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Reduction of DOM fractions and their trihalomethane formation potential in surface river water by in-line coagulation with ceramic membrane filtration

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ABSTRACT

This research was aimed at investigating the reduction of DOM fractions and their trihalomethane formation potential (THMFP) by in-line coagulation with 0.1 µm ceramic membrane filtration. The combination of ceramic membrane filtration with a coagulation process is an alternative technology which can be applied to enhance conventional coagulation processes in the field of water treatment and drinking water production. The Ping River water (high turbidity water) was selected as the raw surface water because it is currently the main raw water source for water supply production in the urban and rural areas of Chiang Mai Province. From the investigation, the results showed that the highest percent reductions of DOC, UV-254, and THMFP (47.6%, 71.0%, and 67.4%, respectively) were achieved from in-line coagulation with ceramic membrane filtration at polyaluminum chloride dosage 40 mg/L. Resin adsorption techniques were employed to characterize the DOM in raw surface water and filtered water. The results showed that the use of a ceramic membrane with in-line coagulation was able to most efficiently reduce the hydrophobic fraction (HPOA) (68.5%), which was then followed by the hydrophilic fraction (HPIA) (49.3%). The greater mass DOC reduction of these two fractions provided the highest THMFP reductions (55.1% and 37.2%, respectively). Furthermore, the in-line coagulation with ceramic membrane filtration was able to reduce the hydrophobic (HPOB) fraction which is characterized by high reactivity toward THM formation. The percent reduction of mass DOC and THMFP of HPOB by in-line coagulation with ceramic membrane filtration was 45.9% and 48.0%, respectively.

Introduction

Dissolved organic matter (DOM) is a complex mixture of hydrophilic and hydrophobic organic materials. DOM can vary in terms of its size and reactivity and can be categorized into various functional groups (Yee et al., 2009). Even when present in a tiny quantity in a raw water supply, DOM can react with chlorine during chlorination to form halogenated disinfection by-products (DBPs) such as trihalomethanes (THMs), which are classified as potential carcinogenic substances and associated with health and aesthetic problems for consumers (Zhang et al, 2013; Rook, 1974; Pereira, 1983; Munro and Travis, 1986). The formation of DBPs depends on the quantity of DOM, which is commonly measured from DOM surrogate parameters: dissolved organic carbon, DOC; ultraviolet absorbance at wavelength of 254 nm, UV-254; specific ultraviolet absorption, SUVA and trihalomethane formation potential (THMFP) (US EPA, 1999).

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To gain a better understanding of the formation of THMs from organic matter, the DOM characteristics should be investigated by grouping the organic matter into different groups according to the physical and chemical properties. The resin fractionation technique has been successfully employed for organic fractionation. Leenheer (1981) conducted a resin fractionation technique to separate DOMs into six fractions, namely hydrophobic acid (HPOA), hydrophobic neutral (HPON), hydrophobic base (HPOB), hydrophilic acid (HPIA), hydrophilic neutral (HPIN) and hydrophilic base (HPIB). The fractionation allows a thorough investigation of the formation of THMs from organic matter in water sources and can provide a better understanding of each DOM fraction in the formation of DBPs. For example, Panyapinyophol et al. (2005) reported that hydrophilic base and hydrophobic base fractions were the most active precursors for THM formation. Marhaba and Van (2000) found that the hydrophilic acid fraction was the most reactive precursor to THMs formation. The obtained results from fractionation are an important factor in the design of an appropriate technique, which can ensure that it can remove the target organic precursors.

The Ping River, the main river of the Chiang Mai basin in Northern Thailand, is one of the main tributaries of the Chao Phraya River. It is currently a major raw water source for water supply production in the urban and rural areas of Chiang Mai Province. In the rural area, the villagers have directly used this water source for many activities. This river contains high concentrations of solids; in terms of turbidity, it can average higher than 100 NTU. The DOM present in Ping River water varies due to seasonal changes. Hata et al. (2009) reported that the Ping River had dissolved organic carbon around of 2.0 mg/L in the dry season and a high of 5.7 mg/L in the rainy season. The high amount of organic matter in this water source had been the most problematic area of concern for the water supply process and drinking water production. The villagers utilizing this water source without the appropriate technology are at risk of exposure to health problems.

