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Removal of short- and long-chain perfluorinated compounds from surface water by coagulation

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Abstract. Per- and poly-fluorinated compounds (PFCs) are persistently found during drinking water treatment processes, which can also be found in tap water. However, the mechanisms for removing PFCs during drinking water treatment processes have not been fully understood. In this study, we investigated the effect of coagulation on the removal of short- and long-chain PFCs. The PFCs mixture (C5–C10) resulted in a lower removal efficacy via coagulation treatment, and the average removals of selected PFCs were found to be below 5%. Only long-chain perfluorodecanoic acid (PFDA) (C10) and perfluorooctanesulfonic acid (PFOS) were significantly removed via coagulation. The removals of suspended particles and bacterial cells via coagulation were correlated with the reduction of PFDA and PFOS. However, higher turbidity, humic substances, and biopolymers in the source water were found to significantly reduce the removal efficiency of PFDA and PFOS, resulting in insignificant changes between the PFC species. We concluded that coagulation was not effective in removing selected PFCs, hence, a multiple-barrier treatment strategy is needed for PFC removal.

Keywords: chain length; coagulation; perfluorinated compounds

1. Introduction

Per- and poly-fluorinated compounds (PFCs) contaminants are widely found in surface water, groundwater, industrial wastewater, landfill leachate, and drinking water (Son *et al*. 2013, Pramanik 2015, Kim and Zoh 2016, Kim *et al*. 2020, 2021, Pierpaoli *et al*. 2021) and have been known to cause chronic and acute toxicity to humans. Recent studies have also reported PFCs in drinking water from source to tap (Jin *et al*. 2009, Li *et al*. 2019, Kim *et al*. 2020). PFCs are aliphatic carbon compounds with carbon-fluorine bonds, where hydrogen atoms are switched with fluorine. Due to their strong carbon-fluorine bonds, they often exhibit high thermal and chemical stabilities (Key *et al*. 1997, Bao *et al*. 2014), making them persistent not only in aquatic environments but also in drinking water treatment processes. Due to their high lipophilicity, PFCs can easily bio-accumulate in animals, including humans. PFCs are manufactured chemicals used in numerous industries to produce alkaline cleaners, paints, non-stick cookware coatings, textiles, soaps, shampoos, floor polishes, denture cleaners, fume suppressants, firefighting foams, semiconductors, packaging, and others (Xiao *et al*. 2013, Rahman *et al*. 2014, Pramanik *et al*. 2015).

Kunacheva *et al*. (2012) summarized the global distribution of PFCs and found significantly higher levels of perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in industrialized areas. In Korea, one of the most industrialized countries, 2–19 and 1–89 ng L^{-1} of perfluorinated carboxylic and sulfonic acids (PFCAs and PFSAs) were detected in stream water, respectively (Rostkowski *et al*. 2006). However, there are no regulations on the concentration of PFOAs and PFOSs in Korea. PFCs in treated water have ranged below health advisory levels, but waterworks have recently started monitoring them to ensure safe water quality (Table 1). Due to health concerns, global industries have replaced long-chain PFCs with short-chain species, having relatively lower bioaccumulation potentials (Renner 2006, Ateia *et al*. 2019, Kim *et al*. 2021). Generally, long-chain PFCs have shown higher toxicity than short-chain PFCs (Gao *et al*. 2019), but a previous study reported higher toxicity for short-chain PFCs (Ateia *et al*. 2019), and mixture toxicity remains largely unknown (Brendel *et al*. 2018).

Coagulation treatment process possibly mitigates PFC levels for the following granular activated carbon filters, often used in advanced drinking water treatment processes. A recent study also confirmed the distribution of short- and long-chain PFCs in drinking water sources, possibly

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