Reclamation of municipal wastewater using direct ceramic membrane filtration for agricultural reuse

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The increasing scarcity of freshwater and its influence on water and food security highlight the need for agricultural wastewater reuse as the most appealing alternative for relieving the demand for freshwater resources, which is especially important in arid and semiarid countries (Yan, Xu et al. 2021). In numerous countries, irrigation with secondary effluents from municipal wastewater treatment plant has already been widely applied on accounts of it being continuously generated and not affected by seasonal droughts (Racar, Dolar et al. 2020). Membrane technologies are considered an essential component in achieving the needed quality of treated wastewater. The direct use of membrane filtration (DMF) is considered a promising method by exhibiting their potential for wastewater treatment due to their ability to produce a high quality permeate (Nascimento and Miranda 2021). Due to the developments in making cost-effective flat-sheet ceramic membranes (CMs), the use of CMs in primary municipal wastewater treatment through direct ceramic membrane filtration (DCMF) is predicted to transform the method of wastewater treatment (Zhao, Li et al. 2020). However, the most significant disadvantage of membrane processes is membrane fouling (Gruskevica and Mezule 2021). This work aims to improve the performance of the reclamation of municipal wastewater using the coagulation and/or flocculation assisted DCMF process for the potential reuse in agricultural irrigation.

Cationic polyacrylamide (PAM) and $FeCl_3$ were used as a pretreatment process performed before DCMF. The pore size of the ceramic membrane used in DCMF experiments is 0.1 μm. The raw municipal wastewater used in the experiments was collected from the primary sedimentation tank effluent located in the wastewater treatment plant of the Kayseri Metropolitan Municipality, Turkey.

Table 1. The characteristics of primary sedimentation tank effluent

Parameters	Raw Wastewater
pH	7.8±0.2
Conductivity (μS/cm)	2810±25
Turbidity (NTU)	194±5
COD (mg O_2/L)	526±14
SO_4^{2-} (mg/L)	96.7±0.1
PO_4^{3-} (mg/L)	8.8±0.1
Cl^- (mg/L)	283.1±2.4
TSS (mg/L)	240±14

Prior to filtration tests, the coagulation and/or flocculation performance was tested by adding PAM and $FeCl_3$ to raw wastewater with different dosages using a six-paddled Jar Tester (Velp JLT6, Italy). In the jar test, PAM was used at concentrations of 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, and 5.0 mg/L, whereas $FeCl_3$ was employed at concentrations of 5, 10, 15, 20, 25, 30, 40, and 50 mg/L. In jar test experiments, PAM concentrations of 1 mg/L and $FeCl_3$ concentrations of 15 mg/L were found as crucial concentrations based on TSS, COD, and turbidity removal efficiencies. Then jar tests with combination of 0.5 and 1 mg/L PAM and 5, 10, and 15 mg/L $FeCl_3$ were performed. In the light of the results achieved with the jar tests, coagulation and/or coagulation+DCMF experiments were carried out at various concentrations and combinations. The transmembrane pressure (TMP) behavior of these coagulation and flocculation+DCMF tests is represented in Figure 2. Prior coagulation and/or flocculation showed improvement to mitigate TMP rising. The best performance in terms of TMP was obtained with 10 and 15 mg/L $FeCl_3$+DCMF. In the DCMF tests without flocculation or coagulation, TMP increased above 500 mbar after 227 minutes. For the PAM/ $FeCl_3$+DCMF tests, using PAM (0.5 and 1 mg/L) and $FeCl_3$ (10 and 15 mg/L)concentrations, TMP increased above 500 mbar after 277, 362, 422 and 497 minutes, respectively.

