CSCE Annual Conference

Growing with youth – Croître avec les jeunes

Laval (Greater Laval)

June 12 – 15, 2019

DEVELOPMENT OF A MULTISTAGE MOBILE SYSTEM FOR OILY WASTEWATER TREATMENT

Yao, Y.[1], Huang, G.[1,3], An, C.[2], Zhao, S.[1], Chen, X.[1]
[1] University of Regina, Canada
[2] Concordia University, Canada
[3] gordon.huang@uregina.ca

Abstract: Produced water comes as a by-product during recovery of natural gas and crude oil from onshore and offshore production operations. Pollution caused by inappropriate disposal of produced water has become a widespread problem in many oilfields. This situation is especially poignant in developing of a new oil field. Many studies have been carried out on produced water treatment. However, traditional physical and chemical processes alone did not meet the requirement of discharge standards. It is also difficult to treat the large volume of produced water generated on remote site, where there is no appropriate infrastructure. The objective of this study is to design a mobile water treatment system to cost efficiently treat the oily wastewater. In this project, the key technical approach of the proposed project is the combination of electrocoagulation and membrane filtration with integrated intelligent automation and process optimization in the framework of a mobile treatment unit for produced water. Various treatment modules have been developed. Multistage electrocoagulation and membrane filtration have been developed and tested. Operating parameters for developed system have been optimized to improve treatment efficiency. Based on process technology and equipment performance, the treatment scheme on trailer platform has been determined to include consideration of both technical and economic efficiency.

1 PROJECT OVERVIEW

Produced water comes as a by-product during recovery of natural gas and crude oil from onshore and offshore production operations. Pollution caused by inappropriate disposal of produced water has become a widespread problem in many oilfields. This situation is especially poignant in developing of a new oil field. Many studies have been carried out on produced water treatment. However, traditional physical and chemical processes alone did not meet the requirement of discharge standards. It is also difficult to treat the large volume of produced water generated on remote site, where there is no appropriate infrastructure. The objective of this study is to design a mobile water treatment station to cost efficiently treat the produced water.

The technical approach of the proposed project is the combination of electrocoagulation and membrane filtration with integrated process optimization in the framework of a mobile treatment unit for produced water. Various treatment modules have been developed. Novel two-stage dynamic electrocoagulation and membrane filtration has been developed and tested. Operating parameters for developed system have been optimized to improve treatment efficiency. Based on process technology and equipment performance, the treatment scheme on trailer platform has been determined to include consideration of both technical and economical efficiency. During the treatment by electrocoagulation-membrane process, more than 95% of oil, TOC, COD, TSS and turbidity in produced water can be removed. The system can

also effectively remove about 90% of TDS and ions, including chloride, sulfate, sodium, calcium, manganese, etc. The quality of treated water can meet discharge requirements. It has been proved to be successful with this treatment system. The overall performance of developed treatment process is satisfactory. Treating produced water for beneficial recycle and/or reuse can mitigate the cost of water disposal, potentially adverse environmental impact and have a significant impact on sustainable development in Canada.

2 Innovation

In this project, the integrated system incorporates the various compact treatment modules into a mobile treatment system. Various integration practices are considered as means of enhancing the resilience of produced water treatment system. All needed treatment stages and equipment including pre-treatment and post-treatment are integrated as part of the container unit through special design. The system can be easily transported to sites where wastewater treatment is urgently needed. The containerized construction concept allows these units to operate as stand-alone portable wastewater treatment plants. The schematic structure of the developed mobile produced water treatment system is shown in Figure 1.

