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Characterization and transformation of dissolved organic matter in a full-scale wastewater treatment plant in Harbin, China

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ABSTRACT

The removal and transformation of dissolved organic matter (DOM) in different units of a full-scale A/O wastewater treatment plant (Harbin, China) were investigated both in summer and winter. DOM in the raw wastewater (RW) and the effluents of the grit chamber, primary sedimentation tank, anaerobic tank, oxidation tank (OT), and secondary sedimentation tank (SST) were fractionated and characterized. Hydrophilic fraction (HPI) was the predominant component in RW, followed by acidic fractions. The results also showed that 89.7% of the bulk dissolved organic carbon (DOC), 52.5% of UV-254, as well as 86.4% of trihalomethanes (THMs) precursors were removed by wastewater treatment plants in summer, while the removal efficiency of DOC and THMs formation potential decreased in winter. A/O facilities were more effective in removing HPI related organics than other units, particularly in summer. Structural changes of organic fractions in different units were also characterized via spectrum analysis. All of the findings were beneficial to optimization of the operation of wastewater treatment plant and reclamation of the secondary effluent.

Keywords: Wastewater treatment plant; Dissolved organic matter; THMFP; Fractionation; Molecular weight; UV-254

1. Introduction

Reusing secondary effluent of the wastewater treatment plants (WWTP) for nonpotable and potable purposes is rapidly becoming a necessity for many municipalities throughout the world [1,2]. The principal issues associated with secondary effluent reclamation are pathogens and residual organic constituents, which are of potential health concern [3]. Meanwhile, the dissolved organic matter (DOM) has been highly concerned, because it could be converted to carcinogenic disinfection by-products during the chlorination of reclaimed water [4]. In the past decades, the development of a tertiary treatment process (granular activated carbon, ultrafiltration, reverse osmosis treatment, etc.) to remove DOM in WWTP effluent attracted great interest [5,6]. However, less information is available on DOM removal within the WWTP itself. To the author's knowledge, more than 2,800 WWTPs have been built and operated in China. To meet the stricter criteria of "Discharge Standard of Pollutants for Municipal Wastewater Treatment Plant (GB18918-2002)," more than half of those WWTPs need to be optimized for preventing the deterioration of receiving water and reducing the relevant environmental risks. Thus, studying the removal and transformation of DOM within the WWTPs is practically urgent for optimizing the operational performance of WWTP.

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Activated sludge process has been recognized as the most powerful technology which is widely applied in industrial and municipal wastewater treatment plants. Although the removal trend of the specific organics in conventional WWTP has been investigated in a few studies [7–9], there is still lack of sufficient information on the transformation of DOM within the WWTP systems. Specially, no research has been reported regarding the use of fractionation procedures such as AMBERLITE XAD resins for evaluating the transformation of DOM during the WWTP operation.

The goal of this study was to examine the removal and transformation of DOM during a full-scale A/O WWTP. Specific objectives included: (1) identifying the characteristic and transformation of DOM within each unit of the WWTP both in summer and winter; (2) evaluating the different WWTP unit operation on the removal of trihalomethanes (THMs) precursors, and (3) examining the impacts of the WWTP units on the chemical compositions of the effluents DOM.

2. Materials and methods

2.1. Plant description

The process of Taiping municipal WWTP of Harbin (China) as shown in Fig. 1 comprised of coarse and fine screens, aerated grit chamber (GC), primary sedimentation tank (PST), anaerobic tank (AT), oxidation tank (OT), and secondary sedimentation tank (SST). The design capacity was 325,000 m^3/d, about 10% of the raw wastewater (RW) was contributed by industry.

Sampling was performed for organic fractionation in summer (three times) and winter (three times), respectively. Twenty-four hours composite, flow-proportioned samples were collected for the RW and the effluents of GC, PST, AT, OT, and SST both in June (averaged 23 ± 2℃) and December of 2009 (averaged 12 ± 2℃). The collected water samples were filtered using 0.45 μm cellulose nitrate membrane filter (Millipore, Shanghai, China) and stored at 4℃.

2.2. Fractionation procedure

DOM was fractionated using XAD-8/XAD-4 resins into five fractions: hydrophobic acid (HPO-A), hydrophobic neutral (HPO-N), transphilic acid (TPI-A), transphilic neutral (TPI-N), and hydrophilic fraction (HPI). Briefly, (1) five liters of acidified samples (pH 2) were passed through XAD-8 and XAD-4 resin columns at a flow rate of 10 bed volumes per hour. HPI was the organic matter in the XAD-4 effluent; (2) each of the resin columns was eluted backward with 0.1 mol/L NaOH at a flow rate of 2 bed volumes per hour, separately, followed by 2 bed volumes of Milli-Q water. The eluate from XAD-8 was defined as HPO-A, and that from XAD-4 as TPI-A; (3) HPO-N and TPI-N were those compounds which adsorbed onto XAD-8 and XAD-4 resins, respectively, but not dissolved during the back elution with NaOH. A detailed description was given in Wei et al. [10].

