Long-term operation of flocculation assisted direct ceramic microfiltration for up-concentration of municipal wastewater

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Introduction

The process of removing pollutants and potentially recovering resources from municipal wastewater through the use of direct ceramic microfiltration (DCMF) is considered to be a straightforward and effective method. However, for the DCMF process to be fully implemented, fouling and a decrease in flux must be overcome as they are the two major barriers. The effective membrane fouling control approaches by determining optimum operational conditions may extend the lifespan of the membranes and reduce the operational costs. Chemically enhanced primary sedimentation (CEPS) is one of the most extensively used methods for reducing the fouling rate of membrane.

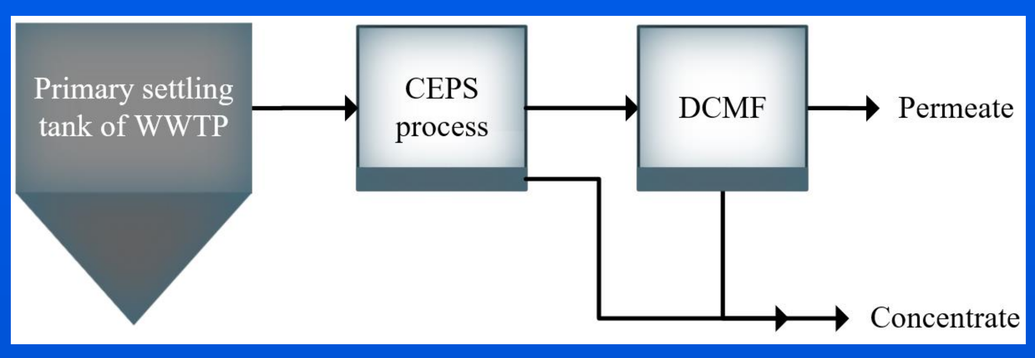

Figure 1. Schematic representation of the CEPS+DSMF process

This study was conducted to evaluate the long-term operating of CEPS+DCMF process with the aim of developing sustainable and effective up-concentration process for further energy recovery processes. To determine the optimum conditions the effect of flux, membrane cleaning procedure, and number of membranes used in the reactors was investigated.

Table 2. Operating conditions for CEPS+DCMF process

Phases of Operation	Number of membranes	Flux (LMH)	Operating time (hour)	Membrane cleaning procedure
Phase I	1	20	30	Chemical cleaning (In-situ)
Phase II	1	20	110	Physical+chemical cleaning (Offline)
Phase III	2	10	190	Physical/Physical+chemical cleaning (Offline)*
Phase IV	2	20	280	Physical/Physical+chemical cleaning (Offline)*

** Chemical cleaning procedures were used when physical cleaning was no longer effective in preventing membrane fouling.*

Results & Discussion

The variations of TMP with time during long-term operation of the CEPS+DCMF process are given in Figure 2. In order to mitigate the fouling, two membranes were integrated in parallel to the CEPS+DCMF system in the third operation phase, and the system was operated at 10 LMH flux with the same feed flow rate (Figure 1c). Therefore, effective management of membrane fouling is achieved, allowing for a process duration of approximately 130 hours without the requirement of chemical cleaning.

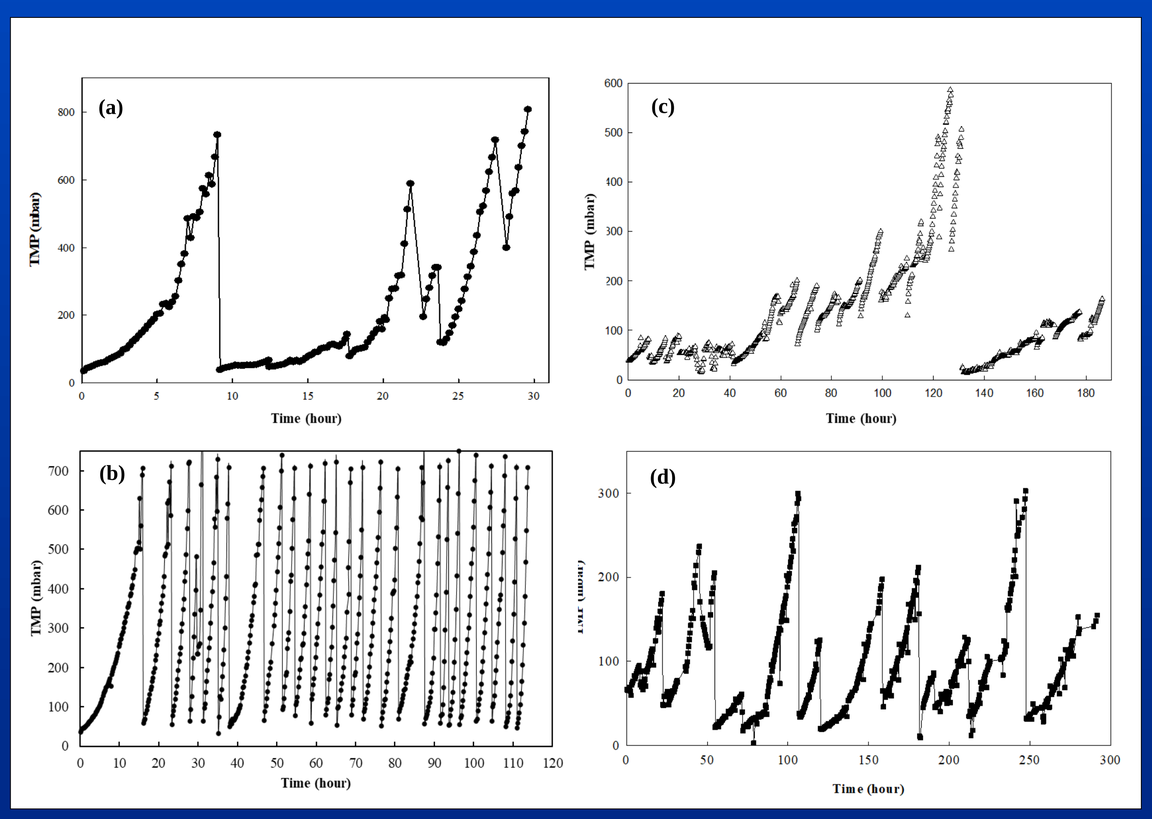

Figure 2. TMP profile as a function of time during Phase I (a), Phase II (b), Phase III (c), and Phase IV (d)