A conventional coagulation process, which consists of rapid and slow mixing, has commonly been used in water treatment and water supply production in Thailand. It is very simple and easy to operate. However, it cannot remove DOM and DBPs effectively and requires a large area for operation. DOM is the primary precursor of DBP production, and traditional treatment units in water treatment plants cannot remove DOM and DBPs effectively (Lou et al., 2011). Thus, ceramic membrane application systems for DOM removal have been developed to replace or enhance conventional treatment processes. Interest in the use of ceramic membrane filtration in the separation process has rapidly increased over the last decade in the water treatment field, for both the water supply and drinking water production. The membrane technology has been considered as one attractive alternative to the conventional drinking water treatment owing to its production of excellent and stable effluent quality (Mo et al., 2002).

Ceramic membranes have gained in popularity because they can offer several advantages over their organic counterparts, such as better mechanical strength, resistance to acidity, superior thermal and chemical stability, narrow pore size distribution, and little pollution to the environment (Dong et al., 2006; Rishi et al., 2003). Many researchers have studied the performance of the membrane filtration with coagulation process. For instance, Laine (1990) found that, without some kind of chemical pretreatment, ultrafiltration is not effective in removing DOM, with DOC removals of less than 20%. Hata et al. (2009) reports that the use of ceramic membrane filtration with coagulation was effective in removing suspended solids from several river water samples in Southeast Asia. The addition of a coagulant as a pretreatment prior to membrane filtration has been proposed for the purpose of not only improving the removal of DOMs but reducing membrane fouling (Wiesner et al., 1989; Jacangelo et al., 1995).

This research was aimed at investigating the reduction of DOM fractions and their THMFP by in-line coagulation with ceramic membrane filtration. The reduction of organic matter in terms of the DOC, UV-254 and THMFP was determined. Furthermore, resin fractionation was utilized to separate DOM into six DOM fractions and evaluate the ability of each DOM fraction to form THMs.

1 Materials and methods

1.1 Sampling site and sample collection

Raw surface water was collected from the Ping River of Chiang Mai, Thailand in July 2012, which represented the DOM in the rainy season. The sampling point was situated 10 km upstream of the Chiang Mai municipal area in order to avoid contamination from human activities. Samples for the analysis of water characteristics, coagulation and ceramic membrane filtration experiments were stored in a cold room, while samples for DOM fractionation were prepared by filtering through a pre-combusted (550°C) GF/F 0.7 μm filter and stored in the cold room until analysis.

1.2 Experimental procedures

1.2.1 In-line coagulation with ceramic membrane filtration

In-line coagulation refers to the use of coagulants without the removal of coagulated solids prior to filtration (Choi and Dempsey, 2004; Wang and Wang, 2006). In the experiments, raw surface water was mixed with polyaluminum chloride or PACL (at the following dosages: 20, 30, and

40 mg/L) in jar tests with rapid mixing at 150 r/min for 60 sec. PACL was selected as the coagulant in this study because it has been used to remove turbidity and suspended solids from raw water supplies in several water treatment plants in Thailand (Musikavong and Wattanachira, 2013). After that, the coagulated water was immediately poured into a clear acrylic 5-L pressurized tank (ADVANTEC). By maintaining the pressure at 0.2 MPa, the coagulated water in the pressurized tank was allowed to pass through a 7-meter nylon tube prior to flowing up through the bottom of the ceramic membrane module and being filtered through a 0.1 μm ceramic membrane. Based on the controlled pressure and volume of coagulated water in the pressurized tank, the detention time of coagulated water in the pressurized tank was about 5 minutes and the flocs were not settled in the pressurized tank. The filtered water samples were collected and measured for their DOC, UV-254 and THMFP values.