2.3. Molecular weight and polydispersity calculations

The apparent molecular-weight (MW) distribution of DOM fractions was characterized by high performance size exclusion chromatography with UV-detection at 254 nm in triplicate. Mobile phases were composed of Milli-Q water buffered to pH 6.8 with 0.1 M NaCl, 0.002 M phosphate buffer and flow rate was set at 0.4 mL/min [11,12]. The weight-average molecular weight (M_w) and the number-average molecular weight (M_n) were calculated from the SEC-UV results with molecular weight standards of polyethylene glycol (600 Da, 1,000 Da, 6,000 Da, 20,000 Da, and 100,000 Da). Polydispersity (d) was calculated as follows: $d = M_w/M_n$.

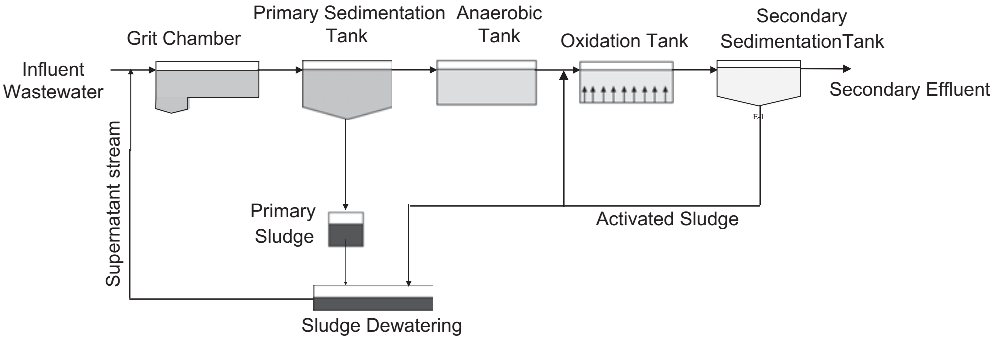

Fig. 1. Flow diagram of the WWTP.

2.4. Chemical analytical methods

DOC and UV absorbance were analyzed using Shimadzu TOC-5000 Total Organic Carbon Analyzer (Japan) and Shimadzu UV-2550 UV/VIS spectrophotometer (Japan), respectively. Specific ultraviolet light absorbance (SUVA) was calculated as UV-254/DOC. THMs formation potential (THMFP) analysis was performed on DOM fractions using Standard Method 5710B [13,14]. The measurements were made in triplicates with average and variance reported. The infrared spectra of HPO-A, HPO-N, TPI-A, and TPI-N were scanned from 4,000 to 400 cm^{-1} using Perkin-Elmer Spectrum One B Fourier Transform Infrared (FT-IR) spectrometer (USA). Spectra were baseline corrected and normalized to 1.0 for a purpose of comparison. Excitation-emission matrix (EEM) was measured in a 1-cm cuvette using a Jasco FP-6500 spectrofluorometer (Japan) at 24°C. Filtered water samples (pH 7) were diluted to a final DOC of 1 mg/L, the excitation and emission slits were set to 5 nm band-pass.

3. Results and discussion

3.1. Fractional DOM removal and distribution during WWTP operation

As shown in Fig. 2, the average DOC of the RW were removed 89.7% in summer as a consequence of WWTP operation (decreased from 102.6 to 10.6 mg/L), in which five units contributed in a trend of AT (40.1%) > OT (32.9%) > PST (15.5%) > GC (9.2%) > SST (2.3%). A higher DOC removal efficiency in A/O units was mainly ascribed to the efficient biodegradation, hydrolyzation, and acidification by the bacteria. Moreover, flocculation and co-precipitation of the PST also played a key role in DOC removal, which should not be ignored by the WWTP operators. For comparison, a higher DOC value of 114.2 mg/L for RW and a lower removal efficiency of 88.2% were observed for WWTP in winter. Specially, a declined DOC removal of AT unit was observed in winter (contributed 36.1% of the bulk removed organics), implying that low temperature would negatively affect the anaerobic biodegradation of the organics. This result was quite similar to the observation that the averaged removal of pathogenic microorganisms was declined at lower temperature conditions [3].

