Optimizing & Upscaling the Dal-SMBR for the on-Vessel Treatment of Decanted Oily Seawater

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Introduction

Background

- Limitations in Canada's legislation require shipment of decanted oily seawater inland for treatment
- Legislation in Canada: treated seawater cannot be discharged back into the ocean
- Dal-SMBR (pilot scale): designed to treat decanted emulsified oily seawater on-site, reducing time, cost and shipping

Objectives

- Evaluate the performance of the pilot-scale Dal-SMBR unit in treating decanted oily seawater
- Validate MBR system using COMSOL Modelling Software
- Upscale MBR system to treat large scale oil spills using COMSOL Modelling

Design Approach

Experimental Design

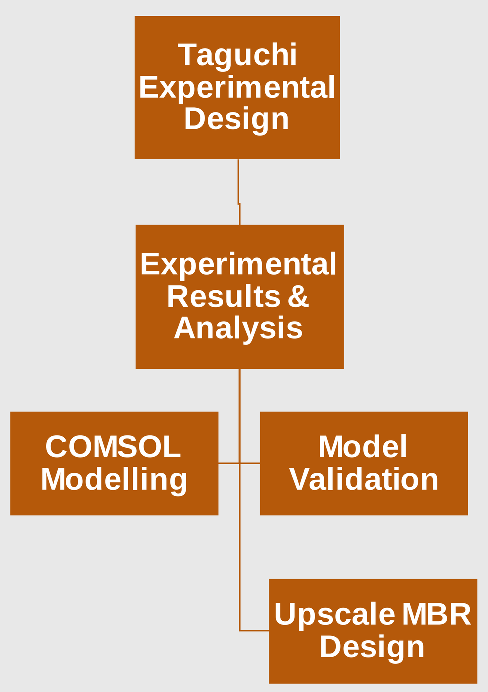
- Designed using Taguchi Method in Minitab
- 3 factors: oil concentration (ppm), flow rate (L/min) and aeration rate (m^3/h)
- 8 runs

Experimental Results & Analysis

- Analyze results using Taguchi Method

COMSOL

- Model Dal-SMBR
- Validate model with experimental results
- Model upscaled version of Dal-SMBR for response vessels



Taguchi Statistical Analysis

Analysis

- Performed using Taguchi analysis in Minitab for both heavy and light oil experimental results

Key Findings

- Oil concentration, flow rate and aeration flow rate all had no impact on removal efficiency.
- There was an impact on fouling (TMP) and amount of water treated, as seen in Figure 1 and Figure 2, respectively.

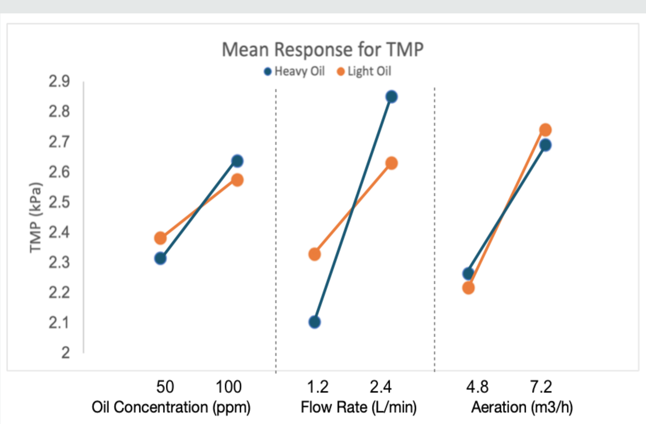


Figure 1: Main effects plot for means of average TMP versus oil concentration, flow rate and aeration flow rate

