Sustainable Projects in Industrial Chemical Processes: Oil and Gas

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Section of Chemical Science and Engineering

ITACA PROJECT

Online Meeting, 23 May 2022

AALBORG UNIVERSITY

OUTLINE

1. Introduction: Chemical Engineering and Oil and Gas at AAU-Esbjerg

2. Examples of Oil and Gas Research Projects at AAU-Esbjerg

3. Didactic Activities Related to Chemical Engineering and Oil and Gas at AAU-Esbjerg within the PBL Framework

Introduction:

Chemical Engineering and Oil and Gas

at AAU-Esbjerg

AALBORG UNIVERSITY

One University – Three Campuses

AALBORG

approximately **19,800** students and **3,100** staff

COPENHAGEN

approximately **3,250** students and **370** staff

ESBJERG

approximately **650** students and **90** staff

DEPARTMENT OF CHEMISTRY AND BIOSCIENCE
2022

Location:

- Aalborg
- Esbjerg

RESEARCH AREA IN CHEMICAL ENGINEERING

AALBORG UNIVERSITY

CHEMICAL ENGINEERING

Active Materials
Self-cleaning membranes for water treatment
Chemical recycling of waste polymer material
New materials for offshore installations by electrolysis

Process Monitoring & Chemometrics
Application of spectroscopy for monitoring and control
Design of Experiments and multivariate data analysis

Oil & Gas
Reduction of environmental footprint
Novel production chemicals
Well Abandonment

Supercritical Fluids
Hydrothermal processes
Supercritical CO_2 extraction
Solvolysis processes

Advanced Redox and Separation Processes
Membrane separation of pesticides
Redox flow batteries for energy storage
3D electrochemistry for pollutant degradation

Process Design & Simulation
Process integration and optimization
Renewable energy systems
Reduction of energy and resource use

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

VISION

Reduce the environmental impact of chemical processes

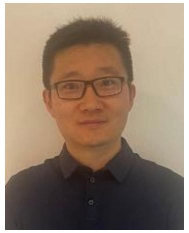
I. Renewable raw materials
II. Reduction of energy consumption
III. Green chemicals in processing
IV. Recycle of chemicals and materials
V. Clean effluents

These targets are pursued by applying novel scientific concepts to engineering applications, in close collaboration with industry both national and international.

Staff in Esbjerg (Department of Chemistry and Bioscience)

Tenured Staff

Jens Muff
- Soil & water treatment and remediation
- Energy storage



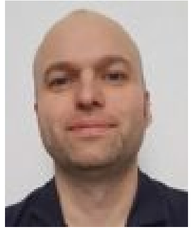
Haoshui Yu
- Process simulation
- Energy systems

Marco Maschietti
- Industrial chemical processes
- Topside offshore oil and gas
- Supercritical fluids

Morten E. Simonsen
- Active materials
- Chemical recycling of polymers

Rudi P. Nielsen
- Process engineering
- Topside offshore oil and gas
- Supercritical fluids

Sergey V. Kucheryavskiy
- Chemometrics
- Spectroscopy



Jens L. Sørensen
- Secondary metabolites
- Fungal biotechnology

Non-tenured Staff

Postdocs	4
PhD Students	8
Lab Technicians	2
Administrative Staff	1

COMPANIES WITH LOCAL OFFICES OR PRODUCTION SITES

Engineering (incl. Oil and Gas)

TotalEnergies
INEOS Oil & Gas
Schlumberger
SEMCO maritime
Ocean Team Group as – Total Purity Solutions
RAMBØLL
HALLIBURTON
Welltec®
MOURITSEN
Crossbridge ENERGY FREDERICIA
VIKING LIFE-SAVING EQUIPMENT

Wind Power

LM WIND POWER – a GE Renewable Energy business
SIEMENS – Siemens Wind Power
Vestas
Polytech – Wind for life™