A diagram of the in-line coagulation process with ceramic membrane filtration is shown in **Fig. 1**. The ceramic membranes were provided by Metawater Co., Ltd., Japan. They were lab-scale ceramic membrane modules with a pore size of 0.1 μm. The dimensions of the ceramic membrane module are as follows: 3 cm in diameter and 10 cm in height, with 55 tubular channels. The filtration surface area was 0.042 m^2.

1.2.2 Coagulation procedure

The conventional coagulation process was conducted using jar tests. Various dosages of the coagulant PACL were used: 0, 10, 20, 30, and 40 mg/L. The jar test procedure was done with rapid mixing at 150 r/min for 1 min, followed by slow mixing at 30 r/min for 20 min, and then the suspension was left undisturbed for 60 min. After settling, the supernatant was collected and the DOC, UV-254 and THMFP were measured.

1.2.3 DOM characterization

The resin fractionation technique as proposed by Marhaba et al. (2003) was utilized to fractionate DOM into six fractions, namely HPON, HPOB, HPOA, HPIN, HPIB and HPIA by using three different types of resins including DAX-8, AG-MP-50 and WA-10 resins. The procedure was followed the resin fractionation procedure proposed by Kanokkantapong et al. (2006). One water sample was fractionated into six fractions and all fractionated samples were collected and analyzed for their DOC, UV-254 and THMFP values.

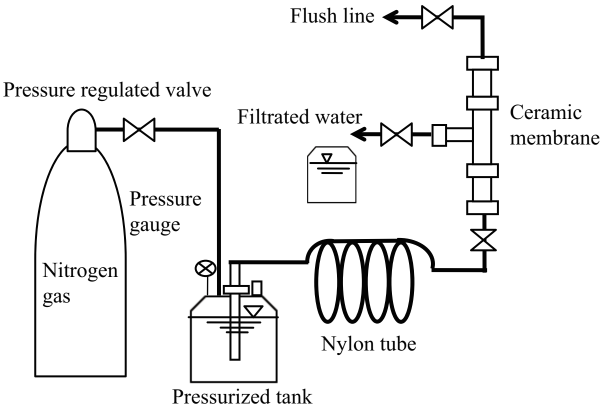

Fig. 1 Diagram of in-line coagulation with ceramic membrane filtration.

Water samples for DOC and UV-254 measurement were filtered through a GF/C 0.45 μm filter before analysis. The DOC concentration was measured using the wet oxidation method (5310D) with an O.I. analytical 1010 TOC Analyzer. UV-254 was measured using a UV/Vis spectrophotometer, the Perkin-Elmer Model Lambda 25, with quartz cells (Method 5910B). The THMFP test was conducted for 7 days according to Standard Method 5710B. At the end of the 7-day reaction period, samples should have a remaining free chlorine residual of between 3–5 mg/L. The residual chlorine was measured according to the procedure described in Method 4500-Cl. The THMs were extracted with pentane in accordance with Standard Method 6232B and then injected into a gas chromatograph with an electron capture detector, Agilent 6890 Series Gas Chromatography System (Musikavong and Wattanachira, 2013).