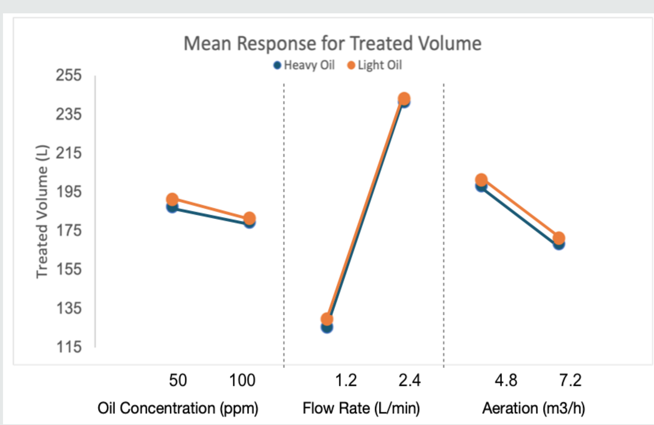


Figure 2: Main effects plot for means of treated water volume versus oil concentration, flow rate and aeration flow rate

Experimental Results

- Overall, the Dal-SMBR achieved an average **99.7% +/- 0.1%* removal** of TPH from decanted oily seawater for both heavy and light oil types
- Effluent TPH concentrations averaged **0.22 +/- 0.03* ppm**
- Results ranged from 0.13 - 0.34 ppm and had a standard deviation of 0.06
- This is well below the desired effluent concentration of 15 ppm
- These results indicate that the Dal-SMBR may be a highly effective and compact option for on-board treatment of decanted oily seawater
- Optimal operational parameters to reduce fouling and increase treated volume:
  Aeration Rate = 4800 L/hour
  Permeate Flow = 240 L/hour

*Based on a 95% confidence interval

Figure 3: Influent (left) and treated (right) water

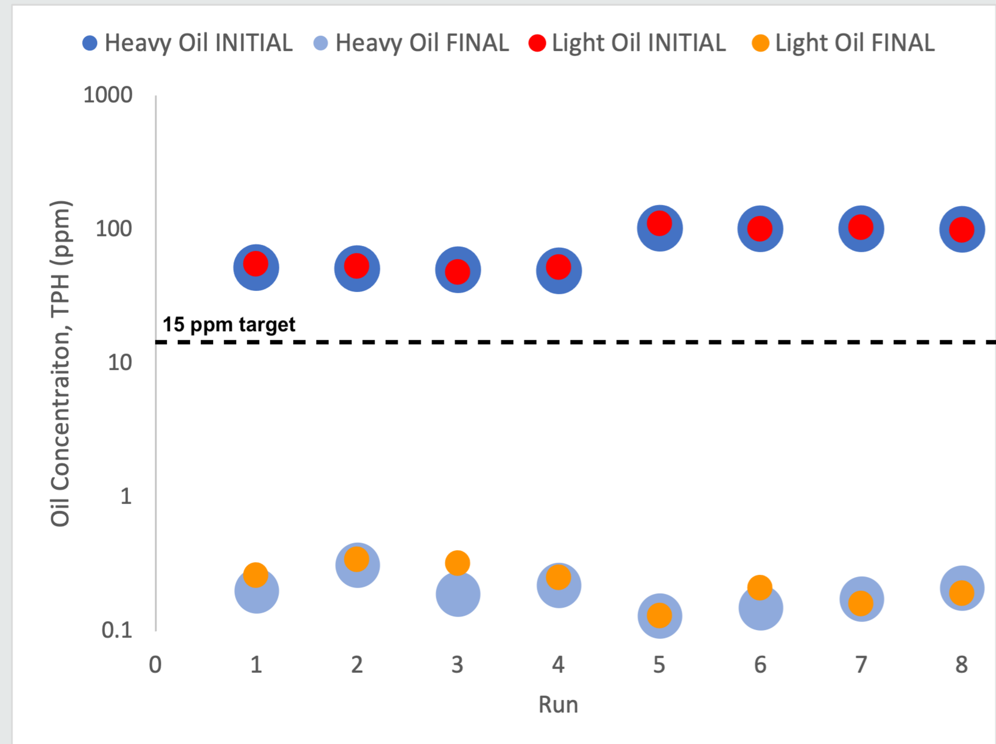


Figure 4: Initial and final TPH (ppm) concentrations from each experimental run for light and heavy oil

