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Characterizations of NOM included in NF and UF membrane permeates

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Abstract

The characteristic changes in the natural organic matter (NOM), from the feed to the permeate, due to nanofiltration (NF) and tight-ultrafiltration (UF), were investigated in terms of size (molecular weight), structure (hydrophobic and hydrophilic fractions), and functionality (charge density in terms of carboxylic acidity). These characteristic changes were expected to be associated with the reactivity of the disinfection by-products (DBP), fractions of biodegradable dissolved organic carbon (BDOC), and assimilable organic carbon (AOC) relative to the total organic carbon. The BDOC and AOC analyses demonstrated that the NOM included in the NF and tight-UF permeates were more biodegradable than those included in the feed waters, which were relatively hydrophilic and smaller, than those in the feed waters. The influence of the hydrodynamic operating condition in terms of the J_0/k ratio on the characteristics of the NOM included in the NF and tight-UF permeates was also demonstrated. In addition, the effects of the pH, ionic strength, and calcium ions on the specific UV absorbance (SUVA) values of the NOM in each of the feed and permeate waters, were demonstrated for a better understanding of the above characteristic changes, and to determine the applicability of the SUVA analysis for the characterization of the NOM.

Keywords: Nanofiltration/ultrafiltration; NOM characteristics; Size/structure/functionality; DBP reactivity; Biodegradability; SUVA

1. Introduction

The natural organic matter (NOM) that occurs in drinking water sources is problematic in that it produce disinfection by products (DBP) during chlorination, enhancing bacterial regrowth and biofilm formation in the distribution system. These adverse aspects of the NOM in drinking water treatment have driven utilities to consider advanced treatment processes. Of particular interest are the uses of nanofiltration (NF), and perhaps tight-ultrafiltration (UF), membranes for the removal of the NOM. NF and tight-UF membranes are usually made of polymeric films with molecular

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weight cutoff (MWCO) values between 200–1000 and 1000–10,000, respectively. Recent research has revealed that the NOM can be effectively removed by NF, and to a less extent, by tight-UF membranes through a combination of size exclusion and electrostatic repulsion mechanisms [1,2]. However, to optimize the operation of NF and tight-UF membranes, for the minimization of the aforementioned adverse aspects, not only the quantitative amount of NOM removed by the membranes, but also the qualitative changes in the NOM characteristics from the feed to the permeate water, should be rigorously considered.

The objective of this study was to investigate the characteristics of the NOM included in the NF and tight-UF permeates, including the size (molecular weight), structure (hydrophobic and hydrophilic contents), and functionality (ionizable functional groups), compared to those of the feed water NOM. Emphasis was placed on the influence of these characteristic changes in 1) the reactivity (= DBP formation potential (DBPFP)/DOC) of haloacetic acids (HAA) and trihalomethanes (THM) and 2) the relative fraction (= BDOC (or AOC)/DOC) of the biodegradable dissolved organic carbon (BDOC) and assimilable organic carbon (AOC), of the total carbon of NOM included in NF and tight-UF membrane permeates. The specific UV absorbance at 254 nm (SUVA = UVA_{254}/DOC) values of the NOM included in the feed and permeate waters were also compared; the SUVA value represents relative fraction of aromatic NOM components as aromatic portions exhibit high UV absorbance at 254 nm. It has been identified that the UVA–NOM relationships depend not only on the origin of the NOM (i.e., specific for a given water source), but also on the seasonal changes and temperature variations [3,4], thus specific UV absorbance (SUVA = UVA_{254}/DOC) is often used to represent these relationships. The effects of the pH, ionic strength (IS), and calcium ions on the SUVA values of the NOM included in the feed and permeate waters were also investigated. Based on our results, the changes in the NOM characteristics in terms of size, structure, functionality, and SUVA, from the feed to the permeate, and their influence, in terms of the DBP reactivities and relative fractions of BDOC and AOC, are delineated and discussed.

2. Experimental methods and analyses

2.1. *Preparation of the feed waters and collection of the permeates*

Two different feed waters containing either Suwannee River NOM (SRNOM) or Nakdong River NOM (NRNOM) were used for both the nanofiltration and tight ultrafiltration. The SRNOM was obtained from the International Humic Substances Society (Golden, Colorado), in powder form, and used without further purification as the bound iron and ash contents were very low. A concentrated NRNOM solution was prepared with the source water (Nakdong River, Bansong, Korea), using a reverse osmosis membrane (Saehan, Gyungsan, Korea), and the salt level was reduced by electrodialysis (ED), followed by freeze-drying to make a powder. Both the NOM were dissolved in de-ionized (DI) water to make 1.0 g/l stock solutions for further uses. The NF and tight-UF membrane permeates were collected during crossflow filtrations by continuously disposing of the permeate [5]. Prior to the permeate collection experiments, the membranes were stabilized and equilibrated in the test cell, using NOM-free DI water for 12 h. At the end of this step, the initial flux was adjusted to the desired value (but crossflow velocity was maintained constant for all cases) to demonstrate the influence of the J_0/k ratio (ratio of water molecule transport by permeate flux to NOM molecule transport by back diffusion [1]) on the characteristics of the NOM included in the permeates. The permeate collection experiments were initiated by the addition of the NOM stock solution to NOM-free feed water, to the desired NOM concentration (i.e., 10 mg/l), with neither the pH nor IS adjusted (after the NOM addition,