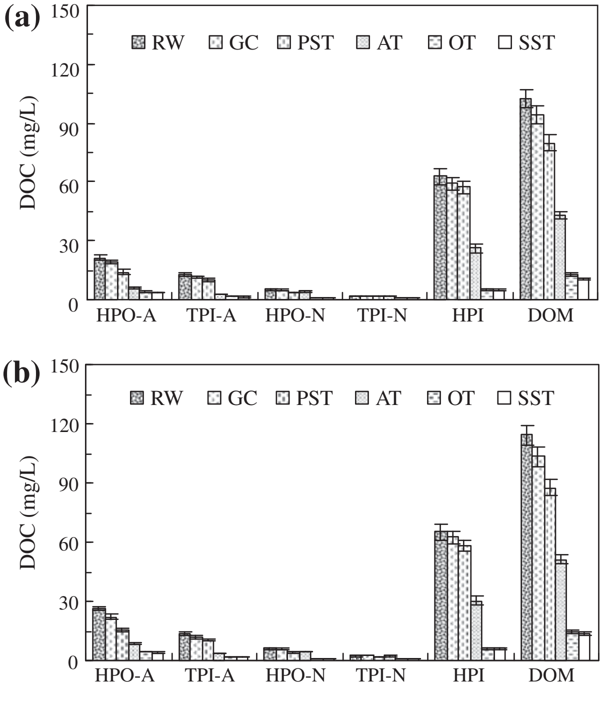

Fig. 2. Fractional DOC of DOM in RW and effluents obtained from WWTP units in (a) summer and (b) winter.

HPI was the predominant component (60.5% in summer and 57.4% in winter) in RW followed by HPO-A (20.3% in summer vs. 23.2% in winter), while DOC value of HPO-N, TPI-A, and TPI-N varied insignificantly at different seasons and averaged 12.1, 5.1, and 1.9%, respectively. The hydrophilic characteristics of RW implied that the organics in RW were mainly anthropogenic contaminated components [15]. Moreover, the RW showed a more hydrophobic characteristic in winter than that in summer, implying a higher molecular weight of the DOM in winter. DOC removal efficiency in the five units of WWTP varied widely (Fig. 2a and b). It was noted that AT unit contributed the most abundant removal of HPI (49.3%) among the five units during summer operation (Fig. 2a), followed by OT (33.2%), PST (5.8%), GC (3.3%), and SST (0.5%). DOC removal efficiencies of HPO-A in WWTP units behaved differently and decreased in a trend of AT (36.8%) > PST (24.0%) > OT (11.0%) > GC (9.1%) > SST (2.8%). The removal trend of TPI-A was similar to that of HPO-A. Differently, both HPO-N and TPI-N concentrations showed slight increases after AT operation, indicating the AT progress would lead to a production of neutral fractions. Those two neutral fractions decreased sharply when OT unit progressed. Consequently, the polarity distribution of the effluent from each unit changed significantly during the WWTP operation. For example, the hydrophobic/hydrophilic ratio of the RW (0.42) decreased to 0.31 when the GC and PST progressed, but significantly increased to 0.99 after the OT unit operation. From above, it might be concluded that the operations of GC and PST tended to co-precipitate those hydrophobic components preferentially, while the hydrophilic components could be more readily biodegraded. It has been well known that the seasonal conditions affect the chemical properties of secondary effluent significantly [9,16]. Our results also demonstrated that low temperature would decrease the activity of the anaerobic biomass in AT unit, and thus lead to a decreased DOC removal efficiency for all DOM fractions, especially for HPI.

Transformation of the organic molecule in different WWTP units in summer was evaluated as shown in Table 1. The M_w of DOM in different effluents decreased in a trend of RW (217842.1 Da) > GC (17747.1 Da) > PST (8333.6 Da) > AT (5067.7 Da) > OT (860.2 Da) > SST (839.9 Da). Since a high ratio of M_w/M_n indicated that organics had a broad distribution of M_w, hence a M_w/M_n ratio of 320.6 for DOM implied the complex molecular characteristics for RW. This result was inconsistent with the study of Wang and Wu [17], who stated that the WWTP influent showed a low M_w/M_n ratio of 1.64. After the RW was progressively treated, the M_w/M_n ratio of RW (320.6) tended to become lower. These results demonstrated that the macromolecular in RW could either be precipitated in GC/PST units and/or destructed in the subsequent biological treatment units.

Fractional M_w value of the organics for RW ranged from 365.9 to 1083913.2 Da, in which the highest M_w value of HPO-A was attributed to its least polarity and highest polymeric structure [17]. Although the majority of the macromolecules ($M_w > 10,000$ Da) in HPO-A were removed effectively in the GC and PST units, the newly produced molecule (with a $M_w > 10,000$ Da) for the A/O effluents indicated new soluble HPO-A was formed in A/O tanks (especially in AT). HPI showed a much lower M_w independent of the WWTP units (ranged from 50 to 3,000 Da), and exhibited a decreased M_w/M_n trend of OT (4.0) > PST (3.7) > AT (1.9) > RW (1.5) > GC (1.3), implying that the majority of small molecules of HPI ($1,000 < M_w < 3,000$ Da) in OT effluent were originated from the destruction of the other four fractions during AT operation. In addition, new neutral fractions were also produced within AT tanks (Table 1). On the other hand, those molecules could be preferentially aerobically biodegraded, as demonstrated by the sharply declined values of M_w/M_n when the OT operation progressed (as compared with that of AT effluents).

