CONTAMINATION OF PERFLUORINATED COMPOUNDS (PFCs) IN SEVEN MUNICIPAL WASTEWATER TREATMENT PLANTS IN BANGKOK, THAILAND

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Perfluorinated compounds (PFCs) are synthetic chemical which is persistent, bio-accumulative and suspected to be toxic. Municipal wastewater treatment plants (MWWTPs) have been identified as sources of PFCs contamination in water environment. This study focused on the contamination of eleven PFCs in samples collected from seven MWWTPs and in Bangkok, Thailand. The samples were collected from major of wastewater treatment processes in order to understand the behavior of PFCs in MWWTPs. All MWWTPs used activated sludge process to treat wastewater. The result showed that Chong Nonsi MWWTPs had the highest of PFCs concentration in final effluent (63.6 ng/L). Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) were predominant PFCs detected in final effluents than other PFCs. Final effluents had higher PFCs concentration than influents of the MWWTP which indicated that conventional wastewater treatment process using activated sludge was not effective to remove PFCs. Long carbon-chain PFCs tended to adsorb on particulate phase more than short carbon-chain ones. Comparing to other countries, the effluent concentration levels of PFOS and PFOA in Thailand were lower than those in Denmark, Taiwan and Singapore. However, several PFCs were detected in MWWTPs, suggesting municipal wastewater is one of the sources of PFCs contamination in the environment.

Key Words : municipal wastewater, PFCs, PFOA, PFOS,

1. INTRODUCTION

Perfluorinated compounds (PFCs) have been an emerging environmental issue. PFCs are fluorinated at all or a portion of the carbon atom of organic molecules with a terminal sulfonate carboxylate, or phosphonate groups 1). PFCs have been used in a variety of consumer products and industrial applications such as polymers, metal plating and cleaning, surfactants, lubricants, pesticides, coating formulations, inks, varnishes, firefighting foam, and stain/water repellents for leather, paper and textiles 2,3).

PFCs are environmentally persistent, water soluble and long-range transport. They also have tendency to bio-accumulate and to magnify in the food chain 4). PFOS was dominant compound in PFCs group and often found in water environment. PFOS belongs to the group of PBTs (persistent, bioaccumulative and toxic) 5) and was recently added to the list of Persistent Organic Pollutants (POPs) in the Stockholm Convention 6). Furthermore, PFOS and its derivative are banned by the European Union 7). However, PFCs have still been detected in water environment. The reason could be due to the substitution of PFOS by other PFCs such as PFBS 8).

PFCs may enter environment via effluent of wastewater treatment, septic discharge, surface runoff, rain or application of sludge to agriculture.
lands. Discharge of treated wastewater from wastewater treatment plants (WWTPs) is recognized as one of the significant point sources of PFCs to aquatic environments\(^9,10\). Conventional wastewater treatment system such as activated sludge (AS) has been reported to be ineffective to treat PFCs\(^11,12\). Many researchers have already reported that their major sources were from industrial wastewater. In Thailand, central WWTPs of many industrial estates were studied and high concentrations of PFCs (PFOS, 190 – 553 ng/L and PFOA, 17 – 150 ng/L) were detected\(^13,14\). Not only industrial wastewater, but also municipal wastewater could be one source of PFCs released into water body. The contaminations of PFCs in municipal wastewater have been investigated in several countries as Germany\(^15\), Denmark\(^16\), Korea\(^17\), Taiwan\(^18\), Hong Kong\(^19\) and Singapore\(^20\). However, the study on PFCs contamination in municipal wastewater in developing countries, like Thailand, is still limited. In Thailand, there has not been any investigation on PFCs contamination in municipal wastewater treatment plants (MWWTPs). Economically booming megacities have high possibility to discharge PFCs along with household sewage\(^21\). Therefore, Bangkok, a megacity of Asia was selected for studying PFCs contamination in seven MWWTPs.

2. MATERIALS AND MEHTODS

(1) Description of MWWTPs in Bangkok

The seven MWWTPs, which are named as follows: Jatujak, Din Daeng, Rattanakosin, Si Phraya, Chong Nonsi, Thoong Kru and Nong Khaem are under controls of the Department of Drainage and Sewerage, Bangkok Metropolitan Administration. The total capacity is 992,000 m\(^3/d\) (approximately 40% of total generated wastewater in Bangkok) and total service area is 191 km\(^2\) (about 12% of total area in Bangkok). Table 1 shows detailed information of seven MWWTPs. Household is major source of wastewater, it contributed about 75% of total wastewater, while 25% was generated from industrial and commercial sources. Wastewater is discharged to both public (canal or river) and combined drainage system. The drainage system also collects storm water in wet season. All MWWTPs use activated sludge process (AS) to treat wastewater. Sludge from each MWWTPs are delivered to sludge treatment center, located at Nong Khaem MWWTP.