2 Results and discussion

2.1 Water quality

The turbidity of the Ping River water in the rainy season was 291 NTU and the pH was 7.6. The organic matter in terms of DOC concentration was 2.3 mg/L, whereas UV absorbance at 254 nm was 0.076 cm^{-1}. The SUVA value was determined by using an absorbance value at the wavelength of 254 nm (UV-254) and dividing that value by the DOC concentration. It was used to indicate the DOM character and its coagulation ability for the removal of THM precursors (Krasner et al., 1996). The SUVA value of this water source was 3.3 L/(mg·m). It can be considered that this water source contains organic matter that is primarily humic. Normally, DOM in surface water is mainly composed of humic substances (50%–65%) (Collins et al., 1986; Leenheer and Croue, 2003). THMFP of this water source was 330 μg/L, which indicates that the organic matter in this water source had a high ability to form THMs when in contact with chlorine. The species of THMFP for raw surface water consisted of three forms as follows: chloroform at 302 μg/L, bromodichloromethane at 26 μg/L and dibromochloromethane at 2 μg/L. The drinking water standard of THMs in Thailand was set according to the WHO guideline value, which stated that the chloroform must be lower than 0.3 mg/L, bromodichloromethane lower than 0.06 mg/L, and dibromochloromethane lower than 0.1 mg/L, and the sum of ratios of THMs to their guideline values (G.V.) must be lower than 1 (WHO, 2006). The sum of ratios was calculated by the summation of the ratios of THMs in each form $[(C_{\text{chloroform}}/\text{G.V.}_{\text{chloroform}}) + (C_{\text{bromodichlromethane}}/\text{G.V.}_{\text{bromodichlromethane}}) + (C_{\text{dibromochloromethane}}/\text{G.V.}_{\text{dibromochloromethane}})] \leqslant 1$ (where, C presents the concentration of THMs species). The sum of ratio of THMs of this water source was 1.49, which is higher than the standard value. Therefore, it is necessary to remove organic matter before it reacts with chlorine during the disinfection process in the water supply.

2.2 Reduction of DOC, UV-254 and THMFP

Use of ceramic membrane filtration with in-line coagulation was able to decrease the DOC concentration in filtered water by 48%, from 2.3 to 1.2 mg/L, at a PACL dosage of 40 mg/L. Increasing PACL dosage increased the DOC reduction (**Fig. 2a**).

The results showed that the addition of PACL as a coagulant before filtration with the ceramic membrane could enhance the percent DOC reduction from 15% in the case without PACL addition to 48% at a PACL dosage of 40 mg/L. When comparing these results with those of conventional coagulation, it was found that the percent DOC reduction of in-line coagulation was higher than that of conventional coagulation at the same PACL dosage. The obtained results correspond with those of Li et al. (2011). They report that hybrid coagulation with ceramic microfiltration could remove DOC more efficiently than coagulation or membrane filtration alone, with DOC reduction in the range of 34% to 54%. Additionally, Abeynayaka et al. (2012) reported that ceramic microfiltration could remove DOC by 48%, while a conventional water treatment system (coagulation, flocculation sedimentation, and sand filtration) could only remove 29%.

UV-254 absorbance is used to indicate the presence of aromatic hydrocarbons in water. The results showed that the UV-254 in the filtered water was gradually reduced from 0.0761 to 0.022 cm^{-1} (71%) when the PACL dosage was increased from 0 to 40 mg/L (**Fig. 2b**). The results corresponded well with the results of Wang and Wang (2006), which report that the UV-254 removal by UF with in-line coagulation increased from 40% (direct UF treatment) to 78%. In comparison, the results of conventional coagulation showed that the UV-254 decreased to 0.038 cm^{-1} (49%) at a PACL dosage of 40 mg/L.

The results of THMFP analysis showed that the THMFP of the ceramic membrane filtered water gradually decreased from 330 to 108 µg/L as the PACL dosage increased from 0 to 40 mg/L. The highest THMFP reduction (67.4%) was obtained at a PACL dosage of 40 mg/L. This result corresponds well with a report by Abeynayaka et al. (2012) of a 68% THMFP reduction by a ceramic microfiltration membrane. The sum of ratios of THMs in filtered water after inline coagulation with ceramic membrane filtration at PACL dosage 40 mg/L was 0.53, which met the standard of THMs in drinking water of Thailand. In comparison, a THMFP reduction of 54.3% was obtained by the conventional coagulation process: the THMFP was reduced to 154 µg/L by a PACL dosage of 40 mg/L (**Fig. 2c**).