Food

Arla
Hjem-IS

Materials

FiberVisions®
LEGO

Energy

COWI
Ørsted

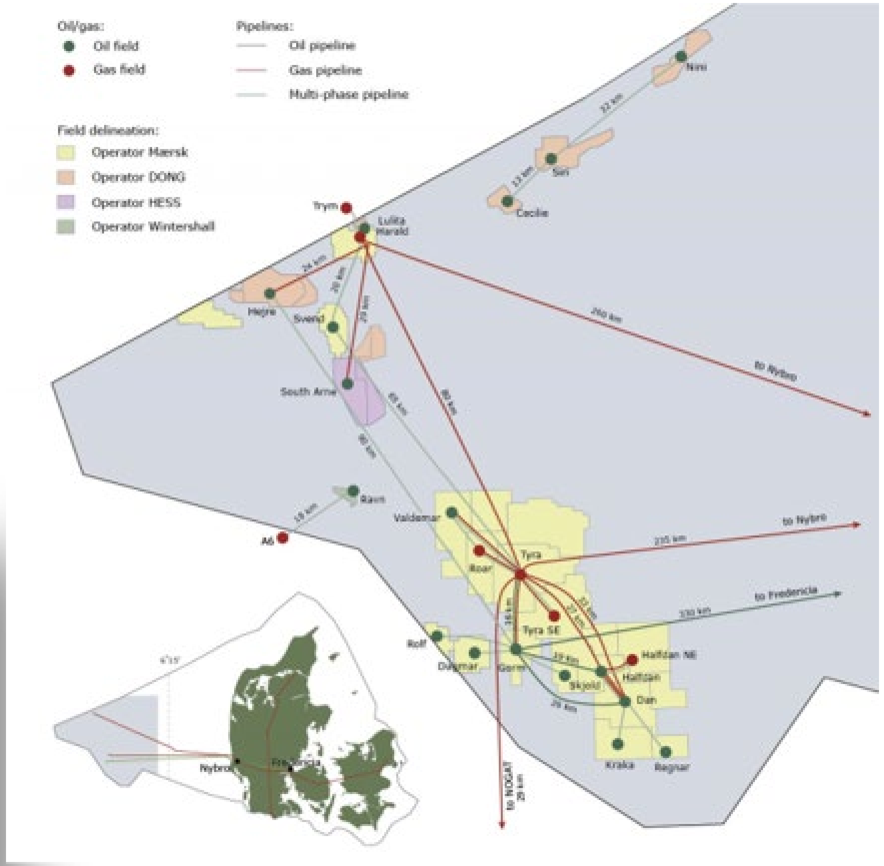
Pharma/Nutra/Biotech

GLYCOM
Mezina – Din sundhed - Vores hjertesag
ZPD – ZERIA GROUP

Waste, water treatment, heating

DIN FORSYNING

AAU-ESBJERG AND OIL AND GAS



Examples of Oil and Gas Research Projects at AAU-Esbjerg

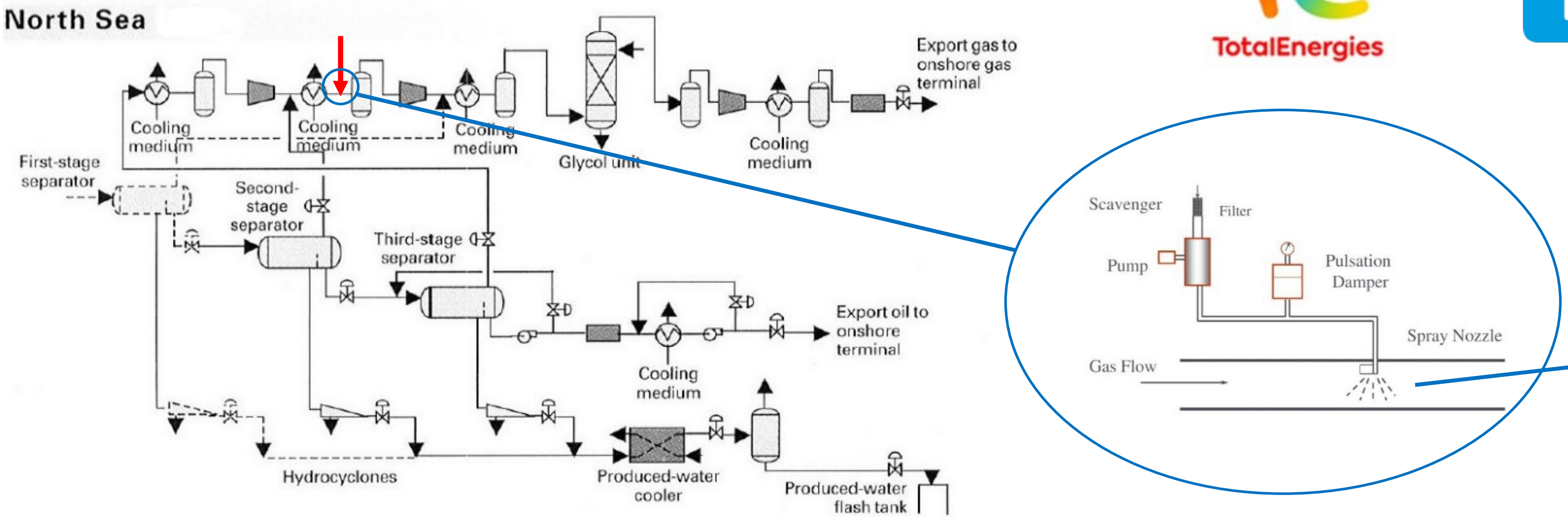
OPTIMIZATION OF H_2S SCAVENGING OF NATURAL GAS

TotalEnergies

EUDP

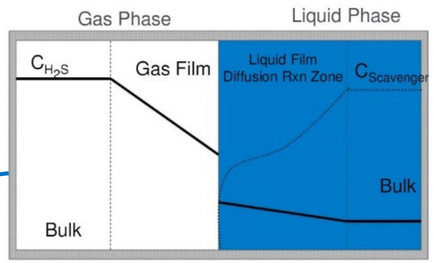
RAMBOLL

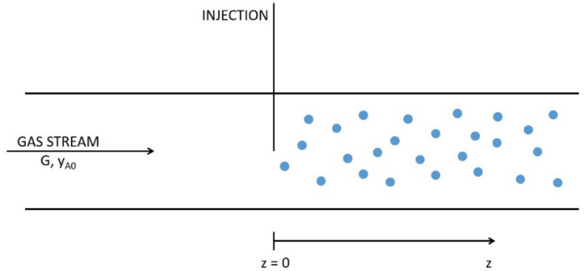
MOURITSEN



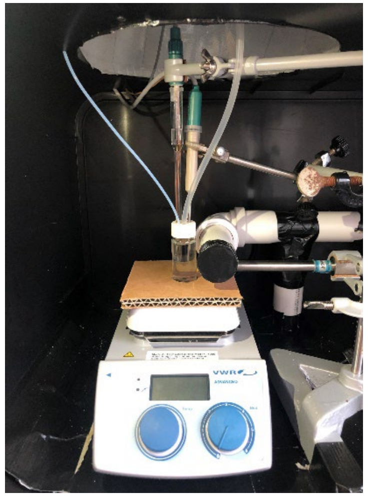
Adapted from Bothamley, Oil and Gas Journal 102 (2004) 47-55

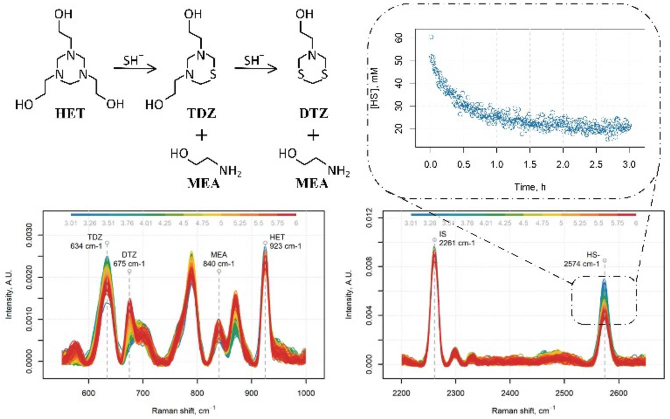
Adams, Scavengers, Presented at 9th NACE International, 2017