(2) Chemicals and reagent

The eleven PFCs were investigated as target chemicals. Two kinds of PFCs stock solutions were prepared for PFASs (perfluorooalkyl sulfonates, C\(_4\), C\(_6\) and C\(_8\)) and PFCAs (perfluorooalkyl carboxylates, C\(_5\) – C\(_{12}\)). In each solution, these PFCs were mixed into acetonitrile (LC/MS grade) and stored in polypropylene (PP) bottle at 4 °C. The stock solutions were diluted at different concentrations by 40% acetonitrile and used as PFCs standard. PFASs consisted of perfluorobutane sulfonate (PFBS, C\(_4\)), perfluorohexane sulfonate (PFHS, C\(_6\)) and perfluorooctane sulfonate (PFOS, C\(_8\)). PFCAs consisted of perfluoropentanoic acid (PFPeA, C\(_5\)), perfluorohexanoic acid (PFHxA, C\(_6\)), perfluoroheptanoic acid (PFHpA, C\(_7\)), perfluorooctanoic acid (PFOA, C\(_8\)), perfluorononanoic acid (PFNA, C\(_9\)), perfluorodecanoic acid (PFDA, C\(_{10}\)), perfluoroundecanoic acid (PFUnDA, C\(_{11}\)) and perfluorododecanoic acid (PFDoDA, C\(_{12}\)). PFC surrogate standards were prepared from mass labeled internal PFCs standards which were \(^{13}\)C\(_2\)-PFHxA, \(^{13}\)C\(_4\)-PFOA, \(^{13}\)C\(_8\)-PFDA and \(^{13}\)C\(_7\)-PFOS. These were purchased from Wellington Company, Canada. Surrogate standards were mixed into acetonitrile and kept at 4 °C. The surrogate standard solutions were prepared by diluting single stock solutions with 40% acetonitrile. HPLC grade solvents (methanol and acetonitrile) were used in this study.

(3) Sample collection

The performances of MWWTPs for PFCs removal were investigated by collecting samples from
(4) **Sample pre-treatment and extraction**

All filtration material were pre-washed by methanol and dried at room temperature. Samples were filtered through dry GF/B filter paper (1 µm, Whatman, Japan), which were washed by methanol and dried. The samples were separated to analyze PFCs in liquid and particulate phases.

**Liquid phase:** Samples (500 mL) were concentrated into two cartridges in order to enhance recovery of PFCs. The samples were passed through PresepC-Agri (C18) cartridge (Wako, Japan) connected inline with Oasis®HLB (Water, Japan). Both cartridges were pre-conditioned by 10 mL of methanol and 20 mL of ultrapure water, manually. The concentrator pump was pre-washed by deionized ultrapure water (HPLC grade) at a flow rate of 0.25 mL/min, separation process began with initial condition of 30% (B), increased to 50% (B) at 16.5 min, then went to 70% (B) at 16.6, held at 70% (B) for 3.4 min, then went up to 90% (B) at 21 min, kept at 90% (B) for 1 min, and then each sample. Mass spectrometer was operated with the electrospray ionization (ESI) negative mode. Analyte ion was monitored by using multiple reactions monitoring (MRM) mode.

Calibration curves for quantification, consisting of six points ranges from 0.05 to 10 µg/L. The determination coefficient (R²) of linear calibration curve was more than 0.99. Limit of detection (LOD) was defined as concentration with signal to noise ration (S/N) 3:1. Limit of quantification (LOQ) was defined as 10:1 of S/N, was used for quantifying analytes. The analysis was replicated on all samples and coefficients of variations (CV) of concentrations were below 20%. The recovery percentages were calculated by spiking normal PFCs and surrogate standards into the duplicated samples. For liquid phase samples, standards were spiked before loading into cartridges, while particulate samples were spiked standards before extraction process.

