Detection, occurrence, and fate of fluorotelomer alcohols in municipal wastewater treatment plants (WWTPs), and the long-term influence of textile manufacturing industry

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Emerging pollutants and managing wastewater and waste

Abstract Fluorotelomer alcohols (FTOHs), the most well-known precursors and substitutes of perfluoroalkyl carboxylic acids (PFCAs), have been widely used in the textile industry as waterproofing. Municipal wastewater treatment plants (WWTPs) were considered as one of emerging contaminants into the environment. But limited information was available on occurrence and fate of FTOHs in municipal WWTPs, and the influence of textile manufacturing wastewater on occurrences of FTOHs in municipal WWTPs. Thus, the occurrence of six FTOHs in 12 municipal WWTPs of China and the mass balance of FTOHs and PFCAs in one WWTP with an anaerobic-anoxic-oxic process (A/A/O) was explored. And the long-term trend of FTOH concentrations and profiles in 2013-2021 in a WWTP receiving discharges from the textile manufacturing industry (T-WWTP) and other four domestic WWTPs (D-WWTPs) were investigated. This study found that FTOHs were widely detected in municipal WWTPs and 8:2 FTOH was the predominant congener. The mass balance analysis found the decrease of FTOHs mass loads and the increase of PFCAs mass loads through aerobic treatment, suggesting the potential biotransformation of FTOHs to PFCAs. For the long-term investigation, the total concentrations of FTOHs in wastewater and sludge samples of the T-WWTP were significantly higher than those of the D-WWTPs (p<0.01). The variation in FTOH concentrations of the T-WWTP was in accord with the variation in annual output of textile products in the sewershed (p=0.005), which suggested the textile manufacturing industry as a significant discharge route for FTOHs to municipal WWTP. This study will improve our understanding on the occurrence, fate and source of FTOHs in municipal WWTPs.

Method

- Wastewater and sludge samples were collected from 12 municipal WWTPs (Plant A−Plant L) in nine cities of China from June 2014 to April 2016, with the treatment capacity 60,000−2,000,000 m^3/d and three treatment processes (A/A/O, oxidation ditch, and cyclic activated sludge technology).
- Mass flow samples were collected from Plant A (A/A/O) on 6, 7, and 8 June, 2014.
- Wastewater and sludge samples were collected from a wastewater treatment plant receiving domestic and textile manufacturing industrial wastewater (T-WWTP) and four wastewater treatment plants receiving domestic wastewater (D-WWTPs), with the treatment capacities 100,000–170,000 m^3/d.
- A derivatization method based on dansylation UPLC-MS-MS was employed to determine FTOHs.

Results and discussion

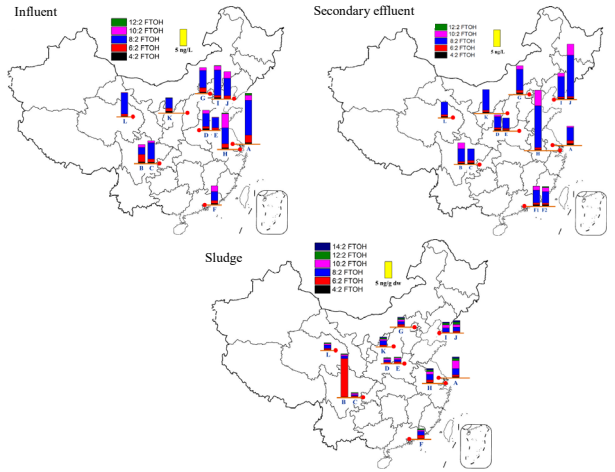


Fig. 1 Concentrations and distributions of FTOHs in influent, secondary effluent and sludge samples from 12 municipal WWTPs.

FTOHs were detected in all of 12 WWTPs, and 8:2 FTOH was the predominant congener, with concentrations of 2.10−11.0 ng/L, 3.05−12.4 ng/L, and 0.36−1.91 ng/g dry weight in the influent, secondary effluent and sludge samples, respectively.

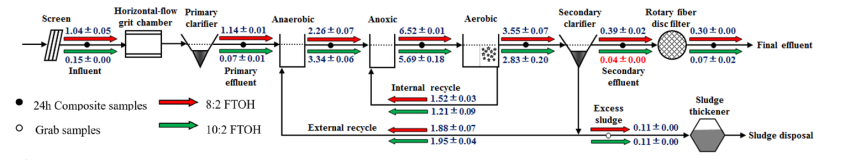


Fig. 2. Total mass flow (g/d) of 8:2 FTOH, and 10:2 FTOH along the treatment processes in Plant A (A/A/O).