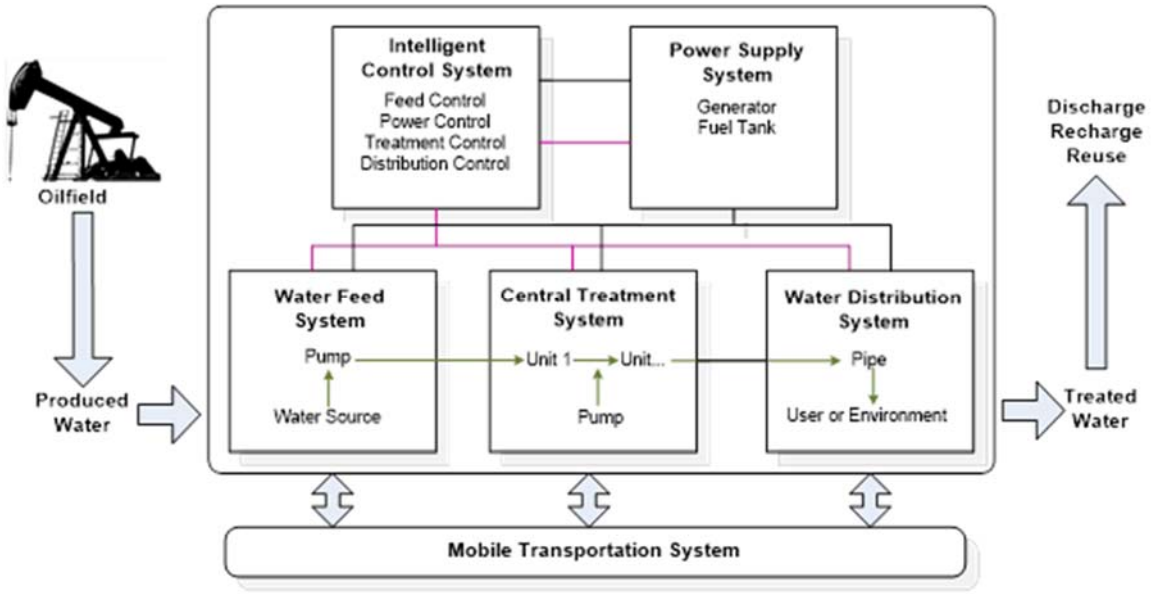

Figure 1. Schematic structure of mobile produced water treatment system

Figure 2 shows the treatment scheme. It's a complete process from oil pump to end user. In detail, the scheme is started with the EC. After EC, a dosing system is designed as chemical treatment for particular ion overload such as calcium. The aim is to reduce the calcium concentration if it's over the influent requirement of RO unit. This system can dose appropriate agents to facilitate the formation and precipitation of low-solubility calcium salts. Also, a flotation and sedimentation reactor is added after EC to relive the load of the bag filter. Otherwise the bag filter will need frequent manual operations which will lead to dramatic increase of operational cost. The ceramic UF and RO units have been tested to be effective and stable and they are also included in this treatment scheme. Detailed design is shown in Figures 3. Based on the experimental work using the pilot-scale system, the optimum operating parameters have been determined for each module. The results are shown in Table 1.