**Particulate phase:** Filter paper of separate solid content from each sample was used for PFCs analysis in particulate phase. Each filter paper was placed into 15 mL PP tube and 5 mL of methanol was added. Then, they were shaken at 120 rpm for 30 min. Extracted sample was separated into another PP tube. Extraction processes were conducted 2 times. Final extracted sample (10 mL) was passed through ENVI-Carb cartridge (Supelco, USA), which was cleaned up by 4 mL of methanol in advance. Then, eluent solution was dried by nitrogen gas and reconstituted with 1 mL of 40% acetonitrile in ultrapure water.

(5) **Sample analytical technique by HPLC-electrospray tandem mass spectrometry**

Separation of PFCs was performed by using Agilent 1200SL high performance liquid chromatography (HPLC), (Agilent, Japan). 10 µL of extracted sample was injected to a 2.1 x 100 mm (5 µm) Agilent Eclipse XDB-C18 column. Mobile phase consisted of (A) 5 mM ammonium acetate in ultrapure water (HPLC grade) and (B) 100% acetonitrile (HPLC grade). At a flow rate of 0.25 mL/min, separation process began with initial condition of 30% (B), increased to 50% (B) at 16.5 min, then went to 70% (B) at 16.6, held at 70% (B) for 3.4 min, then went up to 90% (B) at 21 min, kept at 90% (B) for 1 min, and then each sample. Mass spectrometer was operated with the electrospray ionization (ESI) negative mode. Analyte ion was monitored by using multiple reactions monitoring (MRM) mode.

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### Table 2: Analytical parameters of analyzed PFCs by HPLC/MS/MS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Parent ion (m/z)</th>
<th>Daughter ion (m/z)</th>
<th>CE (eV)</th>
<th>Retention time (min)</th>
<th>LOD (ng/L)</th>
<th>LOQ (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFBS</td>
<td>299</td>
<td>80</td>
<td>55</td>
<td>2.7</td>
<td>0.03</td>
<td>0.11</td>
</tr>
<tr>
<td>PFHxS</td>
<td>399</td>
<td>80</td>
<td>55</td>
<td>13.8</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>PFOS</td>
<td>499</td>
<td>80</td>
<td>55</td>
<td>7.9</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>PFPA</td>
<td>263</td>
<td>219</td>
<td>5</td>
<td>1.9</td>
<td>0.08</td>
<td>0.20</td>
</tr>
<tr>
<td>PFHxA</td>
<td>313</td>
<td>269</td>
<td>5</td>
<td>2.8</td>
<td>0.04</td>
<td>0.08</td>
</tr>
<tr>
<td>PFHpA</td>
<td>363</td>
<td>319</td>
<td>5</td>
<td>4.7</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>PFOA</td>
<td>413</td>
<td>369</td>
<td>5</td>
<td>7.2</td>
<td>0.04</td>
<td>0.12</td>
</tr>
<tr>
<td>PFNA</td>
<td>463</td>
<td>419</td>
<td>5</td>
<td>9.9</td>
<td>0.04</td>
<td>0.08</td>
</tr>
<tr>
<td>PFDA</td>
<td>513</td>
<td>469</td>
<td>5</td>
<td>12.7</td>
<td>0.04</td>
<td>0.16</td>
</tr>
<tr>
<td>PFUnA</td>
<td>563</td>
<td>519</td>
<td>5</td>
<td>15.4</td>
<td>0.28</td>
<td>0.88</td>
</tr>
<tr>
<td>PFDsA</td>
<td>613</td>
<td>569</td>
<td>5</td>
<td>18.0</td>
<td>0.28</td>
<td>0.88</td>
</tr>
</tbody>
</table>

Note: CE = Collision Energy

LOD = Limit of Detection

LOQ = Limit of Quantification

\[ 13C_2-PFHxA = 315 \]
\[ 13C_2-PFPA = 417 \]
\[ 13C_2-PFOS = 503 \]
The extraction recoveries of PFCs were determined from the samples as shown in Table 3 for quantification. The recoveries were calculated on the basis of detected spiked concentration in both liquid and particulate phase samples. Recoveries were different, depending on the alkyl chain length and type of functional group of each PFC. In addition, recovery varied indicating matrix effects on recovery, which is one of the issues in PFCs analysis. Recovery percentages of normal PFCs and surrogate were in range of 77% to 103% and most of PFCs were more than 90% in both liquid and particulate phases (Table 3).