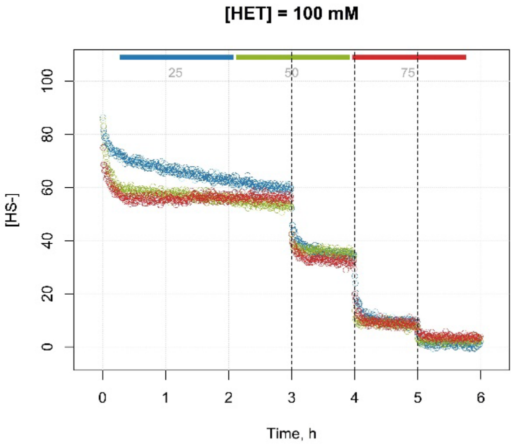


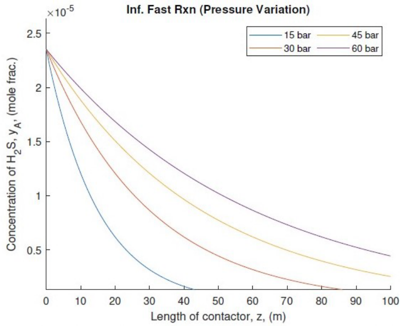


Study of the reaction kinetics of H_2S scavengers via Raman Spectroscopy and Gas-Liquid Reaction Modelling







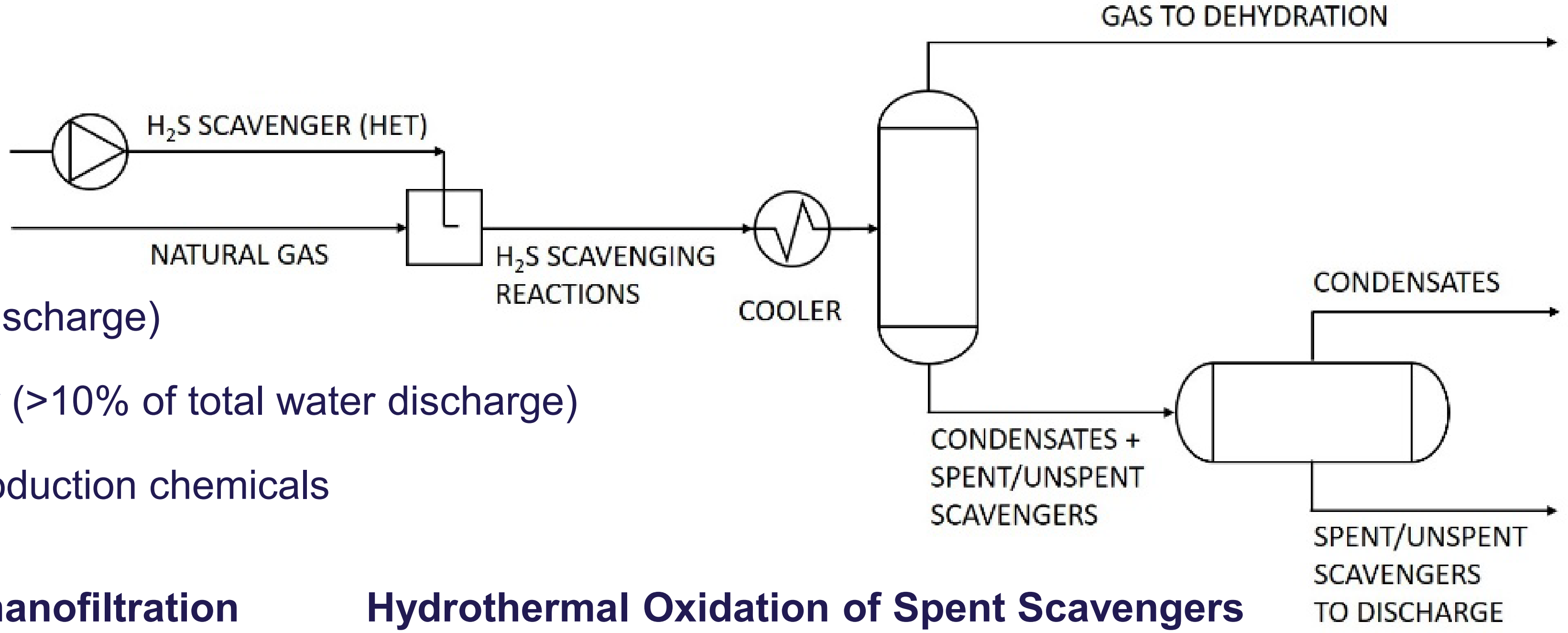


Romero, Kucheryavskiy, Maschietti, Industrial and Engineering Chemistry Research 60 (2021) 15549-15557

ZERO H_2S PROJECT

DTU Offshore
Danish Offshore Technology Centre

TotalEnergies



THE PROBLEM

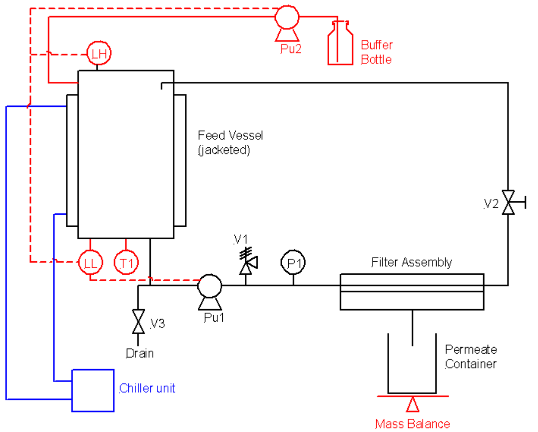
- Spent and Unspent Scavengers:

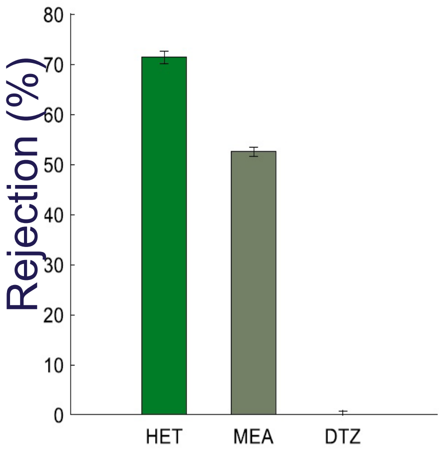
  small quantity (<0.1% of total water discharge)

  but high Environmental Impact Factor (>10% of total water discharge)

