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Design of an Electrocoalescer Cell for Oil-Water Separation: Comparison of Droplet Distribution

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INTRODUCTION & AIM

Large amounts of oily effluent are always produced throughout the petroleum refining process. One of the petroleum industry's main challenges is disposing of oily effluent in an environmentally acceptable manner. The methods for treating oily wastewater have received increased attention recently. As a result, treating oily wastewater has become a pressing issue that all oilfield and petroleum companies need to investigate and address [1]. Since the coalescence of water droplets induced by an external electric field is widely acknowledged as one of the most effective methods for the petroleum industry to separate water from crude oil, electrostatic coalescence is a viable and efficient way to promote the coalescence of oil droplets and boost the efficacy of conventional methods [2]. Within this context, this work reports both simulations and experimental conditions for the design of an electrocoalescence cell intended for oil-water separation.

METHOD

The FEMM 4.2 program was used to define the electrode shape (Fig. 1), which led to the construction of the ideal electric field for the electrostatic cell (Fig 2).

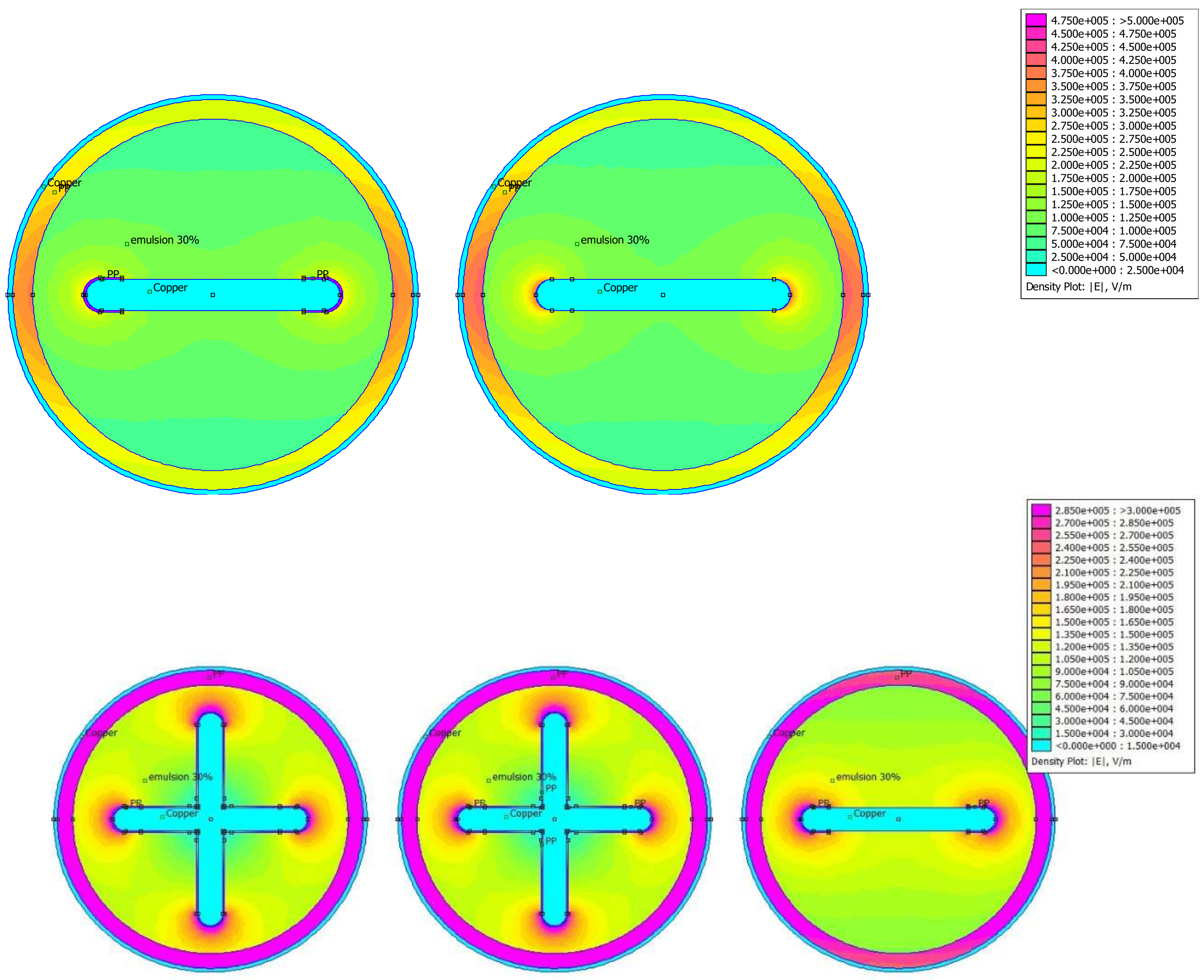


Figure 1. Electrode configuration chosen for this study: a) single bar; b) cross-bar