4. RESULTS AND DISCUSSION

(1) PFCs concentration in municipal wastewater

Several types of PFCs were found in most samples. PFCs concentrations in influent (n = 14) and effluent (n = 14) of seven MWWTPs are shown in Table 4. The total PFCs concentration in influents ranged from 9.4 to 18.4 ng/L while PFCs concentration in effluent were found higher than influent ranged from 12.7 to 63.6 ng/L. Among seven MWWTPs, Chong Nonsi (63.6 ng/L) had the highest PFCs concentration in effluent followed by Jatujak (37.2 ng/L), Nong Khaem (29.5), Din Daeng (28.8 ng/L), Si Phraya (24.1 ng/L), Rattanakosin (20.9) and Throong Kru (12.7), respectively. PFOS and PFOA were predominant and their concentration levels of other PFCs were mostly lower than PFOS and PFOA. The concentrations of PFCs among PFASs group (C₂, C₅, and C₆) in effluents found that PFOS (2.6 to 9.3 ng/L) had the highest concentration in all MWWTPs. PFBS (0.4 – 8.5 ng/L) was found to have higher concentration than PFHS (0.1 – 6.5 ng/L) in effluent. Similar results were reported from effluent of a MWWTP in Germany. Lange reported that increase of short carbon-chain PFCs as PFBS concentration in wastewater was due to substitute for PFOS. For PFCAs (C₃ – C₁₂), PFOA was the dominant compound, which was found at higher concentration (2.2 to 7.4 ng/L) in most effluent samples. Short carbon-chain PFCs as PFPeA (1.3 – 5.7 ng/L), PFHxA (2.5 – 5.1 ng/L), and PFHpA (0.8 – 6.8 ng/L) were found to have higher concentration than long carbon-chain PFCs such as PFNA (0.4 – 6.5 ng/L) and PFDA (0.8 – 5.3 ng/L). PFUnDa and PFDoDa were not detected in most of samples, except effluent from Chong Nonsi MWWTPs. Previous studies have reported that perfluoroalkyl carboxylates are produced as biodegradation products of

Table 4 Concentrations of PFCs (ng/L) in influent and effluent from seven MWWTPs in Bangkok

<table>
<thead>
<tr>
<th>Phase</th>
<th>Jatujak</th>
<th>Din Daeng</th>
<th>Rattanakosin</th>
<th>Si Phraya</th>
<th>Chong Nonsi</th>
<th>Throong Kru</th>
<th>Nong Khaem</th>
<th>Ave.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inf</td>
<td>1.4  4.5</td>
<td>2.3  6.5</td>
<td>1.7  3.7</td>
<td>2.2  4.3</td>
<td>5.9  9.3</td>
<td>1.1  1.8</td>
<td>5.0  8.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Eff</td>
<td>1.2  3.5</td>
<td>2.6  4.8</td>
<td>1.7  4.5</td>
<td>2.2  4.3</td>
<td>8.3  12.0</td>
<td>1.1  2.6</td>
<td>8.0  12.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Inf/Inf</td>
<td>0.8  1.6</td>
<td>2.0  2.6</td>
<td>1.1  1.6</td>
<td>0.9  2.2</td>
<td>1.3  1.5</td>
<td>0.7  1.5</td>
<td>0.6  1.3</td>
<td>1.6</td>
</tr>
<tr>
<td>Inf/Inf</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0  1.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Note: Inf = Influent, Eff = Effluent, ND = Not detect, Ave = average
fluorotelomer alcohols (FTOHs) in the activated sludge process\textsuperscript{25}. Thus, the biodegradation of precursor compounds during activated sludge process is also a likely source of perfluoroalkyl carboxylates in effluent. Short carbon-chain PFCs in municipal effluent wastewater were detected at higher concentrations than long carbon-chain ones\textsuperscript{17}). The comparison of PFCs concentration in influent and effluent showed that total PFC concentrations increased in effluents approximately 2.5 times. The concentration of PFOS and PFOA were found to be higher in effluent than in influent, which describes that both compounds can also be generated through degradation of their precursors in the treatment processes\textsuperscript{26}).

PFCs composition profile in effluent of each MWWTPs was shown in Fig. 1. PFCs have been used in several products include protective coatings for food packaging, textiles, carpets, paper, coats, fabrics, leather and non-stick cooking materia\textsuperscript{27}). Daily domestic activities using PFCs containing products could be possible source of PFCs in MWWTP. Therefore, MWWTPs have potential to be one of the sources of PFCs contamination in water environment.