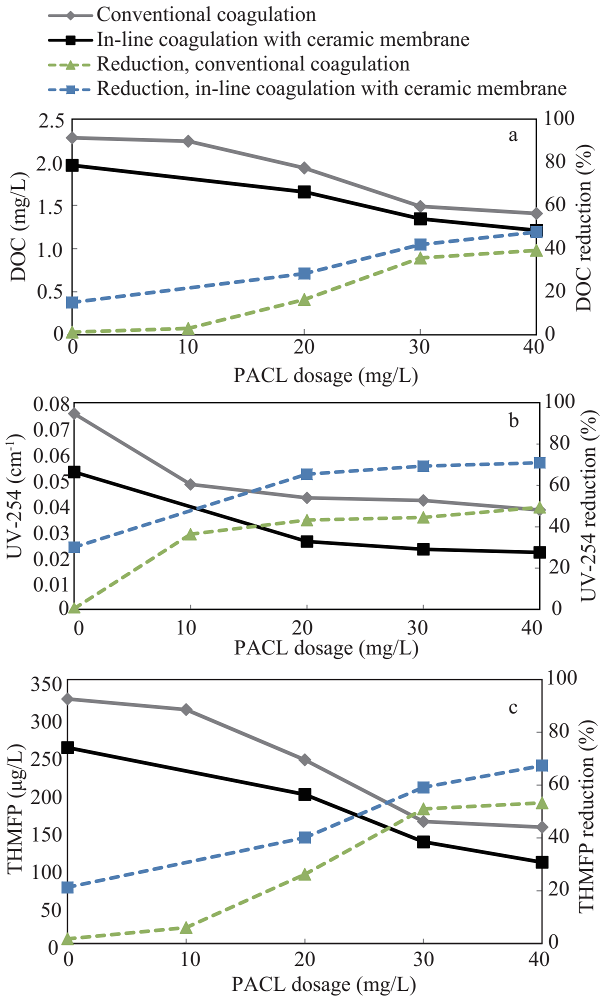

Fig. 2 Residual and percentage of DOC (a), UV-254 (b) and THMFP (c) reduction.

The optimal condition for in-line coagulation with ceramic membrane filtration for Ping River raw water during the rainy season was a PACL dosage of 40 mg/L, because this provided the highest DOC, UV-254, and THMFP reduction. For conventional coagulation the greatest reduction was obtained at a PACL dosage of 40 mg/L. PACL dosages in the range of 10–40 mg/L are currently utilized in water treatment applied for Ping River raw water. Thanaporn (2013) reported that PACL dosages for Ping River raw water depended on the turbidity values of water. The optimal PACL dosages for turbidity removal of 65, 115 and 213 NTU were 10.4, 23.6 and 33.3 mg/L, respectively. When comparing the results of DOM reduction at optimal conditions, it can be stated that the in-line coagulation with ceramic membrane filtration provides higher efficiency for DOC, UV-254 and THMFP reduction than conventional coagulation.

The DOC, UV-254, and THMFP results indicate that in-line coagulation coupled with ceramic membrane filtration could not only provide higher reduction efficiency of DOC, UV-254, and THMFP but also required a lower chemical concentration and a shorter operational time than the conventional coagulation process. Because complete flocculation is unnecessary for membrane filtration, in-line coagulation can utilize a lower PACL dosage than conventional coagulation.

2.3 DOM fractions and their THMFP reduction

Raw surface water and filtered water at the optimal PACL dosage 40 mg/L were collected and fractionated by resin fractionation procedures. The mass DOC distribution and THMFP results for the DOM fractions of both water samples are shown in **Table 1**.

The results showed that the mass DOC distribution of the six DOM fractions in raw surface water, from high to low, were HPIA, HPOA, HPIN, HPON, HPOB, and HPIB; while those in filtered water were HPIA, HPIN, HPOA, HPON, HPIB, and HPOB. The total weights of all organic fractions were about 9.76% and 9.39% higher than their total weights in the raw surface water and filtered water before fractionation, respectively. This weight surplus may have come from resin bleeding during the elution process (Leenheer, 1981). Variation from 8%–12% was reported by Croue et al. (1993).