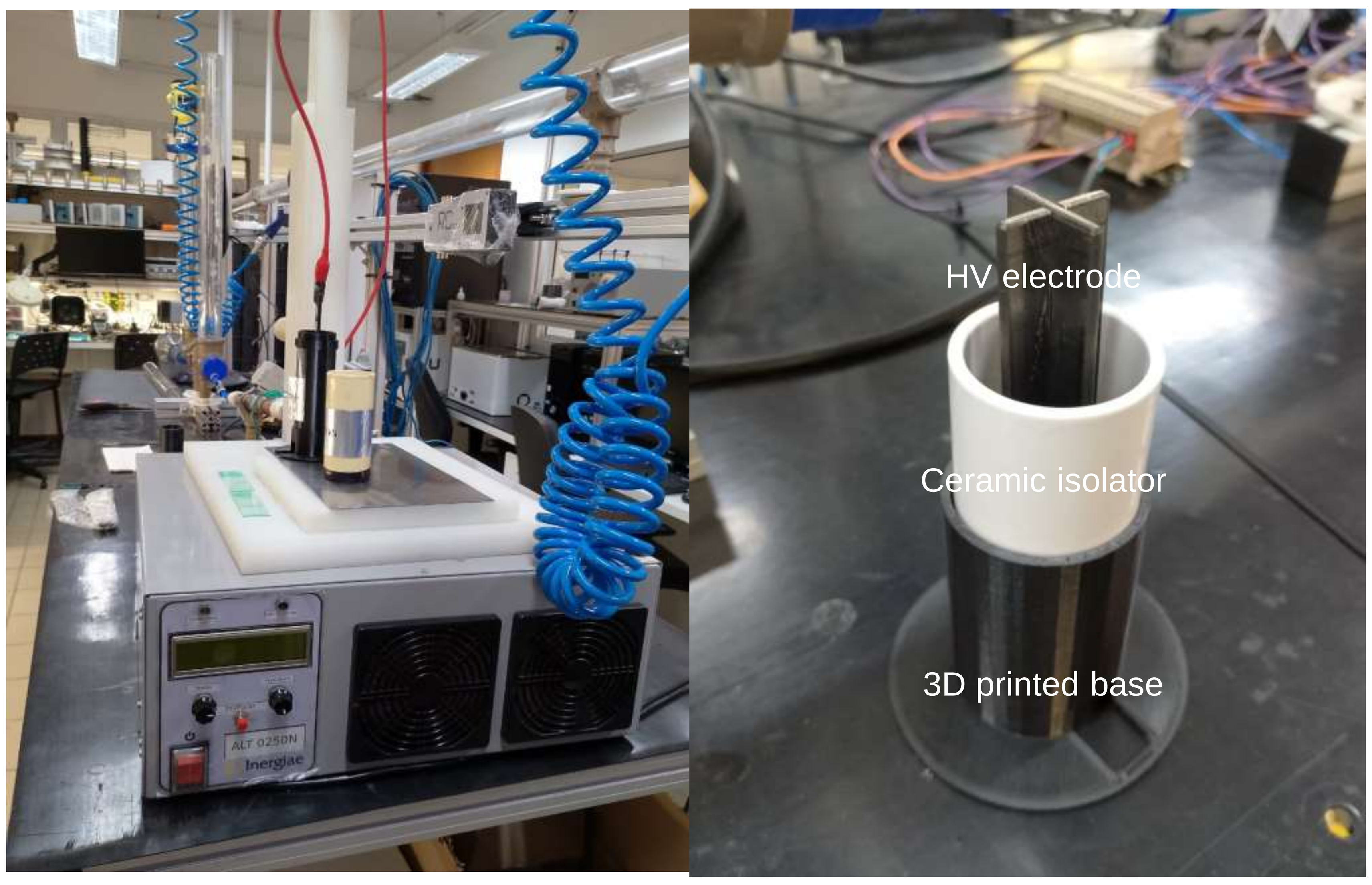