3.2. Fractional UV-254 reduction during WWTP operation

Ultraviolet light at 254 nm (UV-254) is always used to define the aromaticity of DOM, which is proportional to the aromaticity and molecular weight of organic samples [18,19]. The averaged UV-254 removal efficiencies of WWTP was 52.5% in summer and 56.2% in winter (Fig. 3), were much lower than that of DOC reduction. The UV-254 removal of 60% from the RW could be due to the co-precipitation for

Table 1
Molecular weight distributions of DOM fractions in RW and effluents of WWTP units in summer

WWTP units	Fractions	M_w (Da)	M_n (Da)	M_w/M_n	Fractions	M_w (Da)	M_n (Da)	M_w/M_n
RW	HPO-A	1,083,913.2	453.8	2,388.5	TPI-N	120,447	251.2	477.8
GC		473,289.1	560.2	844.9		52,079.5	127.1	409.3
PST		248,393.7	1,011.8	245.6.		42,040.3	152.7	275.3
AT		48,475.5	338.4	143.3		30,967.3	293.5	105.5
OT		50,115.7	531.6	94.3		387.6	156.8	2.5
SST		32,458.4	415.6	78.1		299.5	142.6	2.1
RW	TP-A	68,930.7	208.8	330.1	HPI	365.9	246.9	1.5
GC		410,298.4	628.6	652.7		312.1	243	1.3
PST		208,417.8	573.7	356		1,515.2	405.3	3.7
AT		185,427.9	571.2	353.1		1,759.9	919.6	1.9
OT		8,041.7	526.8	15.3		1,254.7	317.6	4
SST		5,168.3	416.8	12.4		1,078.9	291.6	3.7
RW	HPO-N	186,944.3	425.1	439.8	DOM	217,842	679.4	320.6
GC		41,222.1	93.5	440.7		17,747.1	632.5	28.1
PST		35,507.6	95.1	373.3		8,333.6	933	8.9
AT		74,575.5	574.6	129.8		5,067.7	1,067.8	4.7
OT		1,909.5	509.1	3.8		860.2	222.7	3.9
SST		1,443.6	424.6	3.4		839.9	179.6	4.7

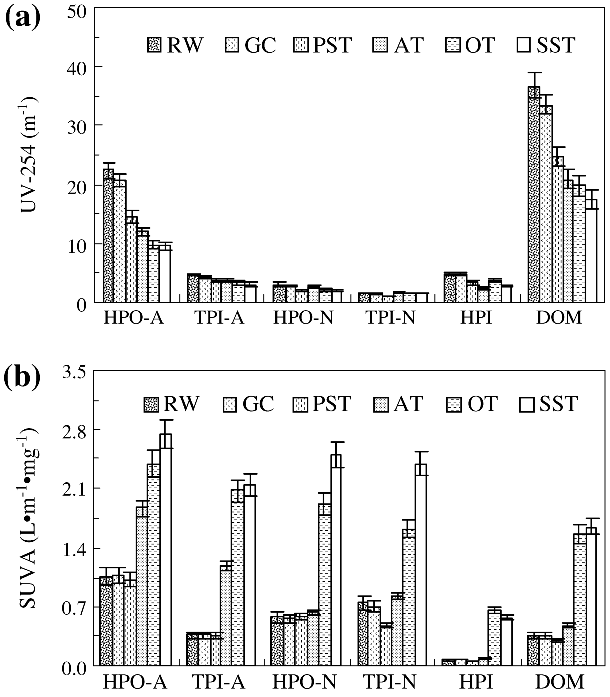

Fig. 3. Fractional (a) UV-254 and (b) SUVA of DOM in RW and effluents of WWTP units in summer.

summer operation (45.4% for PST and 16.9% for GC), while that of the AT (20.2%), OT (5.7%), and SST (11.9%) were quite lower. Similarly, removal trend was also observed in winter (data not given). These results implied that the aromatic macromolecules were preferentially co-precipitated within GC and PST units, similar to the results of the molecular size distribution. On the other hand, partially destructed aromatic materials were quite refractory and accumulated in OT unit.

