Controlled Advanced Electro-oxidation for removal of dissolved WSO fraction from Produced Water

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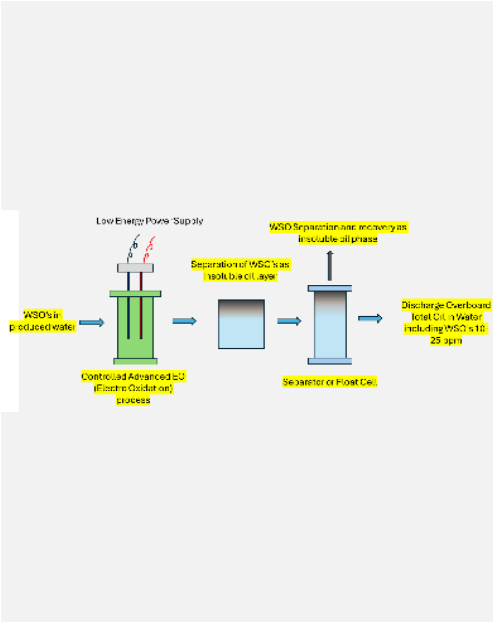

A controlled advanced electrooxidation technique has been developed as an alternative to chemical dosing and filtration systems for removal of WSO's (polar component of Hexane Extractable material (HEM) in oil) from produced water. The technique utilizes a proprietory composition of mixed metal oxides combined to convert the soluble WSO's in produced water into an insoluble organic layer that can be separated and recovered. The proprietory nature of coating and advanced PLC controlled process along with automatic polarity reversal provdies the benefit of performance at low enegy consumption, self cleaning electrode surfaces, reduced temperature, no chemical/ acid addition, no carbon filtration and a long operating life of 2-4 years in high saline and high scaling produced water. This technique is utilized for removal for strong chemical oily water emulsions, WSO's, BTEX, Sulfides, ammonia, glycols, PFAS/PFOS, biologicals and other TOC's (Total Organic Carbon) from contaminated produced water and wastewater streams.

Introduction

WSO's (Water Soluble Organics) are polar fraction of oil content (HEM -Hexane Extractable Material) in Produced water generated from Oil and Gas facilities. To discharge the produced water overboard, the effluent quality must comply with legal requirements, having no more than 29 ppm of HEM (determined according SM 5520 B). Presence of WSO's in produced water add to the HEM and cause problems to Oil and Gas operators to meet the overboad discharge limits. Traditionally high acid dosage combined with de-emulsifiers, flocculants, coagulants, carbon or membrane filtration have been utilized to remove the WSO's. However, this approach has been expensive and also impacts the asset Integrity and reliability due to corrosive nature of the acid/ chemicals added in produced water treatment trains and hazardous logistics involved. Various electrocoagulation and electroxidation techniques have been tested to remove the WSO's in contaminated water streams. However, the high scaling/ fouling in produced water, gas generation, footprint, high energy consumption and associated costs has limited the viability of the field scale deployment of the technology in offshore produced water.

The authors present a controlled advanced electro-oxidation technique which has been tested and implemented in commercial scale to remove the WSO's, BTEX, sulfides, PFAS/PFOS, Biologicals and TOC from various saline produced water and industrial wastewater both offshore and onshore. This field tested and proven technique overcomes the limitations of fouling, scaling, temperature, footprint, energy, gas generation and costs. Also there is added benefit of not needing to adjust PH with acid or add chemicals or carbon/media filtration.

Material and Methods

The technique has been tested in bench scale, pilot scale at WP&E Test facility and at offshore and onshore customer sites. The controlled advanced electro-oxidation system has been tested and deployed post LP separation system and pre-Flotation Units. The WSO's and contaminants in the test produced water and waste streams have been analyzed through Field IR spectroscopy and EPA

1664B through HEM and HEM SGT analysis. Additionally, the aquatic ecotoxicology of the samples has been determined according ABNT NBR 15411-3.

Results and Discussion

Various produced water samples from PRIO sites at offshore Brazil were tested at testing facility in Atlanta, GA, obtaining excellent results (Table 1).

