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Technical Note

The role of a combined coagulation and disk filtration process as a pre-treatment to microfiltration and reverse osmosis membranes in a municipal wastewater pilot plant

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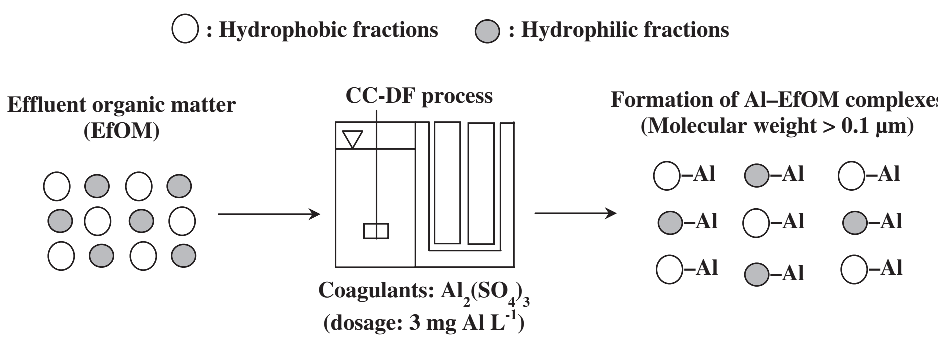
HIGHLIGHTS

- CC–DF was effective to reduce turbidity associated with cake layer formation.
- Residual coagulants after CC–DF could lead to formation of aluminium–EfOM complexes.
- Aluminium–EfOM complexes had a higher MW than the pore size of MF membranes.
- Formation of aluminium–EfOM complexes might increase the fouling potential of EfOM.
- Control of residual coagulants was required to use CC–DF as a pre-treatment of MF and RO membranes.

GRAPHICAL ABSTRACT



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ABSTRACT

A pilot study was conducted to assess the performance of a municipal wastewater reclamation plant consisting of a combined coagulation–disk filtration (CC–DF) process, microfiltration (MF) and reverse osmosis (RO) membranes, in terms of the removal of water contaminants and changes in characteristics of effluent organic matter (EfOM). The CC–DF and MF membranes were not effective for the removal of dissolved water contaminants. However, they could partially reduce the turbidity associated with the cake layer formation by particulate materials on the membrane surfaces. Furthermore, most of water contaminants were completely removed by the RO membranes. Although the CC–DF process could remove approximately 20% of turbidity, the aluminium concentrations considerably increased after the CC–DF process due to the residual coagulants complexed with both carboxylic acid and alcohol functional groups of EfOM. Those aluminium–EfOM complexes had a lower negative charge and higher molecular weight (>0.1 μm pore size of the MF membranes) compared to non-complexed EfOM. These results indicate that the control of the formation of the aluminium–EfOM complexes should be considered as a key step to use the CC–DF process as a pre-treatment of the MF and RO membranes for mitigation of membrane fouling in the tested pilot plant.

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1. Introduction

Municipal wastewater reclamation and reuse have become an attractive option to overcome the problem of water scarcity caused by industrialisation, urbanisation, rapid growth of population, and climate change (Wintgens et al., 2005; Chon et al., 2012a). Nevertheless, the direct use of the reclaimed wastewater for drinking and/or irrigation may provide adverse impacts on the aquatic ecosystem and/or human health due to its high contents of heavy metals, metalloids, and micropollutants, including pharmaceuticals and personal care products, endocrine disrupting chemicals, disinfection by-products and other persistent organic compounds (Tanaka et al., 2001; Kolpin et al., 2002; Kim and Aga, 2007; Alturki et al., 2012; Chon et al., 2013a). Therefore, the application of a tertiary treatment process to remove micropollutants (i.e., pharmaceuticals and personal care products, endocrine disrupting chemicals, disinfection by-products and other persistent organic compounds) from secondary effluents after conventional biological wastewater treatment is considered as an essential step for municipal wastewater reclamation and reuse (Chon et al., 2012b).

Among various wastewater treatment processes, membrane processes, including membrane bioreactor (MBR), microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), reverse osmosis (RO), and membrane distillation, have received great attention as a promising technology for reclamation and reuse of municipal wastewater due to its high efficiency and cost effectiveness (Wang et al., 2011; Alkhudhiri et al., 2012; Chon et al., 2012c). In general, biological wastewater treatment processes (i.e., activated sludge and MBR) and/or low-pressure membrane processes (i.e., MF and UF) are not effective for the removal of dissolved organic, inorganic materials, nutrients and micropollutants (Qin et al., 2004; Bellona and Drewes, 2007; Kim et al., 2007). Thus, high-pressure membrane processes (e.g., NF and/or RO) are usually applied to municipal wastewater reclamation systems after MF/UF or MBR for the removal of dissolved water contaminants, mainly micropollutants from secondary effluents (Chon et al., 2011, 2012b). Based on these reasons, the dual membrane process composed of MF/UF and RO is regarded to be one of the best combinations to meet the water quality criteria for municipal wastewater reclamation and reuse (Del Pino and Durham, 1999; Comerton et al., 2005).