(2) PFCs distribution in municipal wastewater treatment processes and their removal

Earlier it was mentioned that PFCs were detected in most effluent samples. Therefore, the performance of municipal wastewater treatment processes needs to be investigated. Fig. 2 shows the comparison of PFCs concentration at influent, aeration, secondary clarifier, and final effluent in both liquid and particulate phases. PFCs concentration of liquid and particulate phases in influents are almost similar in all MWWTPs which had lower of PFCs concentration than aeration, secondary clarifier, and final effluent. As wastewater reaches into aeration process, the concentrations of PFCs increased by many folds than compared with influent samples. Particularly, its concentration in particulate phase samples increased 2 to 7 times higher than in liquid phase. Increase of PFCs concentration in aeration process is a common phenomenon in WWTPs as many researches have reported\textsuperscript{20,26}). PFCs concentration can be increased by two main reasons. First, probably due to transformation of precursors

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**Fig. 2** Comparison of total PFCs concentration (ng/L) in each municipal wastewater treatment processes both liquid and particulate phases.

**Wastewater treatment processes:**

- Inf: Influent
- AT: Aeration tank
- SC: Secondary clarifier
- Eff: Effluent

**Note:** Value above each bar charge is the ratio of PFCs concentration in liquid and particulate phases.
into PFCs at aeration process and it is a widely discussed possibility among the researchers\textsuperscript{9,16,25,28}. Biotransformation of precursors such as alcohol (N-EtFOSE) and acetic acid (N-EtFOSAA) of 2-(N-ethyl-perfluorooctane- sulfonamido) into PFOS and fluorotelomer alcohols into PFCAs were often mentioned in those studies. Another reason could be adsorption/bioaccumulation of PFCs from fresh batch of wastewater into activated sludge. Each batch of wastewater is retained in the aeration tank for certain period of time (hydraulic retention time, HRT), which mixes with activated sludge. Moreover, the activated sludge is retained in the aeration tank for several days (sludge retention time, SRT) and also recirculated. Hence, repeated contact of activated sludge with fresh batch of wastewater containing PFCs for several days, increases concentration of PFCs absorption/bioaccumulation into activated sludge. Further, the hydrophobic properties of PFCs also enhance their adsorption into activated sludge\textsuperscript{32}.

In secondary clarifier process, PFCs concentration in particulate phase decreased than from aeration process, while increased in liquid phase. This could be due to degradation of PFCs precursors, desorption of PFCs from particulate phase, or matrix interference in the samples. All MWWTPs investigated in this study found higher PFCs concentration in effluent than influent. In effluent, most of MWWTPs showed similar or increase of PFCs concentration in liquid phase, since all MWWTPs used activated sludge, which was returned from the secondary clarifier. PFCs level in the particulate phase increased in the aeration tank and it could be from the sludge system. Therefore, it shows that PFCs are not removed effectively by activated sludge process.

(3) Behavior of PFCs in liquid and particulate phases

Activated sludge is a conventional treatment process and it has been reported that it is not sufficient to remove PFCs. High concentrations of PFCs were detected in aeration tank in both liquid and particulate phases. Therefore, PFCs behavior in aeration was observed. The percentage of each PFCs in both liquid and particulate phases from all MWWTPs was showed in Fig. 3. The graph shows percentage of each PFCs adsorbed on particulate phase. In PFASs group, it was found that PFOS (>99%) was more adsorbed on particulate phase than PFHS (62%) and PFBS (1%). The adsorption potential of PFCs increased with increasing number of carbon chains. PFCAs also showed similar trend and long carbon-chain were more adsorbed on activated sludge than shorter carbon-chain ones. Particularly, PFUnDA and PFDoDA were long carbon-chain PFCs which were non-detectable in most effluent samples. It could be explained that those compounds were highly adsorbed on particulate phase at 72% and 89%, respectively.