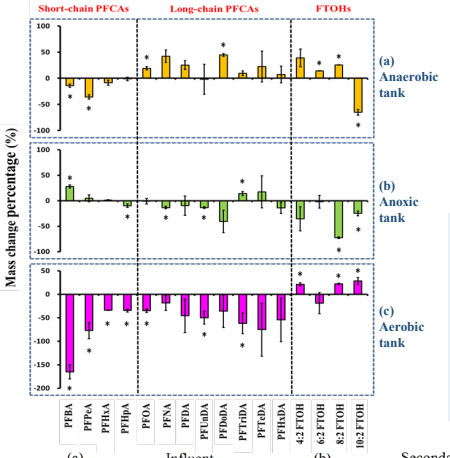


Fig. 3 Mass change percentages of PFCAs and FTOHs in three treatment processes of Plant A (A/A/O). "*" indicates a statistically significant result.

The mass balance of FTOHs and PFCAs in a WWTP with an anaerobic-anoxic-oxic process was explored. The decrease of mass loads was observed for 4:2 FTOH (21±3.3%), 8:2 FTOH (22±1.5%), and 10:2 FTOH (29±7.3%) through aerobic treatment, while the increase of mass loads was observed for 12 PFCAs from 18±16% to 165±15%, suggesting the potential biotransformation of FTOHs to PFCAs in the aerobic unit.

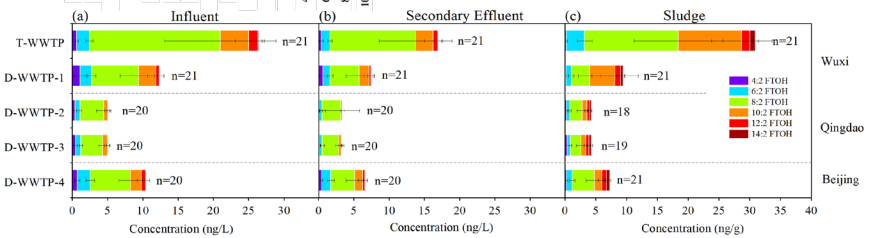
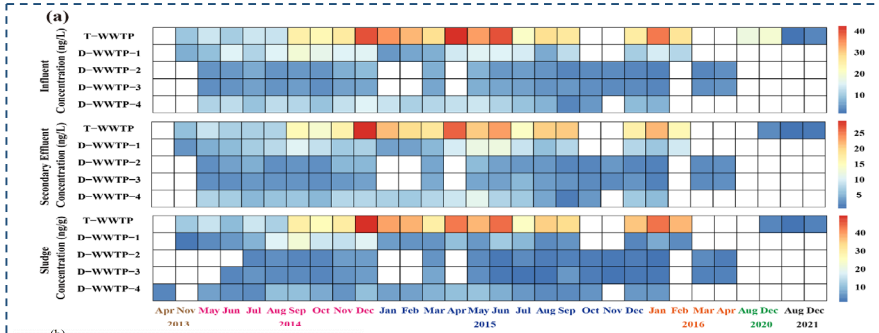


Fig. 4 The concentrations of FTOHs in the (a) influent, (b) secondary effluent and (c) sludge of five municipal WWTPs (2013–2016). D-WWTP: domestic wastewater treatment plant; T-WWTP: co-treated domestic wastewater and textile manufacturing industrial wastewater.

The total concentrations of FTOHs, which were 9.8–43 ng/L, 5.9–29 ng/L and 10–50 ng/g in influent, secondary effluent, and sludge samples from the T-WWTP, were significantly higher than those of the D-WWTPs (p < 0.01)



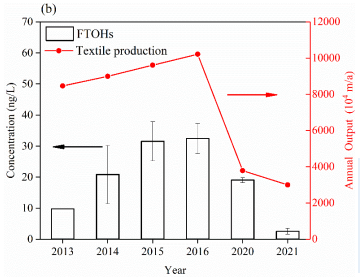


Fig. 5. (a) Long-term concentration variations of ΣFTOHs in wastewater and sludge samples of five municipal WWTPs (empty grid: data was not available) in 2013–2021. (b) Average annual concentration of FTOHs in influent of T-WWTP and annual output of textile products in the sewershed. Due to the successive upgrading of treatment processes in T-WWTP, the samples were not available during 2017–2019.

The variation in FTOH concentrations in the T-WWTP was in accord with the variation in annual output of textile products in the sewershed (p=0.005). The results suggested the textile manufacturing industry as a significant discharge route for FTOHs to municipal WWTP.

Conclusions

- This work provides the first report on the mass balance of FTOHs in municipal WWTPs and indicates part of the FTOHs may have been transformed to PFCAs in the aerobic tank.
- The higher FTOH concentrations of T-WWTP receiving municipal and textile manufacturing wastewater relative to the other municipal WWTPs were found. Significant correlation between annual average FTOH concentration in T-WWTP and annual output of textile products demonstrated the textile manufacturing wastewater as a significant source for FTOHs to enter municipal WWTPs.

References:
Chen Hongrui, Peng Hui, Yang Min, et al. Detection, occurrence, and fate of fluorotelomer alcohols in municipal wastewater treatment plants. Environmental Science & Technology, 2017, 51: 8953-8961.
Ma Chunmeng, Peng Hui, Chen Hongrui, et al. Long-term trends of fluorotelomer alcohols in a wastewater treatment plant impacted by textile manufacturing industry. Chemosphere, 2022, 299: 134442.

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