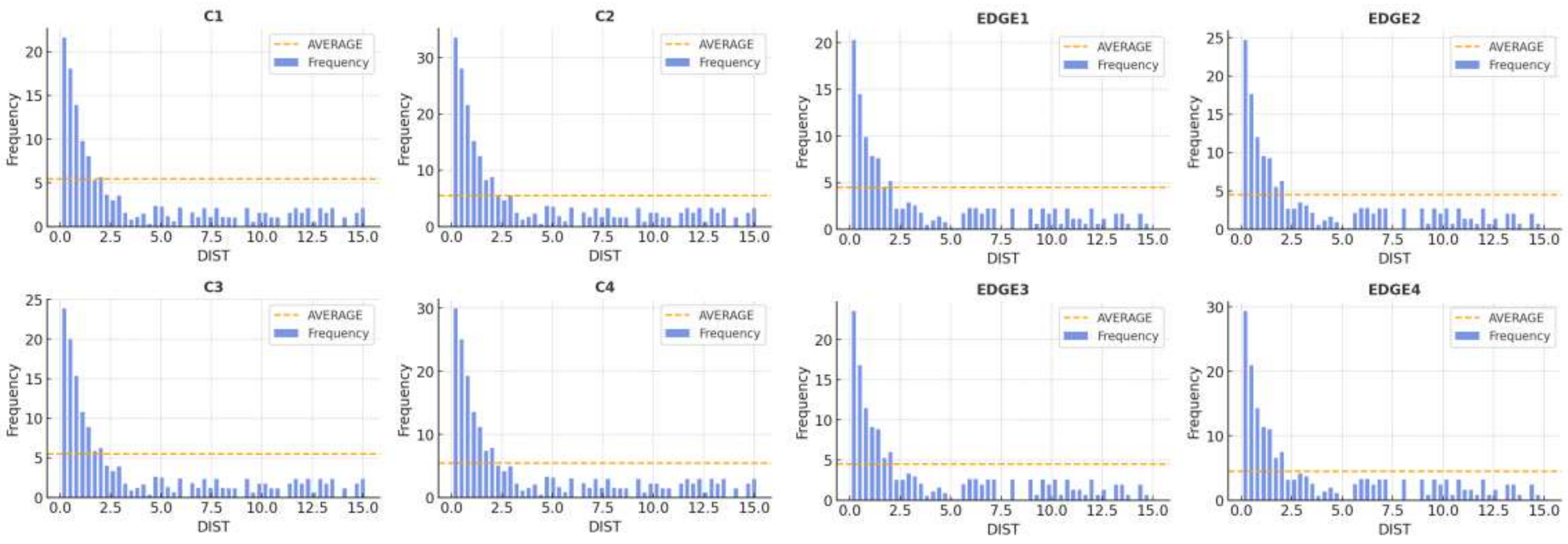