The HPIA fraction was the largest fraction in this water source (38%), while HPOA was the second (29%). These two fractions alone contained as much as 67% of the total organic content. The next two organic fractions were HPIN (15%) and HPON (9%). HPIB and HPOB (4%) were the smallest fractions present. Marhaba and Van (2000) found that the HPIA fraction was the most abundant (53%) of all the fractions in surface water from northern New Jersey, followed by HPIN (13%), HPOA (12%), HPON (10%), HPOB (7%) and HPIB (5%). Panyapinyopol et al. (2005) found that the mass distribution of the six organic fractions in the Chao Phraya River were HPIN (45%), HPOA (34%), HPIA (18%), HPON (6%), HPIB (3%), and HPOB (3%).

The results of the THMFP test on each DOM fraction showed that the THMFP created by each DOM fraction, from high to low, were HPOA, HPIA, HPOB, HPIB, HPIN, and HPON (**Table 1**). The two main precursors of THMs were found to be HPOA and HPIA at 23% and 21% by weight, respectively. Both HPOA and HPIA were the main sources of THMs among the hydrophobic and hydrophilic species. These results agree with the results of Chang et al. (2001), which demonstrated that HPOA was the greatest contributor of precursors of THMs. In addition, the THMFP values of HPOB and HPIB were 69 and 66 μg/L even though their mass DOC values were lower (0.3 mg). From the results, it can be stated that the formation of THMs of each DOM fraction does not only depend on the concentration of a precursor (mass DOC) but also the characteristics of the DOM.

Figure 3 shows the specific THMFP of each organic fraction in raw surface water and filtered water. This was the ratio between the THMFP of each fraction and its DOC, which was used to determine the reactivity of the organic fraction in the formation of THMs. HPOB and HPIB were found to have high specific THMFP values in raw surface water at 680 and 631 μg/mg, respectively. This indicates that HPOB and HPIB were highly reactive with chlorine in forming THMs. These results are consistent with the results of Panyapinyopol et al. (2005), which showed that HPOB gave the highest specific THMFP at 619 μg/mg. Both HPOB and HPIB are of major concern in water treatment operations because a tiny concentration of either can lead to a large quantity of THMs. The HPIA fraction had the lowest specific THMFP (92 μg/mg), which indicates that this fraction was one of the least reactive precursors, and a high THMFP was found for HPIA because it had a high mass DOC concentration.

Based on these results, it should be stressed that the water treatment process used should be sufficient to reduce the HPOA and HPIA fractions prior to the chlorine disinfection process, because these two fractions were present in large quantities of the mass DOC of the studied water source. Furthermore, the HPIB and HPOB fractions should

Table 1 Mass DOC and THMFP distribution of DOM fractions in raw surface water and filtered water

Water samples	Parameter	Before fraction	Fractionated water							Diff. (%)
			HPOA	HPON	HPOB	HPIA	HPIN	HPIB	Total	
Raw water	Mass DOC (mg)	6.4	2.1	0.6	0.3	2.7	1.1	0.3	7.1	9.76
	Mass DOC (%)		29	9	4	38	15	4	100	
	THMFP (μg/L)	325	89	25	69	82	15	4	387	
	THMFP (%)		23	7	18	21	14	17	100	
Filtered water	Mass DOC (mg)	3.3	0.6	0.5	0.2	1.4	0.7	0.3	3.6	9.39
	Mass DOC (%)		18	15	4	37	19	7	100	
	THMFP (μg/L)	104	40	21	36	51	41	51	240	
	THMFP (%)		17	9	15	21	17	21	100	