COMSOL Modelling

COMSOL Modelling

- Software used: COMSOL Multiphysics Version 6
- Goal of COMSOL is to validate the system and upscale the model

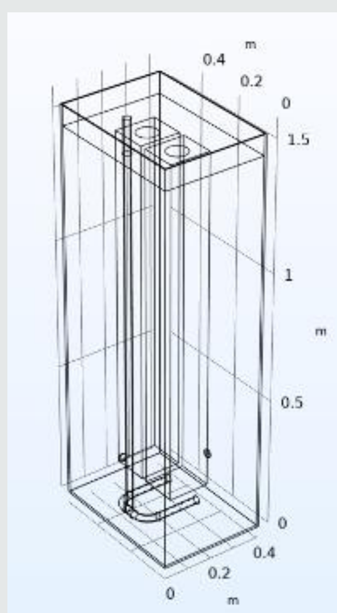


Figure 6: COMSOL model of Dal-SMBR

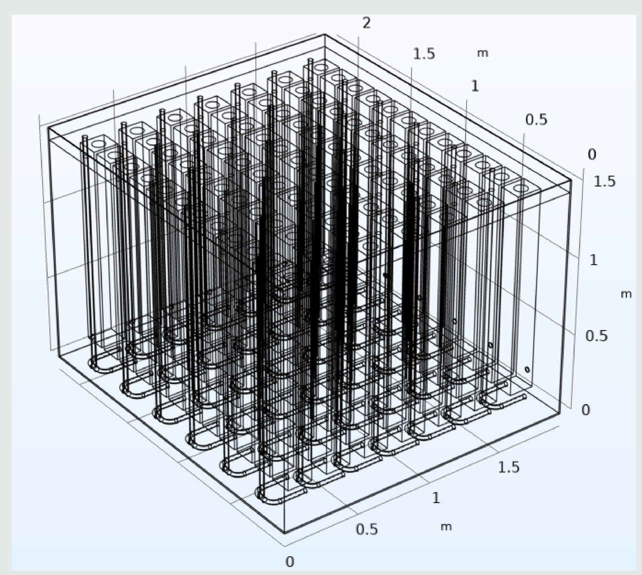


Figure 5: Full Scale Design from COMSOL

COMSOL Upscale

- The pilot system is a single unit which contains 2 ultra-filtration membranes
- The number of units for the upscaled design is scaled permeate flow divided by one unit permeate flow rounded up to a whole number
- Each unit has 20 aeration holes to prevent fouling and promote cross-flow. The aerator flow system flow is 4800 L/h per unit
- The surface area of each membrane which is 6 m.
- Equation 1. $N_{Membrane} = 2 \times N_{Unit}$
- Equation 2. $N_{Unit} = (\frac{Q_{Scaled\ Permeate}}{Q_{Permeate}})$
- Equation 3. $Q_{Aerator} = 4{,}800[l/h] \times N_{Unit}$

COMSOL Validation

- The model was validated by finding if the percent error was less than 5% between the experimental results and COMSOL modelling results for TPH
- The pilot scale model is valid and shows an accurate representation of the real-world outcome
- The Experimental significant figures impact accuracy of the error compared to the model

Run	Experiment (ppm)	Model (ppm)	Error (%)
3	0.19	0.183	3.68
5	0.13	0.125	3.85
9	0.26	0.25	3.85
15	0.16	0.155	3.13

	Pilot Scale	Full Scale
No. Units (2)	1	42
Feed Flow (L/h)	290	12,000
Permeate Flow (L/h)	240	10,000
No. Membranes (1)	2	84
Membrane Flux ($L/m^2 h$)	20	19.8
No. Aerators	10	840
Aerator flow (L/h) (3)	4,800	202,000

