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ECONOMIC EVALUATION FOR COMBINATED MEMBRANE AND AOPs WASTEWATER TREATMENT METHODS

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Abstract: Membrane and Advanced Oxidation Processes (AOPs) are increasingly being considered as an alternative to conventional water and waste water treatment methods in anticipation of future demands for high standards and reduced environmental impact. However, the use of membranes for these applications is currently limited by the high capital and operating costs. This work investigate the economics of membrane processes for modell remediation oily waste water (0.01 wt.% petroleum) applications. The AOPs (eg. Preozonation) may increase the membrane separation process efficiency, especially the retention values. Compared the fixed capital and the working costs at the preozonation combinated microfiltration and for a two stage (MF/UF) membrane separation processes.
Keywords: fixed capital investment, working capital cost, preozonation, microfiltration, oil-in-water emulsion

1. INTRODUCTION

Large quantities of oily wastewater generated from various process industries, particularly refinery and metallurgical industries need to be treated before discharge to a sewage system. Discharging these effluents pollute the environment and also reduce the yield of oil. Amongst various processes for treatment of oily effluent, membrane separation process appears to be a most competent process. It has many advantages such as high oil removal efficiency, low energy cost and compact design compared with other conventional treatment process including mechanical separation, filtration, skimming, and gravity settling [Vasanth et al. 2011].

In recent years membrane technologies have been developing rapidly and their cost is continuing to reduce while the application possibilities are ever extending [Scholz et al. 2003; Ball 1999]. Compared with other separation or concentration systems, their energy and space requirements are low, and their modular design allows for relatively easy expansion [Scholz et al. 2003]. Many researchers have reported the oily wastewater treatment using ultrafiltration (UF) and microfiltration (MF) with polymeric and ceramic membranes [Kong et al. 1999; Waeger et al 2010; Abbasi et al. 2010].

Advanced oxidation processes (AOPs) have attracted much attention for the high efficiencies in the pretreatment of wastewaters (especially pesticides) and less secondary pollution. Ozonation is one of the AOPs widely used for wastewater pretreatment, in which ozone, as a strong oxidant, breaks down organic compounds into smaller molecules. Ozonation has been a treatment method widely used for tackling various industrial wastewaters [Sheng et al. 2003; Esplugas et al. 2002; Zhenglong et al. 2011].

Ozone pre-treatment may also be part of an integrated membrane system, and some researchers relating to membrane material development have combined these two treatments. Most of the membrane material used in these treatments consists of polymers [Sanghyup et al. 2005].

The preozonation combinated microfiltration process one of the possible application is for use petroleum hidrocarbons contaminated soil or ground water remediation.

The hungarian standard [28/2004. (XII. 25.) KvVM direction, Hungary] for soil and ground water remediation procedures threshold limit for the Total Petroleum Hidrocarbons (TPH) is 3 mg/L.

The aim of the research project was to prove the cost of preozonation combinated microfiltration in oil-in-water emulsion treatment.

2. MATERIALS AND METHODS

2.1. Materials

The calculation performing for membrane separation of model solution. In this study the model solution was an 0.01 wt.% petroleum oil-in-water emulsion. The membrane was an Polyethersulfone (PES) membrane with a 0.2 μm pore size, the filtration experiment caried out at 0.11 mPa transmembrane pressure, at 25°C temperature. Therefore in this economic evaluation study, used this parameters in a possible industrial application. The economic informations come from other researcher publication or some price request from the manufacturer. The hibrid process schematic figure in the Fig. 1. showed the possible fitting of preozonation and the microfiltration.

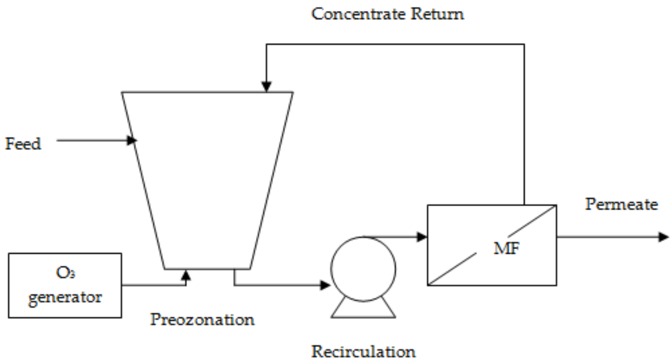

Figure 1. Shematic illustration of hybrid process route

2.2. Determination of the total capital investment – Methods

Salehi et al. (2014) published the calculation of total capital investment for the membrane unit and chemical plant includes fixed capital and working capital investments. Fixed capital investment comprises both direct and indirect costs.

Fixed capital investment:

Direct costs include investments for:

a) Main operating system (Polyethersulfone membrane systems).
b) Installation of main systems (15% of a)
c) Instrumentation and controls (6% of a)
d) Electrical (10% of a)
e) Installation (30% of a)
f) Buildings,yard and auxiliary (15% of a)
g) Land (6% of a)

Indirect costs however, include:

a) Engineering and supervision (30% of a)
b) Contractor's fees (5% of direct cost)
c) Construction expenses (10% of direct costs)
d) Contingency (8% of fixed capitals) [Salehi et al. 2014]

Direct costs are evaluated based up on the main operating systems (here, the membrane system) costs. It is obvious that the key parameter for the economic analysis is the total price of the membrane system required for the operation [Salehi et al. 2014].