- HET: >50% of total expenditure of production chemicals

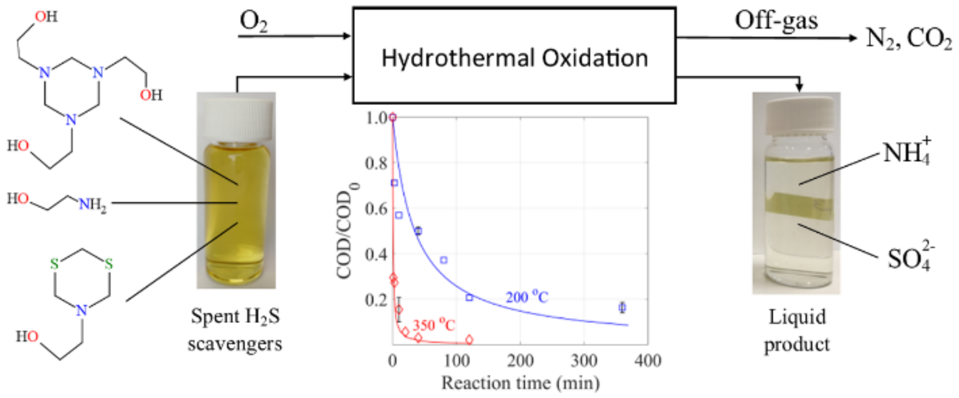
Recovery of unspent scavenger via nanofiltration





Fini, Montesantos, Maschietti, Muff, Separation and Purification Technology 277 (2021) 119641

Hydrothermal Oxidation of Spent Scavengers



Montesantos, Fini, Muff, Maschietti, Chemical Engineering Journal 427 (2022) 131020

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REACTION KINETICS OF GREEN H_2S SCAVENGERS

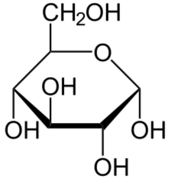
DTU Offshore
Danish Offshore Technology Centre

TotalEnergies

Objective

Test the feasibility of novel green scavengers synthesized by KU.

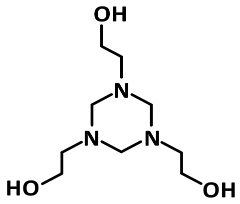
Functionalized

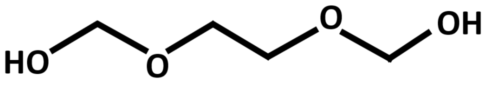


Deliverables

Reaction kinetics of green scavengers.

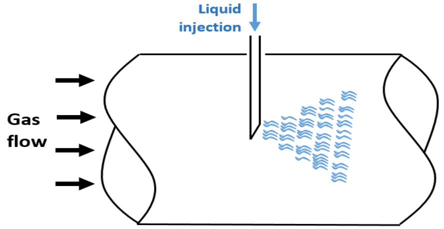
Benchmark against MEA-triazine and formaldehyde releasers.



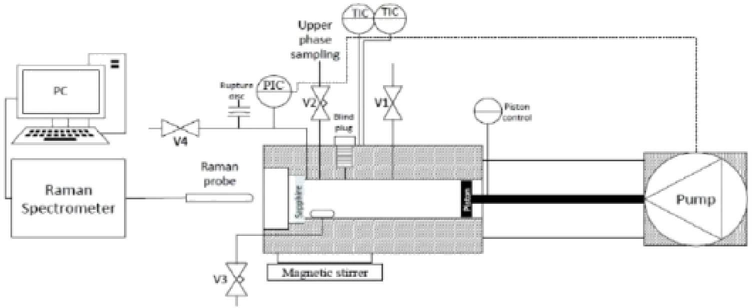


Envisaged application

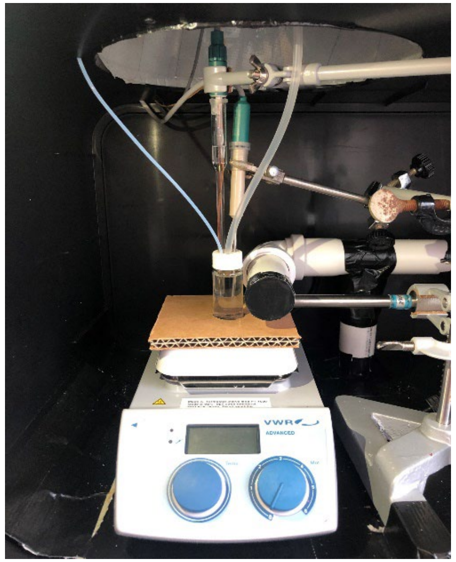
Supporting decisions about implementation in H_2S scavenging of gas streams



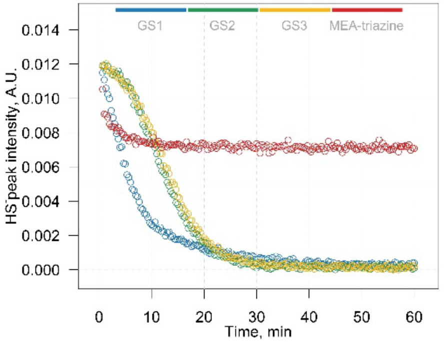
Supporting decisions for implementation in multiphase hydrocarbon streams.

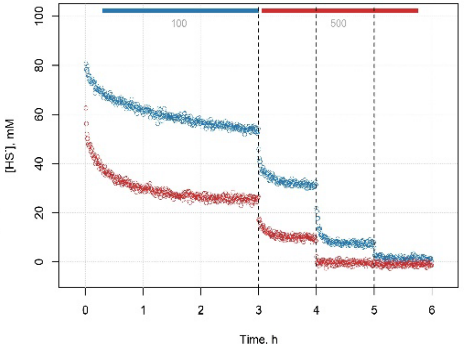


Experiments/ Techniques



Raman Spectroscopy





Research team

AALBORG UNIVERSITY

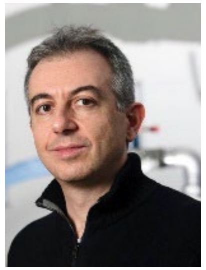
Oil-Water Separation in the Presence of Production Chemicals

