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# Oil Produced Water treatment for oil removal by an integration of coalescer bed and microfiltration membrane processes

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ABSTRACT

This article presents an experimental investigation of Oil Produced Water (OPW) treatment for oil removal by integration of two processes: coalescer bed and microfiltration membranes (MFs). The objective is to overcome operational problems and limitations that both the processes present when used separately.

The coalescer bed was formed by cationic exchange resins, working in upflow condition. The MF unit used a polyetherimide hollow fiber submerged module with a permeation area of 0.5 $m^2$.

The investigations were conducted by using synthetic OPW with oil concentrations of 200–400 mg $L^{-1}$ and oil droplet diameters from 3 to 8 μm. In the coalescer bed the fluid velocity ranged from 4.4 to 17.4 m $h^{-1}$ and the bed height was 5 cm. The water recovery rate in MF was kept in the range of 0.75–0.90 by using a transmembrane pressure varying from −12 to −30 kPa.

The coalecer bed worked in steady state conditions, reaching an efficiency of 35–52%. The overall efficiency of the integrated process reached 93–100% and the oil contents ranged from 0.1 to 14.8 mg $L^{-1}$. These results indicate that the effluent in the integrated process has quality not only for injection, but also for reuse purposes.



## 1. Introduction

Oil Produced Water (OPW) is the major effluent stream of the oil production activities [1]. The management strategies usually adopted to deal with this matter are disposal in the sea or into underground formations, reinjection in the formation for pressure maintenance, enhancement or recovery, and use in other production activities. In all of these cases, a specific treatment may be required.

Apart from its large volumes generated, OPW has a very diversified composition. Oil and grease (O&G) concentration in OPW is a parameter that requires particular attention. Technologies commonly used for O&G removal are not usually capable of reaching the required efficiency [2], in particular if this compound is present in the OPW in the form of oil in water (O/W) emulsions with the oil droplet diameters below 10 μm [3].

Currently, the methods commonly available for the treatment of O/W emulsions are air flotation [4], hydrocyclones [5], coalescer bed [6], membranes [3] and filtration, the latter using beds of different kinds of materials such as sawdust [7], coal or peat [8] or organically modified clay [9].

However, these methods have some disadvantages, as follows [10]: the use of chemicals and costly problems in handling and disposal of large volumes of sludge (the case of air flotation); high operational complexity, power consumption, investment costs and operating costs, as well as dependence on the value of content O&G of OPW to be treated (the case of membranes) and low absorption, inefficient selectivity for the oil and inefficient regeneration of the bed, and high operating costs (the case of filtration).

This article presents an experimental investigation of OPW treatment for oil removal by integration of two processes: coalescer bed and microfiltration membranes (MFs). The main goal is to reach an effluent quality good enough for injection, discharge or reuse in surface activities. The objective of processes combination is to overcome the operational problems and limitations that both processes present when used separately.

Nowadays, it is possible to find a large amount of research work about both processes in the literature, not only in experimental terms but also in theoretical ones. However, there is no information so far about these two processes operating in an integrated manner.

Normally, the MF effluent presents a very low oil content. However, membrane fouling still is a major operational disadvantage

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once it causes flux decline, which implies the need for improvement of different kinds of strategies and techniques commonly used for the physical and chemical cleaning of the membrane system [3,11]. In this research, the coalescer bed is used as MF pre-treatment process, in order to attenuate the oil content in the OPW feed stream. The coalescer bed has already been successfully applied for OPW treatment [6,12]. In some cases, this process was used operating with an inlet oil concentration that is considerably high, reaching values of 2000 mg $L^{-1}$ [6] or 10,000 mg $L^{-1}$ [13]. In spite of that, further improvement is required in order to achieve an effluent with a better quality.

The coalescer bed can operate in either steady state or dynamic condition. The latter can occur if suspended solids are present in the emulsion. In this case, the operation is quite similar to a rapid filter of a water treatment plant, where the solids are gradually retained within the bed and the differential pressure between the feed and the output of the bed increases continuously with time [12].

If there are no suspended solids present in the water, the coalescer operates in a steady state condition. In this case, the coalescer bed retains some of the emulsion droplets at the beginning of the operation, where the permeability decreases. However, after few hours, the permeability is kept constant along the time [12].

In the steady state condition the volume concentration of the dispersed phase at the outlet remains the same as that at the inlet. The main difference between them is that in the outlet, it is assumed that the oil droplets have bigger diameters [13].

In this work, the coalescer bed used was a granular type, with the bed formed by cationic exchange resins with diameters ranging from 0.43 to 1.28 mm and working in upflow condition. The MF unit used was made of polyetherimide hollow fiber submerged module with mean pore size of 0.4 μm and permeation area of 0.5 $m^2$.