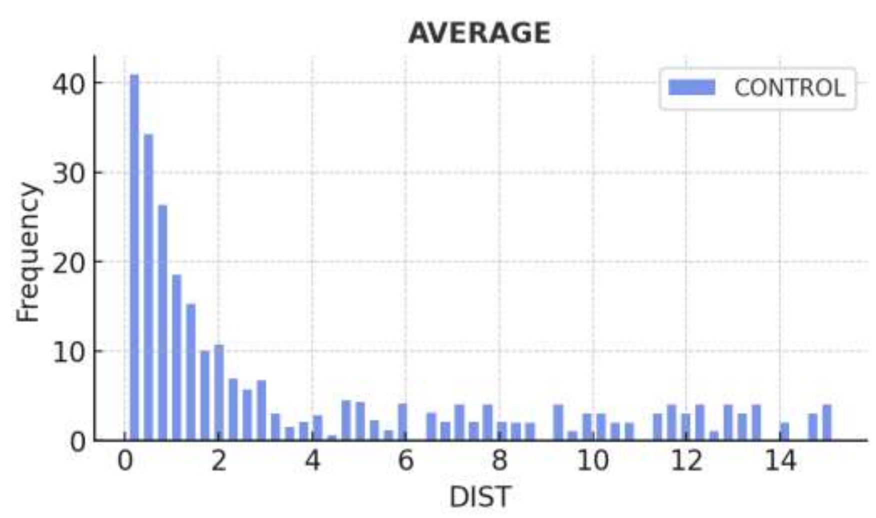
Figure 2. Assembled experimental apparatus and electrostatic cell.

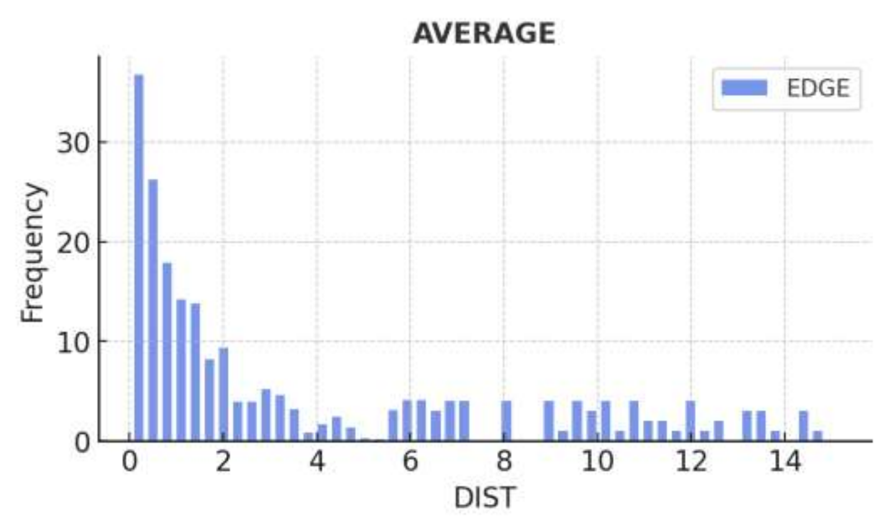
We used 1kV elecrtic field and 1 kHz frequency during 1 min. The emulsion was prepared using mineral oil (60%) and distilled water with dye (40%). The droplet size was analyzed using the imageJ software. To evaluate efficiency, droplet distributions were compared in two scenarios: Control (C1–C4) measurements without the direct influence of the electrodes. Electrodes (EDGE1–EDGE4): measurements performed in the regions of electric field action.