Fractionation results (Fig. 3a) indicated that HPO-A was the predominant aromatic fraction in RW (contributed 61.6% of the bulk UV-254), followed by HPI (13.2%), TPI-A (12.8%), HPO-N (8.2%), and TPI-N (4.2%). Meanwhile, HPO-A tended to exhibit greater aromaticity (SUVA = 1.07 L/(m mg)) and higher reactivity in forming THMs upon chlorination, while that of HPI was the lowest (SUVA = 0.08 L/(m mg)). In comparison with the other four units, PST showed the highest UV-254 removal independent of the characteristic of all five DOM fractions. Moreover, the removal of aromatic components in acidic and neutral fractions was also effective in GC unit, and that of the HPI and neutral fractions were quite low in A/O units (Fig. 3). These results demonstrated that the aromatic components could be effectively removed via co-precipitation instead of biodegradation, which could be further proven by the increased SUVA of five DOM fractions after A/O treatments (Fig. 3b). From this point of view, the PST and GC units should be well operated for removing aromatic DOM in practical WWTPs. To prevent the discharge of the hydrophobic aromatic components from municipal WWTP, more attention should be paid for further removal of those aromatic components within A/O units (especially in AT unit).

3.3. Fractional THMFP reduction during WWTP operation

The THMFP produced by HPO-A was higher than that of HPI, especially in winter (1,576.5 vs. 1,130.0 μg/L), which was quite different from the fractional DOC distribution (Fig. 2). This might be ascribed to the much higher specific THMFP (STHMFP) of HPO-A compared to that of HPI (about 3.5 times higher). TPI-A was another major THMs precursor of the RW (670 μg/L in summer and 725 μg/L in winter). As shown in Fig. 4, the THMs precursors in RW were efficiently removed by the WWTP facilities in summer (86.4%), resulting in a final THMFP of 403.4 μg/L for SST effluent. Specially, 50.5% of the bulk THMs precursors were biologically consumed in A/O tanks and 33.1% were precipitated in GC and PST tanks. It was noted that 88.9% of the THMs precursors in HPI could be collectively removed by A/O facilities owing to their biodegradable characteristics. Because of the high THMFP from HPI during

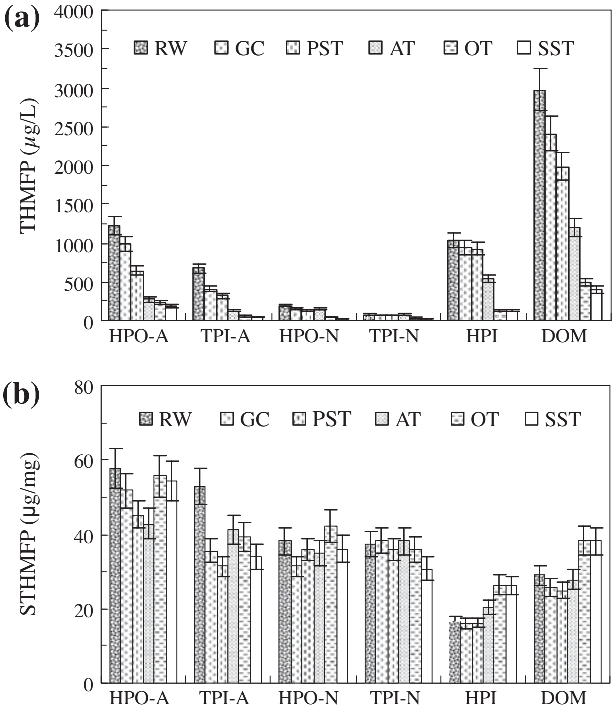

Fig. 4. Fractional (a) THMFP and (b) STHMFP of DOM in RW and effluents of WWTP units in summer.

chlorination [20], ways for well operation of the A/O system is essential for controlling of the hydrophilic THMs precursors. It seemed that co-precipitation in the GC and PST units was the main step for hydrophobic THMs precursors removal (accounting for 56.4 and 55.0% of the bulk THMFP removal for HPO-A and TPI-A, respectively). Since previous study concluded that more hydrophobic and acidic fractions provided more active precursor sites [21], thus the PST and GC units should be well-operated for the removal of hydrophobic THMs precursors. New neutral THMs precursors were observed to produce in the AT tank, which could be readily removed when OT unit progressed. The main differences between the condition of low temperature in winter and high temperature in summer were the decreased THMFP removal efficiency in AT unit and the increased THMFP removal in GC and PST tanks (data not given), ascribing to the higher aromaticity of the influent DOM in winter and a declined activity of the anaerobic biomass.

3.4. *Characteristics and behaviors of DOM fraction during WWTP operation*

In order to further study the structural changes of DOM during the WWTP operation, both FT-IR spectra of the DOM fractions and fluorescence spectroscopic analysis were performed in summer.