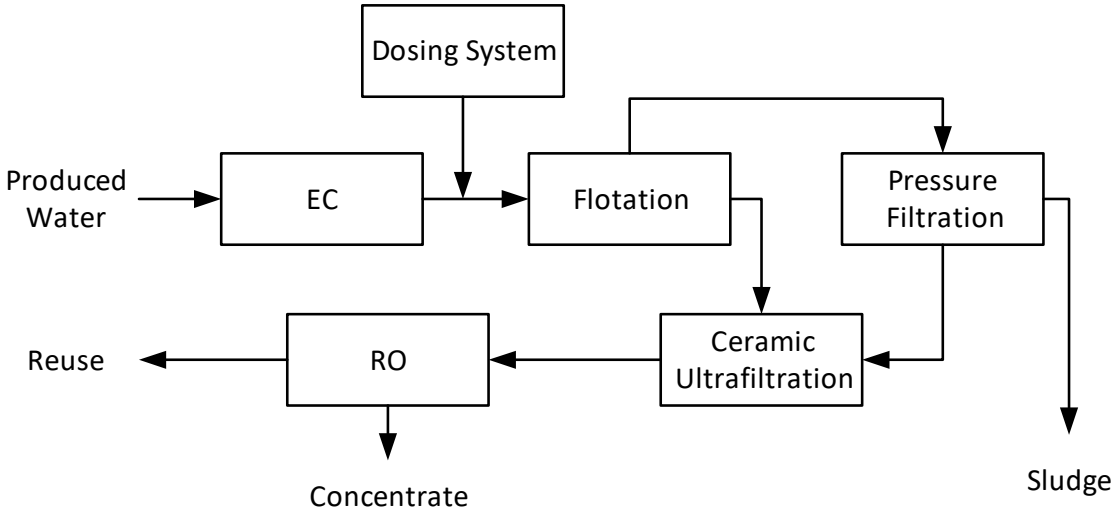

Figure 2. Treatment scheme

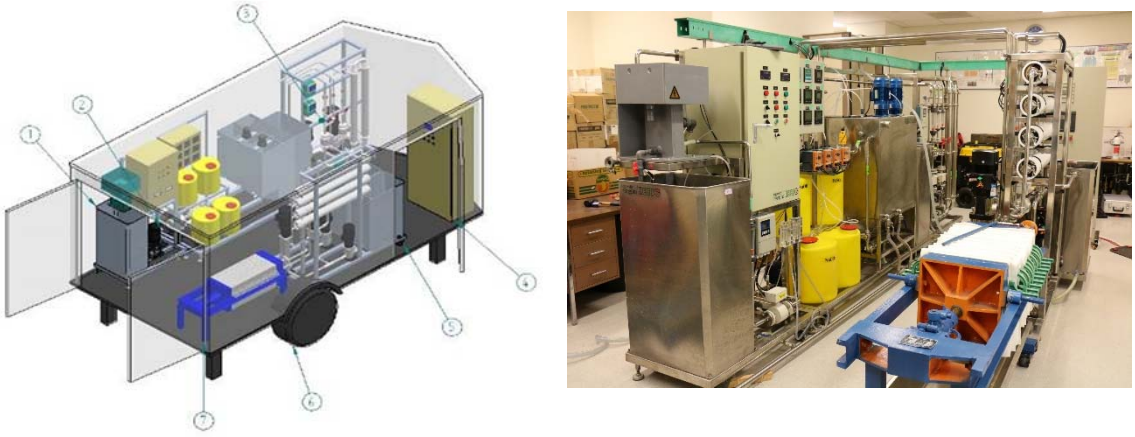

Figure 3. Design of trailer-mounted treatment system: (1) EC equipment; (2) reaction/sedimentation equipment; (3) UF membrane unit; (4) controller; (5) RO unit; (6) trailer platform; (7) pressure filter.

Table 1. Optimum operating conditions of the EC-membrane system and the pollutants removal efficiencies

Process	Parameters	Values
EC	Initial pH	7-8
	Current density (mA/cm^2)	6.46
	Time (min)	30
	Stirring rate (rpm)	150
UF	Transmembrane pressure (Mpa)	0.3
	Crossflow velocity (m/s)	3.2
	Temperature (℃)	45
	pH	~8

RO	Transmembrane pressure (Mpa)	2.1
	Flow rate (m^3/h)	1.5
	Temperature (℃)	35
	pH	8
Removal efficiency (%)	Oil	98.48
	COD	94.64
	Turbidity	99.87
	Hardness	96.53

3 Lessons Learned

To investigate the capability of EC for calcium removal, a test was conducted using EC+UF+RO. The raw water was firstly treated by EC for 1 and 2 hours. After filtered with a bag filter, the effluent was pumped through UF to remove residual oil components and RO to remove ions. The concentration of calcium was tested after EC treatment. It was observed that the EC was able to reduce calcium from 232.15 mg/L to 89.41 mg/L and 63.88 mg/L after 1- and 2-hours' treatment, respectively. The longer the retention, the more calcium reduced. For magnesium, the reduction by EC was insignificant. Due to the treatment of EC, the performance of UF and RO were improved. The quality of treated water was similar with the previous test. The permeate flux of UF was higher and more stable. The permeate flux of RO was much more stable than the previous test. However, the drop of permeate flux was still unacceptable because crystallization of calcium salt was formed, even at a calcium concentration level of 60 mg/L. It could lead to the break of the operation.

In summary, various treatment modules have been developed, operating parameters for developed system have been optimized to improve treatment efficiency of a multistage mobile system for oily wastewater treatment. The EC-UF-RO process was able to remove more than 98% of oil, TOC, COD, TSS and turbidity in produced water. The system can also effectively remove about 90% of TDS. The existence of Ca^{2+} suppressed the performance of OR unit, therefore chemical removal method has been applied to the effluent from EC to reduce the concentrations of Ca^{2+} and Mg^{2+}. During the continuous pilot test under 500L/h flow rate, the removal rate of oil content was 99%, 95% for Cl^-, 90% for SO_4^{2-}, 94% for Na^+, 97% for Ca^{2+} and 93% for Mg^{2+}.