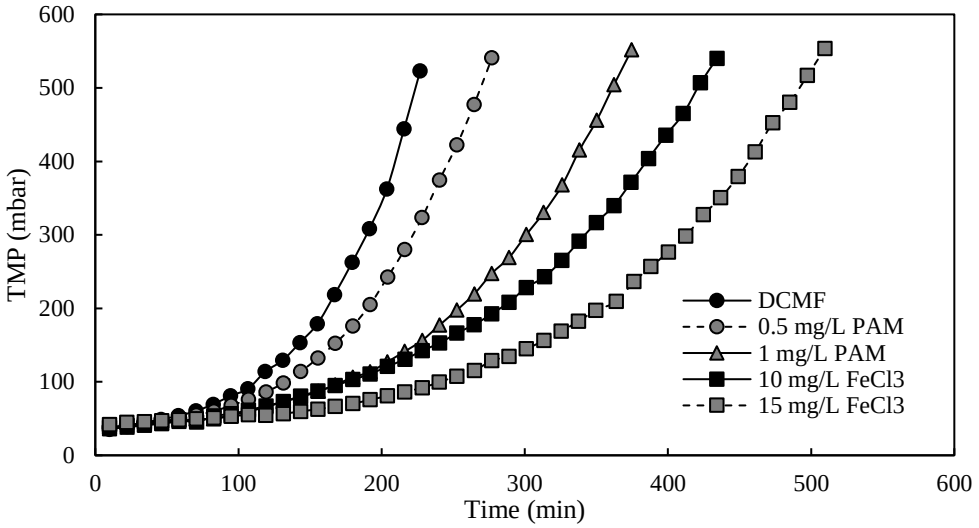

Figure1. TMP profile as a function of time for PAM+DCMF and $FeCl_3$+DCMF

Table 2 shows the samples characterizations collected in this coagulation and/or flocculation+DCMF experiments. The highest COD and PO_4^{3-} removal were achieved with 1.0 mg/L PAM+DCMF and 15 mg/L $FeCl_3$+DCMF, respectively. PO_4^{3-} concentration of DCMF was 7.8±2.1, and PO_4^{3-} concentration range in the permeate samples for PAM+DCMF and $FeCl_3$+DCMF were 7.6- 8.5 mg/L and 2.3-4.3 mg/L, respectively.

Table 2 The characterization of the wastewater (effluent samples) from the DCMF operations

Flocculant/ Coagulant	Sample	Conductivity (µS/cm)	COD (mg/L)	Cl^- (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)
DCMF	Permeate	1978±10	168±37	274±0	7.8±2.1	139±54
0.5 mg/L	Feed*	1971±1	251±10	273±14	9.1±2.1	93±4
PAM+DCMF	Permeate	1934±23	113±20	271±11	8.5±0.5	88±5
1.0 mg/L	Feed*	1916±32	221±56	281±14	6.3±2.2	113±6
PAM+DCMF	Permeate	1937±27	111±3	272±12	7.6±1.5	99±7
10 mg/L	Feed*	2012±54	152±33	277±36	3.8±1.0	88±7
$FeCl_3$+DCMF	Permeate	1978±21	126±23	296±1	4.3±0.6	92±3
15 mg/L	Feed*	2020±14	161±11	300±7	3.3±0.4	104±2
$FeCl_3$+DCMF	Permeate	1966±6	117±51	296±3	2.3±0.1	99±6

*Feed is the wastewater obtained after conducting a jar test

$FeCl_3$+DCMF configuration was found as the promising alternative to overcome fouling. These results indicated that $FeCl_3$+DCMF has a potential as simple and cost-effective pretreatment for producing of reclaimed water for agricultural irrigation from municipal wastewater.

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References

Gruskevica, K. and L. Mezule (2021). "Cleaning methods for ceramic ultrafiltration membranes affected by organic fouling." Membranes **11**(2): 131.

Nascimento, T. A. and M. P. Miranda (2021). "Control strategies for the long-term operation of direct membrane filtration of municipal wastewater." Journal of Environmental Chemical Engineering **9**(4): 105335.

Racar, M., D. Dolar, K. Karadakić, N. Čavarović, N. Glumac, D. Ašperger and K. Košutić (2020). "Challenges of municipal wastewater reclamation for irrigation by MBR and NF/RO: Physico-chemical and microbiological parameters, and emerging contaminants." Science of the Total Environment **722**: 137959.

Yan, Q., Y. Xu, L. Chen, Z. Cao, Y. Shao, Y. Xu, Y. Yu, C. Fang, Z. Zhu and G. Feng (2021). "Irrigation with secondary municipal-treated wastewater: Potential effects, accumulation of typical antibiotics and grain quality responses in rice (Oryza sativa L.)." Journal of Hazardous Materials **410**: 124655.

Zhao, Y.-x., P. Li, R.-h. Li and X.-y. Li (2020). "Characterization and mitigation of the fouling of flat-sheet ceramic membranes for direct filtration of the coagulated domestic wastewater." Journal of hazardous materials **385**: 121557.