3.5. *FT-IR spectra*

According to Fuentes et al. [22], four DOM fractions (HPO-A, HPO-N, TPI-A, and TPI-N) of the RW obtained in summer were characterized by aliphatic C–H (2,950–2,850, 1,450, and 1,390 cm^{-1}), aromatic C=C (1,600 cm^{-1}), C=O (1,720–1,640 cm^{-1}), and C–O (1,280–1,137 cm^{-1}). The aromatic C=O bands were more pronounced for acidic fractions than neutral ones, whereas the hydrocarbons (1,250–1,050 cm^{-1}) were prominent in neutral fractions. FT-IR spectrum of DOM fractions (especially for acidic fractions) changed insignificantly when GC and PST progressed, while new peaks appeared after A/O treatments. Thus, anaerobic/aerobic biodegradation seemed to be the main reason for the structural changes of DOM.

As shown in Fig. 5a, the gradually narrowing of C=C peaks (1,640–1,560 cm^{-1}) in HPO-A after GC and PST treatments (especially PST) suggested that those aromatic materials in HPO-A could be efficiently co-precipitated. Because of the presence of aromatic rings and unsaturated functional groups, those components were always considered to be the major THMs precursors [23]. Contrarily, HPO-A became aromatic as AT progressed, quite consistent to the results of SUVA. Although the C=C peaks (1,640–1,560 cm^{-1}) became less significant after OT operation, the sharply intensity increase of the peaks at 3,000–3,100 cm^{-1} implied that some new aromatic components were formed in OT unit. Transformation of the aliphatic C–H (1,450 and 1,390 cm^{-1}) components in HPO-A was similar to that of C=C materials. Contrarily, C=O related hydrocarbon and aliphatic components (1,720 cm^{-1}) would be readily anaerobically and aerobically biodegraded instead of precipitation.

The decreased absorbance of shoulder C=C peaks (1,580 cm^{-1}) of HPO-N after PST operation indicated that those aromatic components (THMs precursors) could be partially co-precipitated (Fig. 5b). These aromatic C=C components could be further destructed efficiently in AT unit, but accumulated in OT tank for its low biodegradability. Spectrum intensity of C=O related components of HPO-N decreased sharply when A/O units processed, while quite constant within GC and SST units, indicating those carboxylic materials (THMs precursors) in HPO-N could be anaerobically and aerobically degraded preferentially. The removal trends of HPO-N related hydrocarbon were similar to those of the carboxylic C=O components.

Intensity changes of TPI-A related C=C peaks (1,600 cm^{-1}) were similar to those of HPO-A (Fig. 5c), ascribing to their similar acidic characteristics. Specially, the significantly decreased C=C related groups (THMs precursors) in TPI-A after GC and PST operations were consistent to the results of SUVA. The carboxylic C=O components (1,720 cm^{-1}) and hydrocarbon (1,250–1,050 cm^{-1}) in TPI-A could be readily biodegraded instead of precipitation, while aliphatic C–H related components were quite refractory. In addition, the increased intensity of amide-1 groups (1,650 cm^{-1}) after A/O treatments indicated new bacteria-derived glycoprotein materials were produced.

As indicated in Fig. 5d, spectrum intensity of the C=O (1,720 cm^{-1}) and aliphatic C–H (1,380 cm^{-1}) peaks of TPI-N increased slightly, when the GC and SST progressed, but decreased sharply within A/O tanks, indicating those carboxylic acids and aliphatic C–H components (lower molecule) could be preferentially biodegraded. Conversely, spectrum intensity of the C=C (1,550 cm^{-1}) peaks were decreased readily following the GC and PST operations, implying those aromatic THMs precursors in TPI-N precipitated efficiently. In addition, the hydrocarbon related components (1,250–1,050 cm^{-1}) showed significant decreases within AT unit, and the complexion of the peaks implying that some new hydrocarbons were also produced, consistent to the M_w distribution.