Table 1: Results of SGT and SGT-HEM for PRIO samples tested in Atlanta

	TOG (EPA 1664 B)	TPH (Free oil) -EPA 1664 HEM SGT	WSO/ Polar compounds	% Efficiency for WSO	% Total Oil Removal Efficiency
	ppm	ppm	ppm		
FRADE SAMPLE					
INLET SAMPLE FILTERED THROUGH 50 micron FILTER PAPER	165.1	0	165.1		
WPE EO+ SEPARATOR OUTLET	21.7	9.4	12.3	93%	87%
WPE FINAL + 50 micron FILTER Outlet	12.1	0	12.1	93%	93%
ABL SAMPLE					
INLET SAMPLE	1550	17	1533		
INLET SAMPLE FILTERED THROUGH A 50 micron FILTER PAPER	1545	0	1545		1%
WPE EO+SEPARATOR OUTLET	23.5	10	13.5	98.5%	98.5%
WPE FINAL 50 micron FILTER OUTLET	12.2	0	12.2	99%	99%

Greater than 90% removal of WSO's were achieved without pH adjustment or addition of acid/clarifiers. The treatment reduced the ecotoxicity of the sample (Table 2), that shows the results from the tests performed according ABNT NBR 15411-3. Next phase of testing at offshore PRIO sites is scheduled for the last quarter of 2024, for a full scale capacity.

Table 2: Aquatic ecotoxicity of PRIO Field 2 samples, determined according ABNT NBT15411-3

ABL SAMPLE	pH	CE_{50}	L_i	L_s
INLET SAMPLE FILTERED THROUGH 50 micron FILTER PAPER	6,61	17,15	13,75	21,44
WPE EO+SEPARATOR OUTLET	6,10	27,28	20,91	35,67
WPE FINAL 50 micron FILTER OUTLET	5,27	28,02	23,09	43,14

Fig: 1 shows the WSO removal performance data from offshore test site in US. About 85-90% WSO removal efficiency is observed even with fluctuating feed oil and WSO content in produced water. Electrode surface was inspected after the trial and found to be clean with no scaling. Next phase of testing/ implementation offshore in US is scheduled for last quarter of 2024 for a full scale capacity.

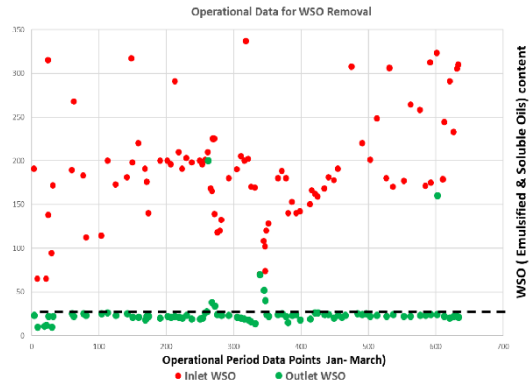

Figure 1. WSO removal performance data from offshore test site in US

Fig 2 shows 2-year operating data from an onshore site in GCC (Middle east) Greater than 90% TOC removal, 90% BTEX and 99% oily water emulsion removal in over 2 years of continuous operation at 10,000 bpd capacity. The estimated OpEx averages to 0.01-0.03 $/bbl.

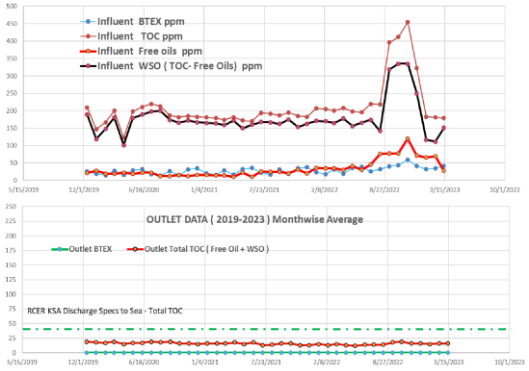

Figure 2 - 2-year operating data from an onshore site in GCC (Middle east

Conclusions

Based on the data and costs, this controlled advanced Electro-oxidation technique can be a viable alternate treatment method for WSO, emulsions, BTEX and TOC removal in produced and wastewater. Cost savings can be more than 90% in addition to lower environmental footprint (lower energy, lower waste, recoverable/ reusable byproduct etc). Further field scale testing and full scale implementation is underway in 2024 and 2025 and data shall be shared from continuous operation.