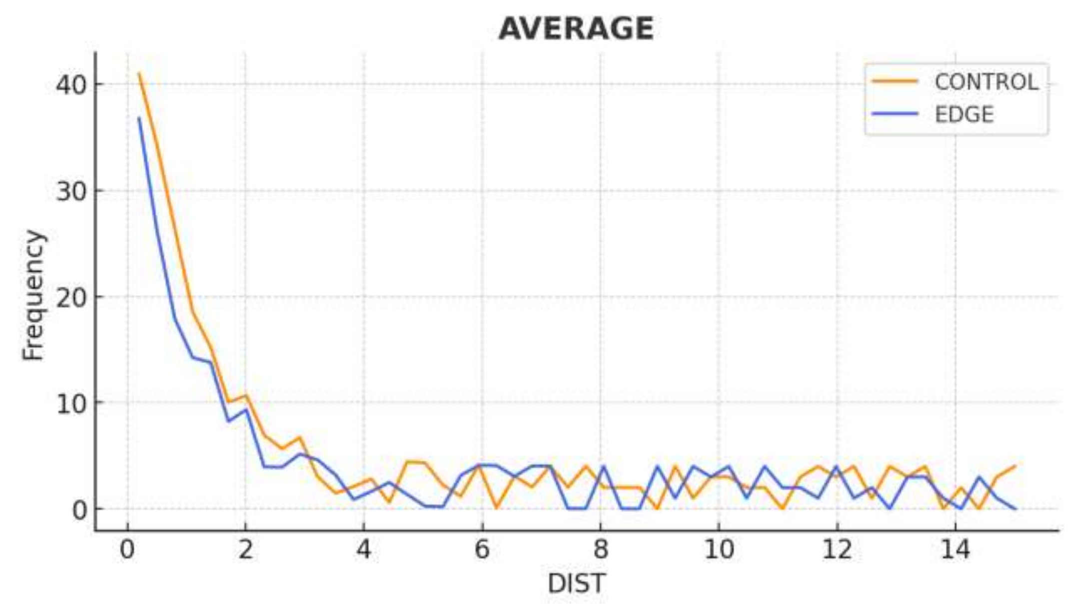
RESULTS & DISCUSSION



Droplet Distribution: In control (C1–C4) most droplets are found in bands smaller than 1.5 µm, with high frequencies. The distribution presents a sharp curve to the left, typical of systems where a high population of microdroplets predominates. The distribution averages (dashed line) show a concentration close to 1.0–1.6 µm, with few droplets larger than 4 µm. This characterizes low spontaneous coalescence in the system without an electric field. In electrodes (EDGE1–EDGE4) a shift in the distribution toward larger sizes is observed compared to the control. The absolute frequencies of droplets below 1 µm decrease, while droplets between 1.6–3 µm appear more prominently. The averages for each edge (EDGE1–EDGE4) are between 1.6 and 2.6 µm, indicating effective droplet growth by induced coalescence. The overall graph shows a longer tail, with the presence of droplets up to >6 µm, which are absent in the control. Microdroplet Reduction: The electric field reduced the concentration of very small droplets (<1 µm), which are essential for improving oil/water separation. Increased average diameter: While most droplets were below 1.5 µm in the control system, the average diameter increased to ~2 µm or more at the electrodes, favoring settling/removal.







EFFICIENCY

$$\gamma = \frac{N_0 - N_1}{N_0} \times 100\%$$

Y electrode edge 18,74 %

Y electrode face 4,42%

CONCLUSION

The electrocoalescence process proved to be more efficient than the control, increasing the average droplet size and reducing the presence of critical microdroplets. The highest efficiency was observed between 1.6–2.6 µm in average diameter, demonstrating the positive effect of the electrodes. The control (C1–C4) showed a low natural coalescence tendency, with a high predominance of microdroplets. The heterogeneity of the results at the edges suggests the need for adjustments in electrode positioning and intensity, seeking greater uniformity in the process. The comparative analysis indicates that the presence of the electric field significantly increased the coalescence rate, resulting in larger droplets and less dispersion. More heterogeneous distribution at the electrodes: Although effective at coalescing, the edge graphs show greater variability, with the coexistence of small and large droplets. This may be associated with uneven electric field strength or localized turbulence zones.

FUTURE WORK / REFERENCES

[1] YU, L.; HAN, M.; HE, F. A review of treating oily wastewater. *Arabian Journal of Chemistry,* Volume 10, Supplement 2, May 2017, Pages S1913-S1922.

[2] WU, Y.; LI, B.; JU, M.; XIANG, W.; SUN, Z.; WANG, H.; YU, K.; WANG, Z.; WANG, J. Nanoparticle-laden droplet-liquid film electro coalescence behaviors: A molecular dynamics simulation. *Journal of Molecular Liquids,* 400, 15, 2024, 124553.