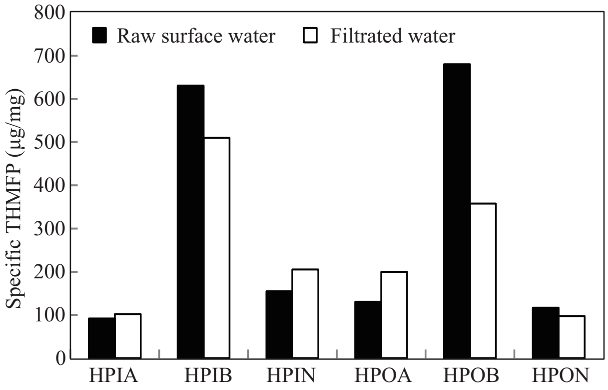

Fig. 3 Specific THMFP values of the six DOM fractions of raw surface water and filtered water.

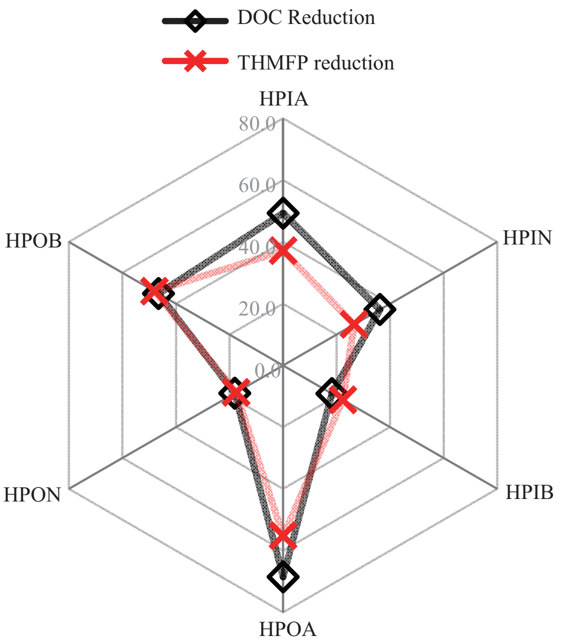

Fig. 4 Percent reduction of DOC and THMFP of the DOM fractions by in-line coagulation with ceramic membrane filtration.

be of concern because of their high potential for forming THMs, even though they were present in low quantities.

The reduction efficiency of DOM fractions and their THMFP by in-line coagulation with ceramic membrane filtration was investigated. Percent reductions of mass DOC and THMFP of the DOM fractions are illustrated in **Fig. 4**.

As seen in **Fig. 4**, the rank order of the percent DOC reduction of the six DOM fractions, from high to low, was HPOA, HPIA, HPOB, HPIN, HPIB, and HPON. The HPOA fraction was the fraction that was reduced the most (68.5%) by in-line coagulation with ceramic membrane filtration. This indicates that the in-line coagulation with ceramic membrane filtration can reduce DOM, primarily its HPOA fraction. The high HPOA reduction led to a 55.1% THMFP reduction of this fraction, which was the highest among all fractions. The HPIA fraction was the fraction that was reduced most among the hydrophilic species (49.3%). Marhaba and Van (1999) revealed that the HPIA fraction was one of the most difficult to remove by coagulation. Thus, it can be stated that in-line coagulation with ceramic membrane filtration can be used to effectively enhance the reduction of the HPIA fraction in water. The THMFP reduction of this fraction was 37.2%, which was the highest among the hydrophilic species.

For the HPOB and HPIB fractions, which have high specific THMFP values, mass DOC levels were reduced by 46.5% and 18.3%, respectively by in-line coagulation with ceramic membrane filtration. Marhaba and Van (2000) reported that coagulation could not effectively remove these two fractions from raw water. The use of alum coagulation can reduce HPOB and HPIB fractions from reservoir water by 10.2% and 10.7%, respectively (Janhom, 2006). The results for the HPIB fraction seem to corroborate their statement; however, the high DOC reduction results for the HPOB fraction appear to contradict it. Thus, it can be stated that the combination of in-line coagulation with ceramic membrane filtration can enhance the reduction of the HPOB fraction in water. Based on the specific THMFP of the HPOB and HPIB fractions, the THMFP reduction of these two fractions were high at 48.0% and 22.3%, respectively, even though their DOC reductions were lower. As can be seen in **Fig. 3**, the specific THMFP of HPOB and HPIB fractions in filtered water decreased to 358 and 510 μg/mg, respectively. This indicates that the in-line coagulation with ceramic membrane process can reduce the functional groups of DOM of HPOB and HPIB fractions that have high ability to form THMs. However, the HPOB and HPIB fractions were found to be the two main fractions for THM formation in filtered water. The specific THMFPs of other fractions in filtered water were in the range of 97–205 μg/mg.