Research team: Khalil Kashefi, Simon Ivar Andersen, Marco Maschietti

DTU Offshore
Danish Offshore Technology Centre

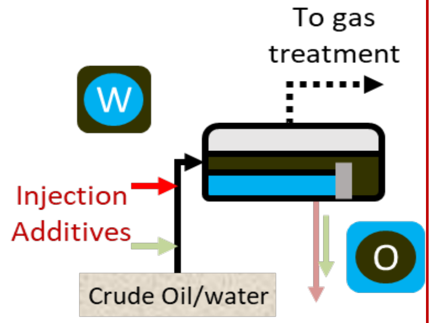
TotalEnergies

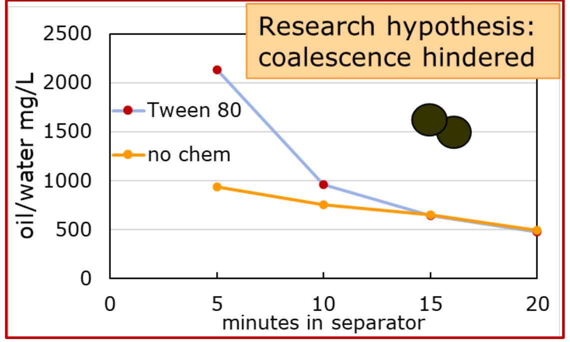




Objectives

- Study the effect of production chemicals on the O/W separation in gravity settlers
- Develop a physicochemical model including the effect of production chemicals





Challenges

- Difficult to get quantitative and reproducible kinetic separation data
- Complex physicochemical model

Envisaged application

- Aid in selection/optimization of production chemicals accounting for side effects on the O/W separators
- Management and prevention of pitfalls in gravity settlers
- Reduction of OiW in the water discharge

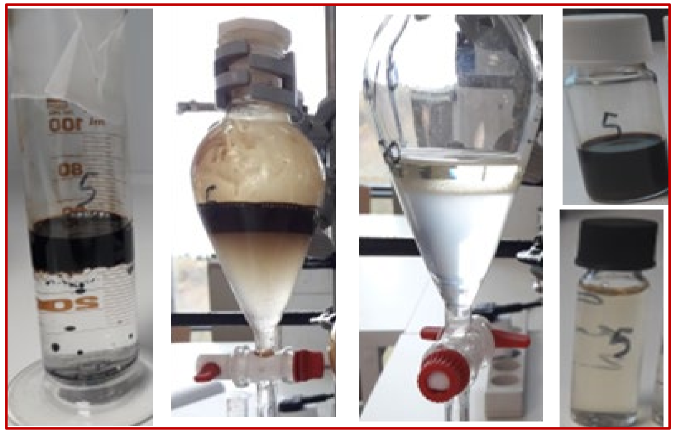
Experiments/Techniques

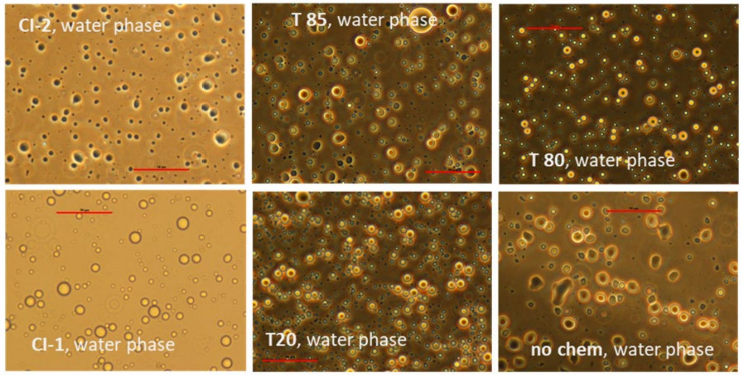
Materials

- Aqueous phase: brine (synthetic and production)
- Oil phase: model oil and downhole oil
- Chemicals: FFCI and demulsifiers

Procedure

- Mechanical dispersion
- Gravity settling (ambient or thermostatic bath)
- Solvent extraction + GC-FID (OSPAR inspired)





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Didactic Activities Related to Chemical Engineering and Oil and Gas at AAU-Esbjerg within the PBL Framework

STRUCTURE OF THE STUDY PROGRAMMES

Bachelor of Science (BSc) – 3 years (180 ECTS)

- Chemical Engineering and Biotechnology (ENG), 180 ECTS – major contribution by the researchers of the Research Area in Chemical Engineering

Master of Science (Msc) – 2 years (120 ECTS)

- Chemical Engineering (ENG), with specialization either in Chemical Engineering or in Oil and Gas Technology – run by the researchers of the Research Area in Chemical Engineering
- Bioengineering (ENG) – contribution by the researchers of the Research Area in Chemical Engineering

BSc in Chemical Engineering and Biotechnology

- Each semester (except Semester 6) allocates 15 ECTS through courses and 15 ECTS through group-based semester projects.
- One course in the first semester is on PBL.
- Semester projects are offered to the students at the start of the semester and are based on one or few semester themes.
- Elective project themes within Oil & Gas

Semester	Project (15 ECTS)	Course (5 ECTS)	Course (5 ECTS)	Course (5 ECTS)
1	Chemical and bio industrial products I Chemical and bio industrial products II	Calculus	General Chemistry	Problem based learning
2	Chemical reactions in natural and technical systems	Linear algebra	Fundamental Chemical Engineering and Thermodynamics	Biological active molecules – introduction to cell biology and biological chemistry
3	Analysis of chemical systems	Methods in quantitative analytical chemistry	Inorganic and organic chemistry	Applied statistics
4	Material science Applied microbiology Petrochemical separation processes	Chemical thermodynamics and separation process engineering	Microbial biotechnology	Material science and material selection
5	Chemical process engineering Bioprocess engineering Refinery products and processes	Chemical reaction engineering	Heat transfer and fluid mechanics	Mathematical modelling and numerical methods
6	Bachelor project in chemical engineering and biotechnology (20 ECTS)	Design of experiments	Process control, instrumentation and safety	-

MSc in Chemical Engineering

- Each semester of the first year allocates 15 ECTS through courses and 15 ECTS through group-based semester projects.
- The second year is entirely project based.
- Semester projects are offered to the students at the start of the semester and are based on one or few semester themes.
- The specialization in Oil and Gas Technology is based on the project selection.