Dal-SMBR Processing Unit

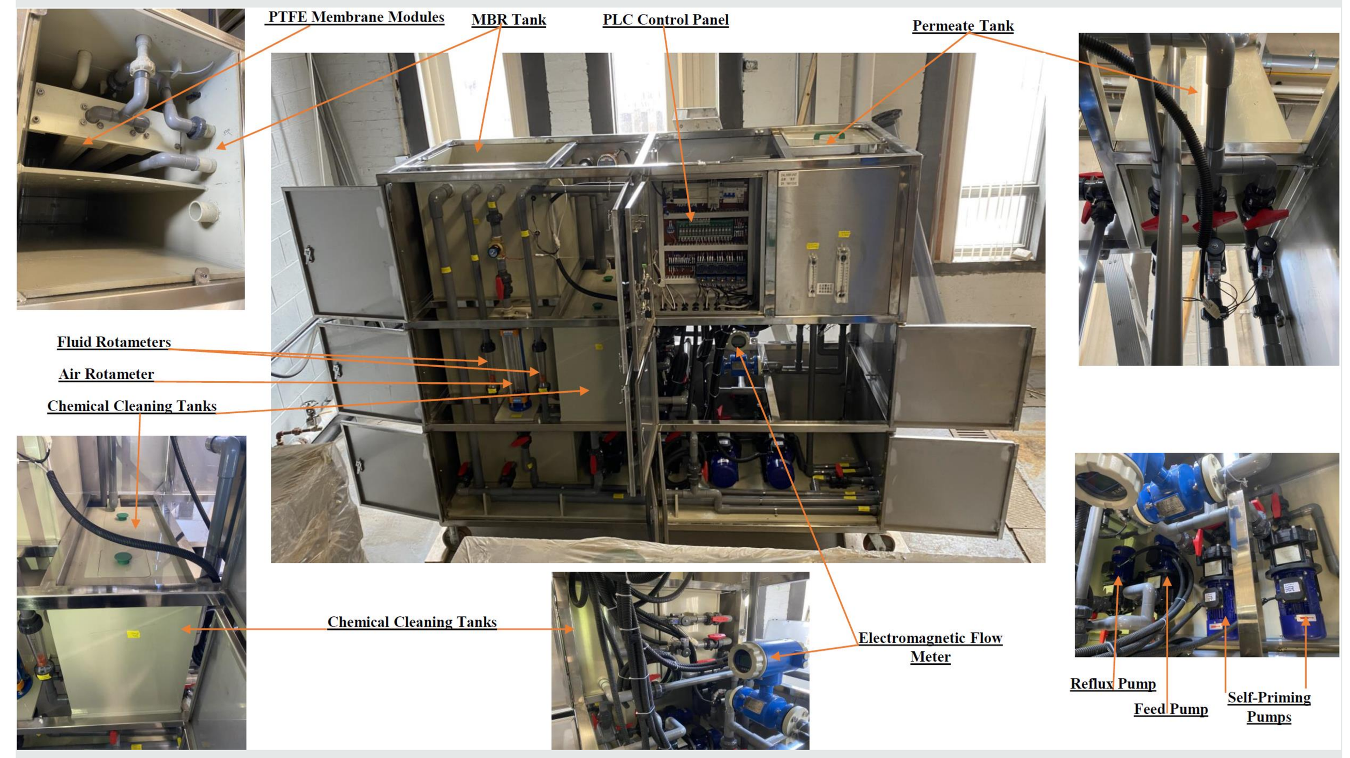


Figure 7: Dal-SMBR processing unit schematic

Conclusions and Recommendations

- Overall, the system performed exceptionally in reducing the concentation of the oily seawater well **below the 15ppm target**
- This method will **reduce oil contamination during ocean cleanup**, as there will be less handling and more time spent remediating the oily seawater
- The TPH removal rates were had very similar efficiency's for both the heavy and light fuel types
- Further research should be completed regarding membrane fouling

Acknowledgements

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