Longer carbon-chain PFCs were more hydrophobic than shorter ones. Therefore, hydrophobic interaction was an important mechanism of PFCs adsorption on activated sludge. Moreover, perfluorinated surfactants were reported to be more hydrophobic than hydrocarbon ones\textsuperscript{29}. Several studies reported that organic carbons in sediment was a dominant parameter affecting PFCs adsorption, indicating the importance of hydrophobic interaction\textsuperscript{30,31}. At equal perfluorocarbon chain, it was found that sulfonate was more adsorbed on particulate phase than carboxylate due to stronger hydrophobicity. For example, PFOS and PFNA have same length of perfluorocarbon chain and also PFHS and PFHpA. PFOS (>99%) was adsorbed more in particulate phase than PFNA (8%) and PFHS (62%) was also adsorbed more than PFHpA (29%), respectively. Zhou\textsuperscript{32} reported that PFOS was highly adsorbed on activated sludge higher than PFBS, PFHxA, PFHS, PFOA and PFDoDA. Overall, higher PFCs concentration were detected in particulate phase in activated sludge process. Therefore, return sludge could cause the increasing of PFCs concentration due to their accumulation during the process.

(4) Comparison with other countries

Several countries have reported increase in level of PFCs concentration in effluent from MWWTPs. In this study, occurrence of PFOS and PFOA were found at higher concentration than other types of PFCs. Similar high concentrations of PFOS and PFOA were detected in MWWTPs in several
countries. Fig. 4 shows the comparison of PFOS and PFOA concentrations in effluents among various countries (Germany\textsuperscript{5}, Denmark\textsuperscript{6}, Korea\textsuperscript{7}, Taiwan\textsuperscript{8}, Hong Kong\textsuperscript{9} and Singapore\textsuperscript{10}). It showed that PFOS was found in lower concentration than other countries, except Germany and Korea, while PFOA was found in lower concentration than in other countries except Hong Kong. The concentration of both PFOS and PFOA were lower than 10 ng/L, which was lower than in many countries. The reason could be sewerage system. Due to the combined sewerage system in Bangkok, wastewater discharged from household had mixed with storm water. Therefore, it had affected PFOS and PFOA concentrations. Moreover, this survey was done during raining season so dilution effect from rain water has high possibility. Thus, the repetition of sampling should be done in dry season for further studies.

5. CONCLUSION

This study demonstrates PFCs contamination in seven MWWTPs, located in urban city as Bangkok. The highest PFCs concentration was detected at Chong Nonsi MWWTP. Contamination patterns of PFCs in wastewater were almost similar in all MWWTPs. Particularly, short carbon-chain PFCs (C\textsubscript{4} – C\textsubscript{7}) were found in higher concentration than long carbon-chain ones (C\textsubscript{9} – C\textsubscript{12}). Dominant PFCs as PFOS (C\textsubscript{8}) and PFOA (C\textsubscript{8}) were found high concentration than other PFCs in most MWWTPs. The remaining PFCs in effluents indicated that the conventional wastewater treatment process was not effective to remove PFCs. Long carbon-chain PFCs were more adsorbed on particulate than short carbon-chain ones, having similar pattern for both PFASs and PFCAs. In comparison with other countries, lower level of PFOS and PFOA were observed in Bangkok MWWTPs. Seasonal variation could have possibly affected on PFCs concentration in wastewater. Seasonal variation and transformation of PFCs are needed in further study.

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タイ・バンコク7箇所の都市下水処理場における
有機フッ素化合物類(PFCs)の汚染実態

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有機フッ素化合物類(PFCs)は難分解性、毒性、生物濃縮性を持つ人工化学物質であり、都市下水処理場は水環境に対するPFCs負荷源として懸念される。本研究は、タイ・バンコクでの都市下水処理場において11種のPFCsの汚染実態を検討するものであり、7箇所の都市下水処理場において、主要な下水処理工程ごとに試料を採取した。なお、すべての下水処理場で標準活性汚泥法を用いていた。調査の結果、Chong Nonsi下水処理場放流水で総濃度63.6 ng/Lの最大値を検出した。放流水では、ペルフルオロオクタンスルホン酸(PFOS)とペルフルオロオクタンカルボン酸(PFOA)は他のPFCsに比べて高濃度で検出され、それぞれ2.7-5.6 ng/L, 2.2-7.4 ng/Lであった。放流水でPFCs濃度は流入水中濃度より高く、標準活性汚泥法による下水処理ではPFCsを除去できていないことが示唆された。長い炭素鎖のPFCsは短い炭素鎖のPFCsに比べて、懸濁態の比率が高かった。他の国と比較すると、処理場流出水におけるPFOS、PFOA濃度はデンマーク、台湾、シンガポールより低かったが、数種類のPFCsが検出され、都市下水処理場が環境中におけるPFCs負荷源のひとつであることが示唆された。