Semester	Project (15 ECTS)	Course (5 ECTS)	Course (5 ECTS)	Course (5 ECTS)
1	Process Analysis Oil and Gas Separation	Fluid Mechanics	Chemical Engineering Thermodynamics	Colloid and Interface Science
2	Process Modeling Modeling of Oil and Gas Production	Process Design and Simulation	Advanced Redox and Separation Processes	Chemometrics and Process Monitoring
3	Specialization in Chemical Engineering Specialization in Oil and Gas Technology Long Master’s Thesis (semester 3+4) Project-Oriented Study in an External Organization			
4	Master's Thesis			

OUR PEDAGOGICAL TARGETS

We aim at supporting our students:

- to become **problem solvers**
- in getting a good understanding of the theory with special attention to its **practical application**
- in developing a **pro-active** attitude
- in carrying out a **structured approach** to solving complex challenges
- in developing **good collaboration skills** with people within and outside the own field
- in acquiring **good communication skills**

All these skills are very much desired by companies!

SEMESTER PLANNING AND COORDINATION

Each semester has a dedicated coordinator who takes care of planning, coordination and quality assurance of the pedagogical activities in the semester.

- **Planning.** Invitation to course lecturers and project supervisors to execution and planning in August and January (i.e., the months prior to semester start).
- **Semester description**. Publish the semester description for the student, at least a couple of weeks before the project start.
- **Project catalogue.** Collection of relevant project proposals and catalogue publication approx. one week before project start.
- **Semester start meeting.** Kick-off meeting of the semester, where the students are reminded the content and structure of the semester, deadlines, and they are supported in the group formation process.
- **Semester meetings**. Two additional semester meetings with the students are carried out during the semester. Feedback is received from the studens and problems are handled.
- **Semester evaluation**. After the end of the semester, the coordinator write a semester evaluation, based on the students' evaluation, the semester meetings, as well as colleagues' and personal considerations.

SEMESTER PROJECTS

Problem-oriented project work: the students form groups that work together during the whole semester on solving a problem of general society interest and/or of a interest of a specific company.

The start-up procedure:

- At the Semester Start Meeting, students are described the projects and they have time for questions.
- They are asked to talk to each other and form semester project groups.
- They are encouraged to form groups of 3-5 students. Solo groups are discouraged.
- No formal project assignment unless all the students enrolled in the semester have a group.

EXAMPLES OF O&G SEMESTER PROJECTS (I)

Oil and Gas Separation

Offshore Separation Train for a Gas Condensate

In the North Sea oil, gas, and water coming from the wells are separated on offshore platforms. The aim of topside separation is to produce oil and gas respecting specifications for export to onshore facilities. On the other hand, the separated water may be re-injected into the reservoir or discharged after proper treatments.

The separation of gas, oil and water is typically carried out in a sequence of separators, operating at progressively lower pressures and temperatures from well stream down to export conditions. The focus of this project is the design of an offshore separation train for a gas condensate (see Feed Data and Table 1). Particular care is required in ensuring that the process design leads to optimal operating conditions. This requires special attention on how the process design influences the quantity and quality of the product streams for export and the energy consumption of the process, as well as the correlation of the separation train design to produced water treatment and gas treatment units. Attention is also to be given to technical, safety and environmental aspects.

The report must include one (or more) Block Diagrams, as well as one (ore more) Process Flow Diagrams (PFD) showing the selected process scheme(s) and the values of the selected operating parameters, as well as a careful selection of relevant plots and tables for illustrating the performance of the train.

Feed data:
The platform receives a mixture of reservoir fluids at an average flow rate of 18000 t/d, with approximately 11000 t/d of which being water. The mixture is available at the platform inlet at 35 bar and 332 K. The composition of the mixture on a water-free basis is given in Table 1.

Title:	**Topside Separation of Reservoir Fluids**
Project:	In the North Sea oil, gas, and water produced from the wells are separated on offshore platforms. The aim of topside separation is to produce oil and gas respecting specifications for export to onshore facilities, while water may be re-injected into the reservoir or discharged after proper treatments. The separation of gas, oil and water is typically carried out in a sequence of separators, operating at progressively lower pressures and temperatures, from well stream down to export conditions. The gas/oil ratio (GOR) of the produced fluids depends primarily on the nature of the reservoir fluids, but also to some extent on the efficiency of the separation, which in turns depends on the number, type and operating conditions (i.e. pressure and temperature) of the separators. The availability of simple and reliable methods for assessing the GOR for given reservoir fluids and separation systems is important for energy and chemical engineering companies working in the oil and gas sector. As reservoir fluids are complex mixtures of thousands of species, the use of thermodynamic models requires the application of so-called characterization procedures, consisting in the definition of pseudo-components representing set of chemical species (lumping), as well as methodologies for associating thermodynamic parameters to the defined pseudo-components. The focus of this project is to retrieve reservoir fluids composition in the technical and scientific literature, to select reservoir fluids archetypes and to assess the reliability of different characterization procedures and methodologies for GOR calculations, evaluating merits and pitfalls.
Supervisor:	Marco Maschietti
Collaboration:	Anders Andreasen (Rambøll Energy, Esbjerg)
Other:	N/A
Electives:	Oil and Gas Separation

EXAMPLES OF O&G SEMESTER PROJECTS (II)

Modelling of oil and gas production

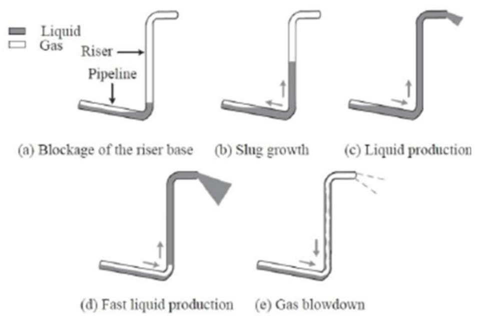
Natural gas TEG dehydration and solvent regeneration

Natural gas produced in the separation train has high water content. Water content needs to be reduced down to stringent specifications, in order to avoid gas hydrate formation and corrosion in the export pipelines. Dehydration is typically performed by means of absorption using TEG as a solvent. The wet solvent exiting the absorption column needs to be regenerated to very high purity levels, which are not achievable in a simple atmospheric distillation process. For these reasons, a number of alternative regeneration processes have been developed and are currently applied in the industry. Examples of advanced regenration methods include gas stripping, vacuum distillation, Coldfinger, DRIZO, etc.