In recent years, there has been a rapid growth and development of membranes technologies, in terms of membrane properties related to fouling resistance (e.g., hydrophobicity), operating and management protocols (e.g., pre-treatment, procedures for backwashing, physical and chemical cleaning, dosage of anti-fouling and anti-scaling agents) (Chon et al., 2013b). However, membrane fouling caused by effluent organic matter (EfOM) composed of natural organic matter derived from drinking water and soluble microbial products produced during biological wastewater treatment processes, such as activated sludge and MBR, remains a major obstacle for practical applications of membrane processes in wastewater reclamation and reuse since it may lead to flux decline which can increase the operating cost (Choi et al., 2006; Choi and Ng, 2008; Her et al., 2008; Chon et al., 2012a). Previous studies reported that hydrophilic fractions of EfOM capable of passing through pre-treatments (i.e., coagulation, MBR, MF and UF) play a key role in the formation of membrane fouling on the surfaces of NF or RO membranes (Jarusutthirak et al., 2002; Li et al., 2007). Even though many studies have been performed to investigate the effects of pre-treatment methods on fouling mitigation of membranes processes for wastewater reclamation and reuse (Chon et al., 2012a), the knowledge on a combined coagulation and disk filtration (CC–DF) process as a pre-treatment of the integrated membrane system (i.e., MF/UF and RO membranes) is still lacking as coagulation has been commonly used as a pre-treatment of MF/UF and RO membranes during the past decades (Chon et al., 2012c). Recent studies have investigated the effects of a CC–DF process on fouling characteristics of UF and RO membranes (Chon et al., 2012a, 2013b). Nevertheless, they have primarily focused on characterisation of membrane flaunts to elucidate fouling mechanisms in a pilot plant. Therefore, there is a great need for investigating changes in physicochemical characteristics of EfOM by a CC–DF process (i.e., functional group compositions and relative hydrophobicity) which are closely related to the formation of EfOM complexes with coagulants.

The main aim of this study is to evaluate the removal performance and mechanism of water contaminants, in terms of organic materials, metals, metalloids and nutrients (i.e., nitrogen and phosphorous species) through the municipal wastewater reclamation pilot plant consisting of a CC–DF process, MF and RO membranes. Furthermore, the physicochemical properties of EfOM in the raw and treated wastewaters were rigorously characterised using various analytical methods to provide valuable insights into the viability of the CC–DF process as a pre-treatment of the MF and RO membranes for membrane fouling mitigation.

2. Materials and methods

2.1. Configuration of the pilot plant

During this study, the tested municipal wastewater reclamation pilot plant comprised of the CC–DF, MF and RO membranes was continuously operated at Ansan wastewater treatment plant (Ansan, Gyeonggi-do, Korea), as illustrated in Fig. 1. Secondary effluents of Ansan wastewater treatment plant (498.5 $m^3\ d^{-1}$) equipped with a biological nitrification–denitrification process were treated by coagulation (dosage of aluminium sulphate ($Al_2(SO_4)_3$): 3 mg Al L^{-1}) and coagulated particles were directly removed by DF consists of two layers of mesh fabrics (effective surface area: 10.5 m^2; recovery efficiency: 97%; PETEX, Sefar, Heiden, Switzerland) and then filtered with hollow fibre MF membranes (effective surface area: 126 m^2; recovery efficiency: 92%; Kolon Industries, Gwacheon, Gyeonggi-do, Korea). The sodium

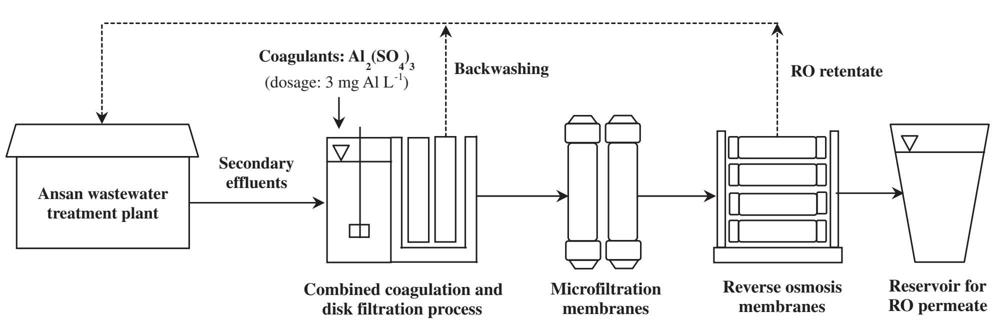

Fig. 1. Configuration of the municipal wastewater reclamation pilot plant consisting of the CC–DF, MF and RO membranes.

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