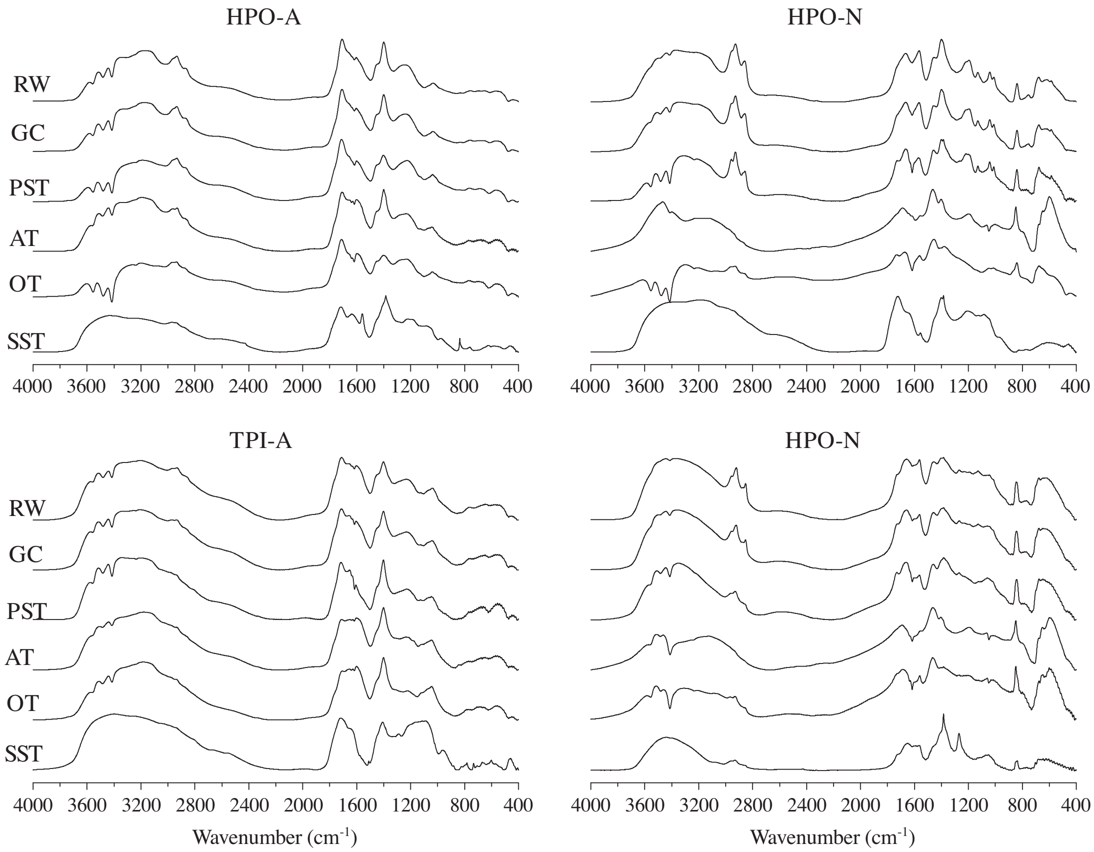

Fig. 5. FT-IR spectra of (a) HPO-A; (b) HPO-N; (c) TPI-A; and (d) TPI-N isolated from RW and effluents of WWTP units in summer.

3.6. EEM spectra

The DOM in the RW revealed significant fluorescence peaks in Regions II and IV [24], referring to the redundancy of aromatic proteins and soluble microbial by-product-like (SMP-like) materials (Fig. 6a). In addition, the EEM spectrum also showed humic-like and fulvic-like fluorescence.

Spectrum intensity of the SMP-like peak decreased sharply during GC, PST, and AT treatments, indicating the co-precipitation as well as anaerobic biodegradation had a better performance in removing those SMP-like components. Contrarily, new production of SMP-like materials was proven after aerobic biodegradation because the fluorophore intensity increased sharply after OT treatment. Transformation of the aromatic protein-like fluorophores was quite similar to that of SMP-like groups. In comparison with the fluorophores of the RW, the intensity of the aromatic proteins decreased 41.2, 41.8, and 53.4% during the GC, PST, and AT treatments, respectively, but increased sharply following the OT treatment, ascribing to the formation of bacteria-derived glycoprotein materials (observed from FT-IR results).

Spectrum intensity distribution of the humic-like fluorophores in different unit effluent was observed to be SST > OT > AT > PST > GC > RW (Fig. 6). These results clearly demonstrated that the humic-like components could not be efficiently removed in either WWTP units and finally accumulated in SST tanks. In addition, significant changes in the structure of the fluorophores were observed in Region III for A/O effluents (especially for OT effluent), indicating new humic-like components were produced after A/O treatment. This might be the main reason for the intensity increase of the aromatic C–H peaks in $3{,}100\,\mathrm{cm}^{-1}$ for the FT-IR spectrum of HPO-A.

In overall, effluent intensity distribution of the fulvic-like substances was observed to be SST > OT > RW > GC > AT > PST. The intensity of the fulvic-like components was decreased significantly during the GC and PST treatments. Besides, gradually increased fluorophore intensity of the A/O effluents also showed that those materials could not be efficiently biodegraded (especially within the OT tank).