This project aims at investigating and comparing different regeneration processes, taking into account thermodynamics, technical and economic aspects. The effect of process parameters such as the number of stages of the separation units, pressure and temperature, solvent to feed ratio (i.e. amount of TEG circulating per unit gas to be dehydrated) is to be investigated. Attention is to be paid on the impact of the proper selection of phase equilibrium thermodynamic models on the outcomes, in order to guarantee that the comparison of process alternatives is made on a solid basis. Self-made MATLAB programs and/or HYSYS process simulations can be considered for the investigation.

MODELLING OF TERRAIN SLUG FLOW

Terrain slug flow can occur in offshore oil and gas production facilities were the pipeline rises from the sea flow to the offshore platform production facilities. Slugging manifests itself as a cyclic fluctuation in both pressure and flowrate. Slugging can lead to overflow of separators and to damage of the production facilities. In practice the flowrate is limited to flow regimes were slugging does not occur. Slug control is a major research topic at AAU campus Esbjerg and an extensive experimental test facility has been constructed to emulate terrain slug flow. A comprehensive data set is also available from previous experiments.



http://hmf.enseeiht.fr/travaux/bei/beiep/book/export/html/145

It is desired to simulate the formation of a terrain slug using commercial or open source CFD code. In CFD there exist several models for liquid-gas flow. For this flow problem, the Volume-Of-Fluid (VOF) model is most often applied. The simulations will be transient and 3D so the computation should be expected to be somewhat heavy. The simulations should be performed using either the commercial code ANSYS Fluent or the open source code OpenFOAM.

The CFD model should be verified using experimental data and should be able to predict the slug frequency as well as flow rate and pressure at the production facilities. . Depending on the number of students working with this project and their interest, this project could involve measurement of experimental data at the test facility and subsequent data analysis. The CFD model can also be verified using existing experimental data.

CONTENTS

- Understanding of the operation of offshore oil facilities
- Understanding of terrain slug formation and related multiphase flow phenomena
- CFD modeling of liquid-gas flow
- Measurement of pressure and flowrate for a slug flow in the AAU Campus Esbjerg laboratory

EXAMPLES OF O&G SEMESTER PROJECTS (III)

Modelling of oil and gas production

Fate of Production Chemicals in the Off-shore Sector

Project description: During production of oil and gas a large amount of chemicals is used to facilitate processing. This may be, but not limited to, hydrate, wax and scale inhibitors, demulsifiers and scavengers. These compounds may not necessarily be cleaned up and separated from the oil or produced water, but may end up in on-shore facilities or in the discharge to the sea.

This project has aim at first achieving a general knowledge of the chemicals used in oil & gas production and how they function in the process, which may be based on a thorough survey of literature. Also, this initial part should give an indication of the fate of the chemicals such as reaction products and if they will end up in the discharge or export. Furthermore, it would be possible to evaluate the recovery of unspent/unreacted chemicals for reuse to gain an economic advantage.

A second aim is to model the fate of these chemicals. This may be approached in several ways depending on focus area. One approach could be using a commercial process simulator such as Aspen HYSYS®, which is a common software package in the petrochemical industry. This would help the analysis of the effect of changed process conditions on the amount of chemicals in various process streams, if proper thermodynamic models are employed. Due to the limitations of process simulators it may be advantageous to model some unit operations using MatLab and then introduce these results in the process simulator.

Dynamic Evaluation of Flare Systems

Supervisor: Rudi P. Nielsen

Flare systems are an important safety system in both offshore oil & gas installations as well as refineries and petrochemical plants. The flare system collects process fluid from Pressure Safety Valves (PSV's), Blowdown valves (BDV's) and spill-over control valves (PCVs). The collected fluid is sent through the flare system piping to a flare drum where liquid is removed. The gas is sent to the flare stack where it is burnt at a safe location. Sometimes the gas is recompressed and sent back to the process via a flare gas recovery system also termed zero flaring system.

PSVs are mechanical devices installed in the process which relieves the process fluid in case of overpressure at a predefined set pressure. Blowdown or depressurisation consist of opening valves on selected process section (maybe the entire installation) in case of fire or gas (F&G) detection on the installation. This ensures that the process is depressurised and emptied through the flare system thereby minimising the risk of a fire escalating into a catastrophic fire on the installation. Spill-over flaring is if the process for some reason has excess gas that cannot be processed but need to be disposed of (e.g. if a compressor is out of service).

Often it is found that capacity is lacking and expensive modifications are required on existing flare systems. However it is industry standard to perform such evaluations as steady-state simulations which are believed to be conservative. However if dynamic investigations are performed instead it may be possible to show that flare system capacity is sufficient and avoid expensive modifications.

EXAMPLES OF O&G SEMESTER PROJECTS (IV)

Examples of exprimental projects.

Hydrothermal oxidation of spent scavengers

Hydrogen sulfide (H_2S) is a very toxic and corrosive chemical species contained in natural gas. In offshore oil and gas facilities, H_2S is removed from natural gas by injecting an aqueous solution of a triazine (H_2S scavenger) in gas pipes. The aqueous phase containing the reaction products (spent scavengers) is then separated from the gas and discharged into the sea. This waste water contains products of the triazine + H2S reaction (spent scavengers) as well as unreacted triazine (unspent scavenger). The "as is" discharge of this spent-unspent scavenger waste water (SUS) into the sea is of environmental concern as some of the chemicals contained are toxic for the marine environment (e.g. monoethanolamine).

This project suggests the use of hydrothermal oxidation (HDO) as a method to clean the SUS by oxidizing the organic chemicals present in it to CO_2, water and inorganic salts like sulphate and ammonium. Hydrothermal oxidation is the use of high temperature and air (or oxygen) as an oxidant to decompose harmful chemicals to benign ones. Wet air oxidation, which is a variation of hydrothermal oxidation typically performed at temperature range of 150–320 ◦C, is widely applied industrially for the treatment of municipal sewage sludge and refinery spent caustic.

