

Contamination of Perfluorinated Compounds (PFCs) from Thai Industrial Estates

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1. Introduction

Perfluorinated compounds (PFCs) are fully fluorinated organic compounds, which have been used in many industrial processes and are distributed all over the world. Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA) recently became a cause for concern as a new group of persistent organic compounds (POPs) that are persistent, bioaccumulated, and toxic⁽¹⁾. Until now, the sources of contamination of these compounds have not been understood. However, some reports revealed that their major sources seem to be related to industrial activities^(2,4). Recently, the major PFCs manufacturers have shifted their factories to developing countries especially in the Southeast Asian region where few researches have reported PFCs contamination. The purposes of this field study were to identify PFCs concentration and loading released by industrial estates.

2. Method and Material

Surveys were conducted in selected seven industrial estates in Central and Eastern Thailand (2007/9/18, 2007/12/6, 2008/2/8, 2008/6/27, and 2008/8/29). There are more than 200 factories located in each industrial zone, including several industry types that have potential of releasing PFCs, such as electronics, chemical, paper, plastic and glass. All industries located in the area discharge their wastewater to each estate's central wastewater treatment plant. Samples were obtained from their central wastewater treatment plants' effluent. Tap water of each estate was collected to determine based PFCs concentration in the estate.

Table 1. Analytical Parameters of Analyzed PFCs by LC-ESI-MS/MS Analysis

Compound	No. of Carbon	Parent ion (<i>m/z</i>)	Daughter ion (<i>m/z</i>)	CE* (eV)	Retention time (min.)	LOQ (ng/L)
PFPA	C5-A	263	219	-15	2.1	0.5
PFHxA	C6-A	313	269	-15	3.2	0.4
PFHpA	C7-A	363	319	-15	5.4	0.3
PFOA	C8-A	413	369	-15	8.1	0.5
PFNA	C9-A	463	419	-15	10.9	0.4
PFDA	C10-A	513	469	-15	13.8	0.2
PFUnA	C11-A	563	519	-15	16.7	0.3
PFDaA	C12-A	613	569	-17	19.1	0.2
PFHxS	C6-S	399	80	-90	8.9	0.4
PFOS	C8-S	499	80	-90	15	0.2

Note: *CE = Collision Energy

S = Perfluorinated sulfonates (PFCsS)

A = Perfluorinated carboxylic acids (PFCAs)

Every sample was collected by grab-sampling, and stored in a new 1.5 L narrow-neck PET bottle. PET bottles were rinsed three times with sample before collection. After sampling, the samples were brought back to laboratory and were filtered with Whatman GF/B glass fiber filters, basically in the same day. Both of filtrates and filters were used for the PFCs analysis of soluble and particulates fractions, respectively. The Dionex Accelerated Solvent Extraction Unit (ASE-200) was applied for treatment of filters. A solid phase extraction (SPE) by using Precep C-Agri (C18) cartridge coupled with HPLC-ESI-MS/MS (Agilent 6400 Triple Quadrupole) were used for the analysis of these chemicals^(3,4). Totally, ten PFCs including PFOS, PFOA, Perfluoropropanoic acid (PFPA), Perfluorohexanoic acid (PFHxA), Perfluoroheptanoic acid (PFHpA), Perfluorohexane sulfonate (PFHxS), Perfluoronanoic acid (PFNA), Perfluorodecanoic acid (PF+DA), Perfluoroundecanoic acid (PFUnA), and Perfluorododecanoic acid (PFDaA) were measured to identify their occurrences. The average recovery rate of tap water samples was 90±17%, while average recovery rate of effluent samples was 74±21%. The analytical parameters of each PFC are shown in Table 1.

Keywords: Perfluorinated compounds (PFCs), PFOS, PFOA, industrial estates, wastewater, Thailand

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3. Result and Discussion

Figure 1 shows combined ten PFCs concentrations in tap water and effluent samples of seven industrial estates. All PFCs were detected in most samples above *LOQ*. Tap water concentration was ranged from 4.2 to 176.4 ng/L. Tap water concentrations were quite different from each estate because the sources of tap water are from lake or reservoir nearby the industrial estate. PFCs concentrations in effluent sample were varied from 94.3 to 10,960 ng/L. Only IE1 indicates that there is no PFCs contamination released from industrial activities, while other estates released significant amount of PFCs from the processes. The result indicates that PFOS (70%) and PFOA (18%) were the dominant among ten PFCs in both tap water and effluent samples. Other eight PFCs were also detected in most samples with relative abundance less than 5%. PFOS concentrations were ranged from 1.4 to 10,030 ng/L, while PFOA were varied from 20.4 to 1,643.4 ng/L. The highest PFOS was detected from IE5, while the highest PFOA was detected in the effluent of IE2. Table 2 shows PFOS and PFOA

loading discharges from seven industrial estates. Seven industrial estates released 209 g/d of PFOS and 32.5 g/d of PFOA. Highest loading of PFOS was detected in IE5 with 201 g/d, while highest PFOA was released by IE2 with loading 19.7 g/d. These amounts of PFCs were released by industrial estates and contaminated to the environment nearby. This indicates that there are specific types of industry released these compounds, such as IE5 and IE2.

4. Conclusion

All PFCs were detected in most samples above LOQ. PFCs concentrations in effluent sample were varied from 94.3 to 10,960 ng/L. Only IE1 indicates that there is no PFCs contamination released from industrial activities, while other estates released significant amount of PFCs from the processes. The result also indicates that PFOS (70%) and PFOA (18%) were the dominant among ten PFCs in both tap water and effluent samples. Seven industrial estates released 209 g/d of PFOS and 32.5 g/d of PFOA.

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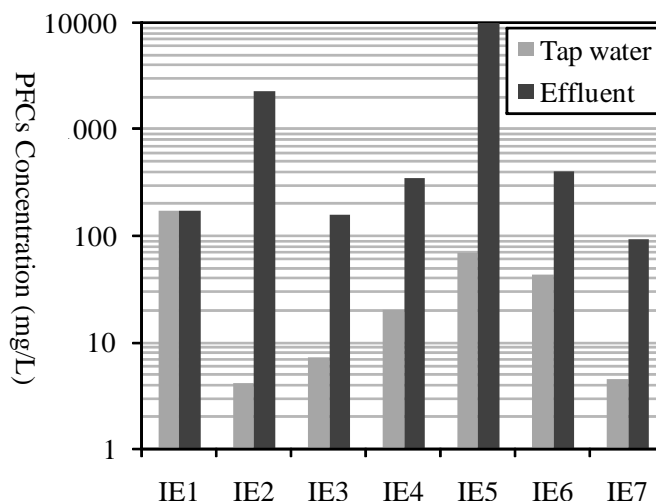


Figure 1. Combined ten PFCs concentration in tap and effluent samples

Table 2. PFCs loading from industrial estates

Industrial Estates	No. of Industries*	Process type*	Flow rate (m ³ /d)*	Loading (g/d)	
				PFOS	PFOA
IE1	478	AS, Wetland	30,000	2.81	1.45
IE2	316	AS	12,000	0.02	19.72
IE3	270	AS	16,800	0.02	0.96
IE4	200	AS	14,000	1.84	1.28
IE5	484	SBR	20,000	200.66	2.92
IE6	398	AS	23,700	2.47	5.75
IE7	320	AS	21,000	1.02	0.43
Total				208.84	32.51

*Source: <http://www.ieat.go.th/> (2009)