan Institute for Water Research (ICRA). Additionally, the Center for Environmental Mass Spectrometry (CEMS, University of Colorado) will be included in this cooperation to evaluate different suspect and non-target methodologies for the identification of unknown compounds in produced water. The aim of this collaboration is to encourage a Green Circular Economy by using new nature-based solutions and continue exploring sustainable technologies for water reclamation.