The focus of this project is to test the HDO process on a real SUS retrieved from an offshore installation in the North Sea. The study of this feed can provide valuable data on the performance of HDO in reducing the environmental footprint of the oil and gas production operations. This can be done by characterizing the oxidation products and evaluating their improvement regarding the impact to the environment compared to the untreated SUS. In addition, the experimental data can be used for modeling of the process and for basic design of the HDO reactor. The project may also include modelling and simulation of the HDO process on the basis of the expeirmental findings, with the aim of sizing the reactor and estimating basis design parameters, such as the energy requirements of the process.

The Section of Chemical Engineering is equipped with a cutting-edge high-pressure-high temperature (HP-HT) reactor to support HDO studies on real SUS samples from the North Sea.

The Effect of Production Chemicals on Corrosion

In the off-shore sector a large number of chemicals are utilized on an everyday basis. This includes scale and corrosion inhibitors as well as oxygen and hydrogen sulphide scavengers and many others. To avoid corrosion in the production facilities, corrosion inhibitors are normally injected into the process stream and even downhole in the well to reduce corrosion as much as possible as corrosion is a major cost of operation.

Qualification of chemicals i.e. evaluations of their applicability is often made on the basis of that single chemical in the oil/gas processing context, however the interaction between different production chemicals is not normally investigated, which may lead to unforeseen consequences.

This project relates to the effect of scavengers and inhibitors on the corrosion of steel surfaces. A selection of commercial scavengers and inhibitors is available, however the study could also be performed on model substances, to achieve a more fundamental understanding of the effects, since commercial products does not necessarily have a fully defined composition.

The main interest is to be able to evaluate if what the effect of each added scavenger/inhibitor has on the corrosion, and what the total observed effect may be, as to any synergistic or antagonistic effects between the chemicals.

EXAMPLES OF O&G SEMESTER PROJECTS (V)

Other examples of experimental projects.

Microfiltration of Produced Water

The fluids produced in oil & gas production installations are mainly composed of hydrocarbons and water. The aqueous stream resulting from the separation of oil and gas is called produced water. It origins from water trapped in subsurface formations or introduced via water injection operations and it is brought to the surface along with oil and gas during production. Nowadays produced water constitutes the largest volume of waste associated with oil and gas production. It can be reinjected into the reservoir or into disposal wells, or discharged after proper treatment.

In North Sea offshore installations, the discharge into the sea requires to be in compliance with OSPAR regulations. This requires, among other things, the oil-in-water content to be substantially reduced prior to discharge. The reduction of the oil-in-water content is currently obtained by using hydrocyclones and flotation units. Cross-flow microfiltration using ceramic membranes has also been proposed, due to the potential of reaching extremely low values of oil-in-water. However, operating problems (e.g. membrane fouling) have so far hindered the spread of this technology within offshore oil & gas production.

The focus of this project is on the assessment of the potential of microfiltration using ceramic membranes, including both the capability of reducing oil-in-water content and the extent of operating problems related to membrane fouling. The analysis can be supported by a lab-scale cross-flow microfiltration unit available at AAU-Esbjerg. The experimental information can be used for supporting the design of a full scale membrane treatment system on the platform with respect to dimensioning, control, instrumentation and safety on an introductory level.

Separation Kinetics of Oil-in-Water Emulsions

In the North Sea, oil and gas are produced on offshore platforms, where oil from the reservoirs is separated from gas and water on the platform. Downstream the primary separation, oil and gas may be further processed in order to reach suitable specifications for export to onshore facilities. Recovered water may be re-injected into the reservoir or discharged after treatment.

The first stages of the separation of dispersed oil from water are typically based on gravity settling. Oil particles, lighter than water, coalesce and float and therefore separate from water. The kinetics of this process depends on a number of parameters, such as the type of oil, temperature, presence of electrolytes and their concentrations, etc.

In recent years, the implementation of enhanced oil recovery methods based on the injection of water with modified saline composition (e.g. SMART water injection) has been proposed in the Danish North Sea in substitution to standard waterflooding. The injection of modified water may result in physico-chemical changes in produced water that may affect the oil/water separation and have implications in the design of the topside separation units. These compositional effects are mainly related to the size of oil droplets and, perhaps more importantly, to their surface electrical charge that can alter to large extent the coagulation kinetics and, therefore, the overall separation kinetics.

This project focuses on the evaluation of the effect of modified water composition on the kinetics of the oil/water separation in gravity settlers. Possible approaches include batch laboratory experiments of oil-in-water separation, measurements of the size and surface charge of oil droplets, analysis on how these parameters influence the design of gravity settlers, etc.

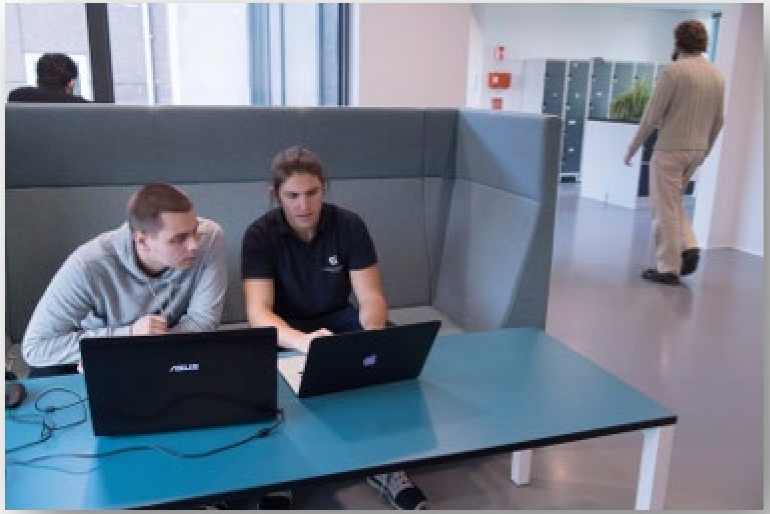
HOW DO THE STUDENTS WORK ON THE PROGRAM?

Modern teaching

- Mix of digital and physical teaching
- Course-based physical teaching is based on 4-hours seminars, with lecture, problem solving, workshops, etc.

Project work

- Each group as one (or more) supervisors, but the group manages how and when project work is carried out
- Flexibility, but with clear expectations of active participation



Exam

- Group-based exam, based on a report and an oral exam
- Individual grading

Thank you for your attention!

Questions?