Working capital investment includes the following elements:

a) Deprecations and amortization = (1/30) maintenance cost + (1/15) engineering and supervision + (1/5) membrane system
b) Energy consumption (4% of fixed capital)
c) Maintenance (4% of fixed capital)
d) Operation and performance (2% of fixed capital)
e) Laboring (3% of fixed capital)
f) Cleaning (3% of fixed capital) [Salehi et al. 2014]

Table 1. Fixed capital investment for membrane separation

Component	Cost (HUF)
Main operating system	2,108,925
Installation of main system	316,339
Instrumentation and controls	126,536
Electrical	210,893
Installation	632,678
Building, yard and auxiliary	316,339
Land	126,536
Sum of direct cost	**3,838,245**
Engineering and supervision	632,678
Contractor's fees	191,912
Construction expenses	383,825
Sum of indirect cost	**1,208,415**
Contingency	403,732
Fixed capital investment	**5,450,392**

Table 2. Working capital investment for membrane separation

Component	Cost (HUF)
Deprecations	471,231
Energy consumption	218,016
Maintenance	218,016
Operation and performance	109,008
Laboring	163,512
Cleaning	163,512
Working capital	1,343,295
Fixed capital	5,450,392
Total capital investment	6,793,687

Table 3. Data sheet of A2Z Onyx A-016 ozone generator

Data Sheet	
Voltage	110/120 or 220/240
Power	350 Watts
Flow Rate	6 LPM / 0.31 Nm^3/hr
Max. Ozone Production	560 g/hr
Output Pressure	9 psig / 62 kPa
Purity	93% +/- 3%
Dew Point	-100 F or -73 °C

Table 5. Working capital investment for preozonation

Component	Cost (HUF)
Deprecations	134,242
Energy consumption	111,012
Maintenance	111,012
Operation and performance	55,506
Laboring	83,259
Working capital	**495,031**
Fixed capital	**2,775,312**
Total capital investment	**3,270,343**

Table 6. Comparison the different combinated processes

	Total capital investment (Ft)
Preozonation/MF	10,064,030
MF/UF	13,587,374

3. RESULTS

3.1. Preliminary experiments

The model solution of 0.01 wt.% petroleum concentration TPH value is 81.27±3.52 mg/L. Alone the microfiltration experiment caused 5.71±0.38 mg/L TPH content. But if combinated the preozonation with microfiltration, 12 min ozonation is enough to reduced the permeate TPH content below 3 mg/L. 51.46 mg/L ozone dose (12 min long ozonation with 1 L/min ozone flow rate) reduced the TPH content 0.68±0.09 mg/L. At the model solution separation the membrane flux at VRR=5 (Volume Reduction Ratio) was 110.64±6.13 L/m^2 h. The yield of the process was 80% (VRR=5). Long time ozonation (60 min) is enough to oxidate the molecules, and the COD (chemical oxygen demand) and also the TPH value reduced to 0.0 mg/L, therefore in this study the concentrate also can treated with ozonation.

3.2. Economic evaluation for membrane separation

The feed volume is 200 m^3/day (8333.33 l/hour), therefore the effective membrane filtration area can determined as a following equation (1) [Vas-Vincze 2010]:

$$A = \frac{Y \cdot V_F}{J} \tag{1}$$

where: A – filtration area (m^2), Y – yield of the process, VF – feed volume (L/h), J – flux (L/m^2 h)

The membrane filtration area 60.255 m^2

The membrane unit cost is 35,000 Ft/m^2 (MF and UF membrane cost are very similar) [Vas-Vincze 2010] therefore the total membrane cost is 2,108,925 Ft. The fixed capital investment showed at the Table 1. The working capital investment showed at the Table 2, this is 4 times lower than the fixed capital investment. One membrane system total capital investment is 6,793,687 Ft, which include the working capital investment, and for one year long operation cost.

3.3. Economic evaluation for preozonation

The Ozone generator cost: 51.46 mg/L ozone is enought to icreased the membrane filtration efficiency, especcially the TPH retention, therefore at 8333.33 l/hour feed need 416 g/hour ozone, which can produce with A2Z Onyx A-016 ozone generator (Table 3). The ozone generator use air, and can separated to oxygen and nitrogen. The generator cost is 593,376 Ft. In this treatment process need a special (acid proof) vessel with diffuser (the ozone treatment place), which volume is 10 m^3, the cost is 1,143,000 Ft. The fixed capital investment calculation showed at Table 4, which demonstrated, the preozonation system fixed capital cost are about half part than the membrane separation process fixed capital. The working capital investment showed at the Table 5.

3.4. Economic evaluation of different separation processes

The Comparison of the different process cost showed that, alone the microfiltration is the cheapper, but the TPH removing efficiency is lower, than the other types of filtration apparatus. The two stage membrane filtration (MF/UF) system gave higher retention value of TPH (99,99 %), but the cost of this system are higher, because two membrane system need. Alone the UF is major to remove the TPH, but the concentration polarization layer resistance is high in this case, the operation cost are higher because the permeate flux is lower than the MF process, or the two stage processes. The optimum process for this oil-in-water separation is the preozonation combinated microfiltration, which total capital investment are lower, and the TPH remove is remarkable, showed the Table 6.. In this hybrid process the membrane separation concentrate, also can eliminated, with higher ozonation time, about 5 times longer ozonation is enough the TPH and COD total elimination.

4. CONCLUSIONS

The economic evaluation of hibrid processes showed that, the preozonation is an economic process at oil-in-water membrane separation, because the short time ozonation increased the membrane separation efficiency at the TPH retention values. The two stage membrane separation process gave higher efficiency, but the fixed capital and the working capital cost are about 25% higher than the preozonation combinated microfiltration.

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