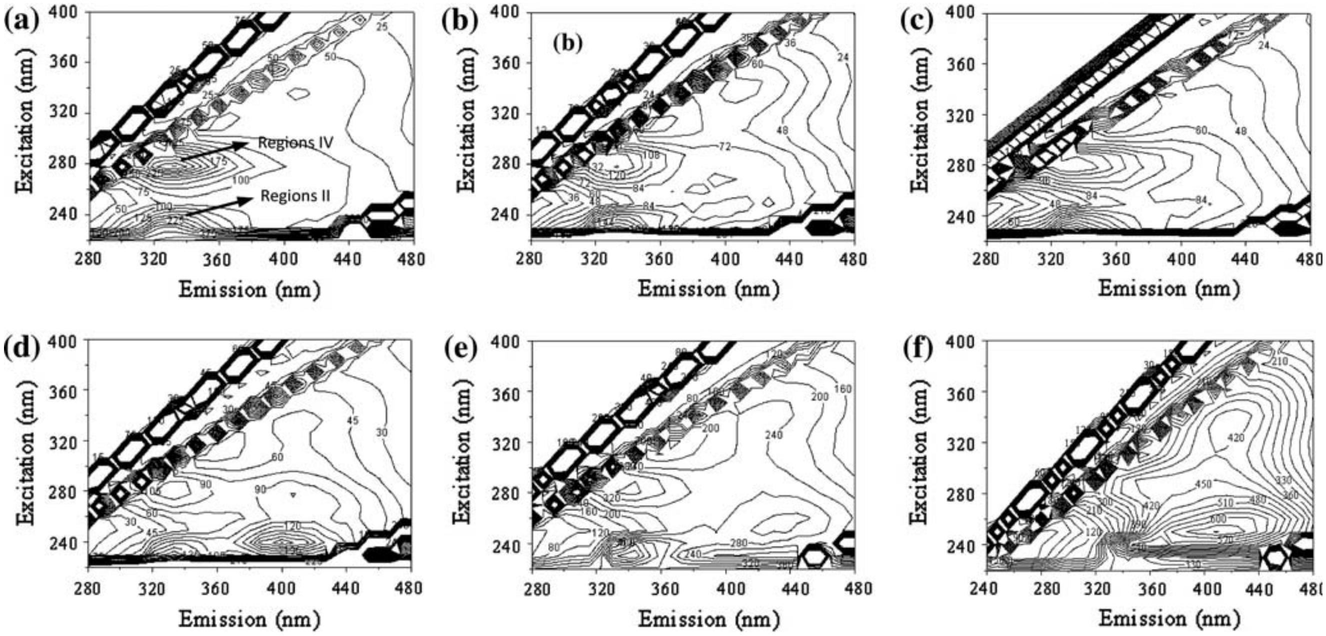

Fig 6. EEMs for (a) RW; (b) GC; (c) PST; (d) AT (e) OT; and (f) SST effluents in summer.

4. Conclusions

The following conclusions can be drawn based on the experimental results:

(1) The majority of the DOM in RW was contributed by HPI (60.5% in summer and 57.4% in winter), followed by HPO-A. The remainder fractions were averaged 12.1% for HPO-N, 5.1% for TPI-A, and 1.9% for TPI-N, respectively. A total of 89.7% DOM in RW was removed by WWTP operation in summer, during which anaerobic, oxidation, and PSTs played key roles. Low-temperature condition negatively affected the performance of AT.

(2) Removal of the hydrophobic fractions was effective in the PST, especially in winter. The A/O units were predominant in reducing HPO-A, TPI-A, and HPI. New neutral fractions were produced in AT, particularly in summer.

(3) UV-254 of the RW was removed 52.5% in summer and 56.2% in winter during WWTP operation, and the aromatic components could be preferentially co-precipitated and anaerobically biodegraded, especially for the acidic fractions. PST and GC should be well-operated for removing aromatic DOM in practical WWTPs.

(4) HPO-A, TPI-A, and HPI were the main THMs precursors, accounting for more than 90% of the bulk THMFP in RW collectively. A total of 86.4% THMs precursors removal was observed in summer while 85.5% in winter. The operators should insure the GC and primary sedimentation better functioned for the removal of hydrophobic THMs precursors, while A/O facilities for hydrophilic THMs precursors removing.

(5) The aromatic C=C and C=O (fulvic-like and humic-like fluorophores) related components could be effectively removed in GC and PST, while hydrocarbons (SMP-like) removal could definitely benefit from A/O treatments.

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Appendix: Nomenclature

Symbols		Definitions and units
AT	—	anaerobic tank
DOC	—	dissolved organic carbon (mg/L)
DOM	—	dissolved organic matter
EEM	—	three-dimensional excitation emission matrix
FT-IR	—	Fourier-transform infrared

(*Continued*)

Appendix (*continued*)

Symbols		Definitions and units
GC	—	grit chamber
HPI	—	hydrophilic fraction
HPO-A	—	hydrophobic acid, HPO-A
HPO-N	—	hydrophobic neutral
OT	—	oxidation tank
PST	—	primary sedimentation tank
RW	—	raw wastewater
SMP	—	soluble microbial by-products
SST	—	secondary sedimentation tank
STHMFP	—	specific trihalomethanes formation potential (μg/mg)
SUVA	—	specific ultraviolet light absorbance (L/(m mg))
THMFP	—	trihalomethanes formation potential (μg/L)
THMs	—	trihalomethanes
TPI-A	—	transphilic acid
TPI-N	—	transphilic neutral
UV-254	—	Ultraviolet light at 254 nm (m^{-1})
WWTP	—	Wastewater treatment plant

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