The coupled processes performance was investigated by using synthetic OPW produced by an industrial plant, with oil concentrations in the feed stream with values of 200 and 400 mg $L^{-1}$ and oil droplet diameters from 3 to 8 μm.

## 2. Experimental

### 2.1. Preparation of the OPW

The OPW used in testing was produced by an industrial plant specifically designed to generate synthetic samples of O/W emulsion. This plant is installed in a laboratory of water treatment and reuse, which is inside Cenpes, the Petrobras research centre.

In this plant, the oil is dosed in water, which flows through a pipeline containing a needle valve. This valve provides the necessary shear forces to create the emulsion. The desired diameters for the oil droplets are obtained by adjusting the intensity of the flux restriction inside this valve. This intensity is measured through differential pressure, whose values are obtained by two manometers located near the valve, one upstream and the other downstream. The oil droplets diameters are, then, measured by a "Malvern master sizer" in order to confirm if their values are within the desired range.

The oil used in the preparation of this emulsion was from an oil field called Roncador, which is located near the city of Rio de Janeiro. Its main features are: kinematic viscosity at the temperature of 50 °C of 9.950 $mm^2\,s^{-1}$, API density of 28.3° and relative density of 0.8824 kg $L^{-1}$. The oil is composed of 55.4% of saturated hydrocarbons; 27.0% of aromatics; 16.0% of resins and 1.6% of asphaltenes. The oil concentrations in the feed stream ranged from 200 to 400 mg $L^{-1}$ and oil droplet diameters from 3 to 8 μm. The oil droplets size distribution was characterized for each

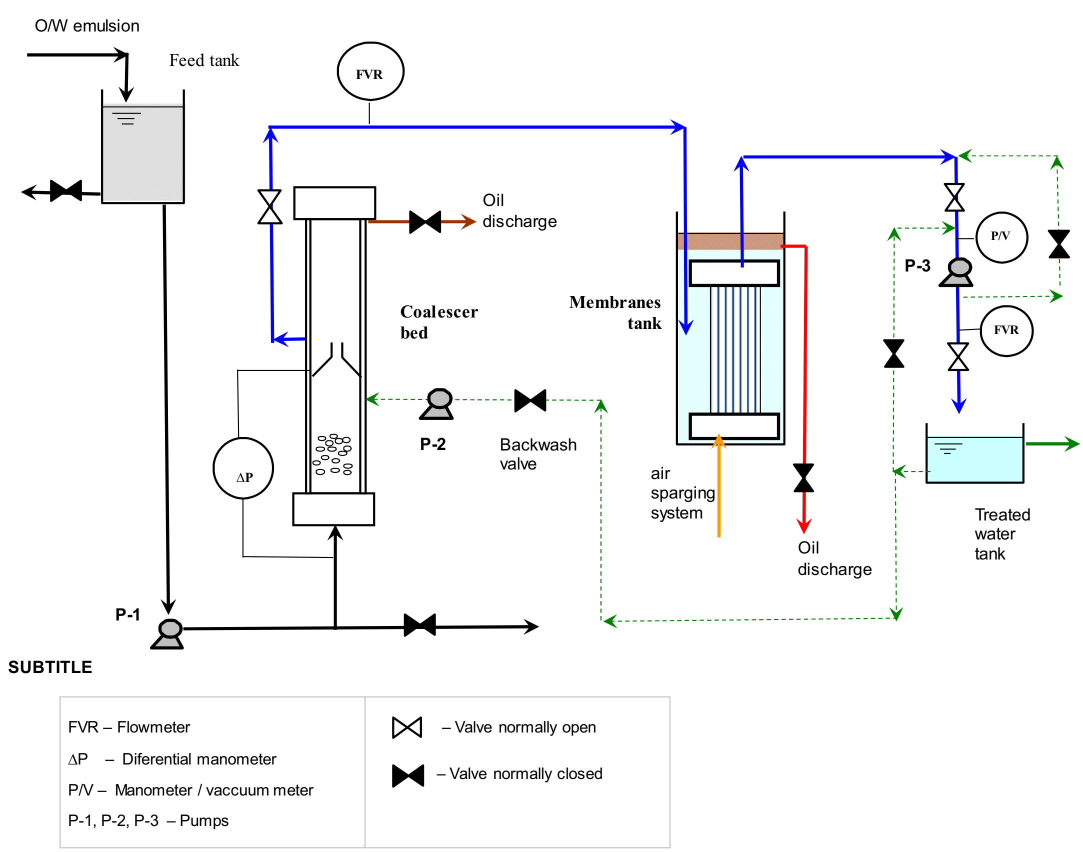


**Fig. 1.** Experimental unit containing the integrated process of coalescer bed and microfiltration membrane processes.