The specific THMFPs of HPIA, HPIN, and HPOA of filtered water were higher than those of raw surface water, even though their THMFP and DOC values in filtered water were lower than those of raw water. This can be explained by the fact that the formation of THMs in water was based on the level and characteristics of DOM. Some groups of DOM that are present in a tiny quantity may create a high level of THMs in water. In-line coagulation with ceramic membrane filtration was able to remove the functional groups of DOM of HPIA, HPIN, and HPOA that had a low ability to form THMs. Thus, the remaining ones had a high ability to form THMs.

Finally, considering the unfractionated water, the raw water before the in-line coagulation with ceramic membrane filtration process had a specific THMFP of 152 μg/mg, while that after treatment was lowered to 95 μg/mg. This ensures that the in-line coagulation with ceramic membrane can be utilized for reducing the THMFP level of raw surface water.

The HPON and HPIN fractions were of least concern as they were present in small quantities in this water source and were relatively inactive with chlorine (low specific THMFP values). These two fractions tend to exhibit low specific THMFP values in comparison to other organic fractions (Marhaba and Van, 1999, 2000; Chang et al., 2001). In-line coagulation with this ceramic membrane filtration was able to reduce HPIN and HPON fractions by 36.2% and 18.1%, respectively, which led to 26.6% and 17.5% THMFP reduction.

Based on these results, the use of in-line coagulation with ceramic membrane filtration can reduce DOM fractions as follows: HPOA (68.5%), HPIA (49.3%), HPOB (46.5%), HPIN (36.2%), HPIB (18.3%), and HPON (18.1%). This indicates that in-line coagulation with ceramic membrane filtration can reduce DOM, primarily its HPOA fraction, which thus reduces the THMFP of this fraction as well. In addition, it was able to effectively reduce the HPOB and HPIB fractions, which are difficult to reduce by conventional coagulation.

3 Conclusions

In this investigation, it was found that in-line coagulation with ceramic membrane filtration was not only able to improve the efficiency of the water treatment process, but also required lower chemical concentrations than the conventional coagulation process. The highest percent reductions of DOC, UV-254 and THMFP by in-line coagulation with ceramic membrane filtration at a PACL dosage 40 mg/L were 47.6%, 71.0% and 67.4%, respectively, which were greater than the reductions obtained by the conventional coagulation process.

The DOM fractionation results showed that the HPOA fraction had the highest DOC reduction (68.5%) from in-line coagulation with ceramic membrane filtration, followed by HPIA (49.3%). High percent THMFP reduction of these fractions was thus obtained: 55.1% for HPOA and 37.2% for HPIA. It can be concluded that the in-line coagulation with ceramic membrane filtration process can be applied to enhance the HPOA and HPIA reduction from surface water, which the conventional coagulation cannot remove effectively. Furthermore, in-line coagulation with ceramic membrane filtration can reduce the HPOB fraction, which is characterized by high reactivity to form THMs and difficulty in removal by conventional coagulation from this water source. The percent mass DOC and THMFP reduction of this fraction were as high at 45.9% and 48.0%, respectively.

From the obtained results, it can be concluded that the in-line coagulation with ceramic membrane filtration process is an alternative and effective technology to apply and replace the conventional coagulation, for reduction of the DOM fractions and their THMFP from surface water.

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