The effluent of the CEPS process was fed to the DCMF process, the samples collected from concentrate and permeate samples were characterized and the characterization results are given in Table 3. During the third phase of operation, COD in the supernatant ranged from 147 to 191 mg/L, COD in the concentrate reached a maximum concentration of 1752 mg/L, and COD in the permeate ranged from 46 to 81 mg/L. The wastewater influent on the CEPS+DCMF process was concentrated by about 7 times in terms of COD in this phase of operation.

Table 3. Characteristics of samples acquired by CEPS+DCMF process

Phases of Operation	Samples	pH	Conductivity (µS/cm)	COD (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	PO_4^{3-} (mg/L)
CEPS process	Feed	6.9-7.7*	1768-2080*	269-324*	197-352*	78-121*	7.9-10.1*
	Concentrate	7.2-7.7*	1817-2260*	1147-1239*	199-362*	54-120*	9.8-25.7*
	Supernatant	7.1-7.9*	1846-2070*	147-191*	197-358*	74-92*	8.1-9.3*
Phase I	Concentrate	7.9±0.2	2110±320	192±35	337±50	68±32	10.6±3.2
	Permeate	8.5±0.2	2000±320	74±20	326±55	81±22	8.0±1.8
Phase II	Concentrate	7.4±0.5	2046±83	290-822*	302±43	100±13	15.9±5.5
	Permeate	7.7±0.5	1940±71	38-151*	300±39	101±8	9.5±2.1
Phase III	Concentrate	8.0±0.9	1873-2360	194-1752*	196-405*	57-121*	9.9±5.4
	Permeate	8.5±0.5	1767-2280	46-81*	198-400*	76-111*	9.1±3.8
Phase IV	Concentrate	7.6±0.3	2270±65	792-1665*	346±19	78±23	15.7±2.3
	Permeate	7.9±0.2	1891±428	61±14	204±32	51±10	10.7±0.8

**These values are the lowest and highest values daily measured during operation of the CEPS+DCMF process.*

Figure 3 presents images of the SEM analyses performed, and provides the elemental composition obtained from the EDX results. In addition, the area where the EDX analysis was conducted is indicated in Figure 3 by a red box. Figure 3b shows the pollutants that foul membrane pores during long-term operating experiments and cannot be removed through physical cleaning.

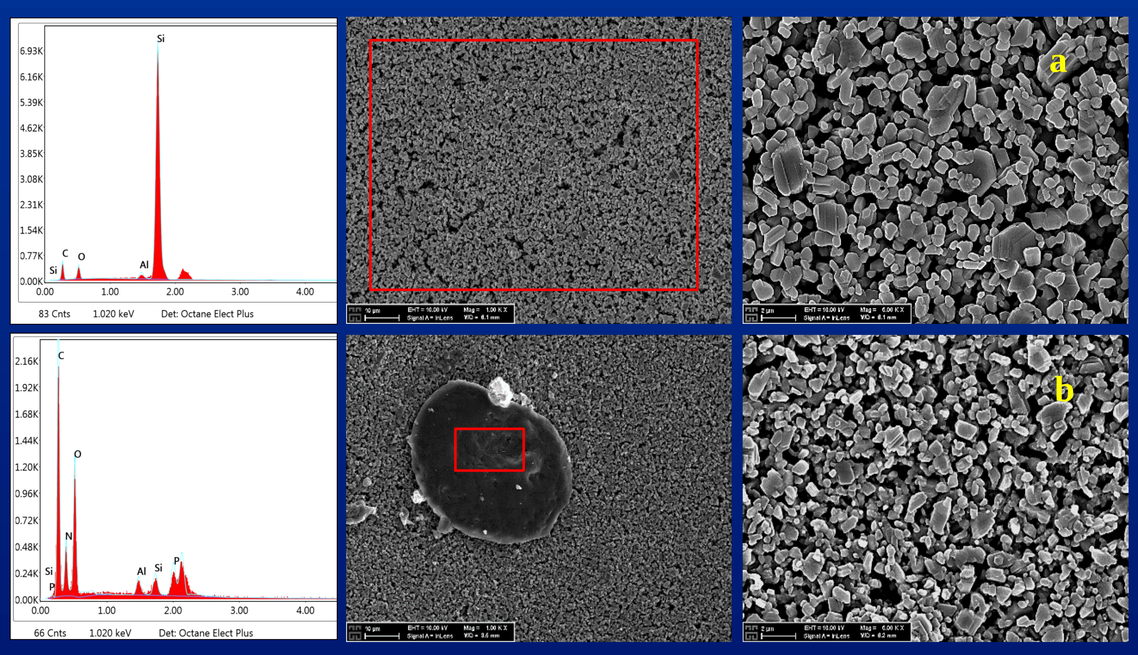

Figure 3: SEM images of the virgin (a) and physically cleaned ceramic membrane (b)

Conclusions

DCMF for up-concentration of municipal wastewater over the long term is possible through the use of straightforward and cost-effective procedures. The effective mitigation of membrane fouling is attained, enabling a process duration of roughly 130 hours without a requirement for chemical cleaning.

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