Thailand PFAS Country Situation Report

By Ecological Alert and Recovery Thailand (EARTH)
March 2019

Executive summary

This report provides information about PFAS substances and summarizes scientific studies on per- and polyfluoroalkyl substances (PFAS) in Thailand – including those in the Thai language that may not be easily accessible. Thailand is a Party to the Stockholm Convention and ratified the amendment listing PFOS in 2010.

Scientific studies of PFAS and examination of regulatory policy in Thailand raise concerns about these substances and reinforce the need for regulatory action.

PFAS substances are poorly controlled in Thailand

Thailand became a Party to the Stockholm Convention in 2005 and the treaty added PFOS to its global restriction list in 2009. This amendment went into legal force in Thailand in 2010. However, other PFAS are essentially unregulated.

PFAS water pollution is widespread

PFAS water pollution occurs in major rivers, ground water, tap water, and bottled drinking water. The Chao Phraya River covers 160,000 km^2 (30% of Thailand's area) and supplies water to millions of people. In the Chao Phraya River, PFOS levels ranged up to 20 mg/L (ppt) and PFOS ranged from 0.7 – 20 ng/L (ppt). Levels increased from the upstream area to the outlet and the highest levels were found at the port where one of Bangkok's wastewater treatment plants discharges effluents. Industrial wastewater contained PFOS with average levels of 264 ng/L (ppt) and reaching 6,200 ng/L (ppt) – a very high level. The authors suggest that the data indicates that industrial wastewater is one of the major sources of PFOS contamination in the water system in Bangkok.

PFAS pollution occurs in ground water near municipal waste dumps and an industrial waste disposal site, including PFOS, PFOA, PFHpA, PFNA, PFUnA, and PFHxS. Some of the PFAS levels exceed modern health advisory and regulatory standards in US states.

The main tap water source in Bangkok is the Chao Phraya River which is known to contain PFAS substances including 20 – 30 ppt PFOA. Wastewater released into the river is known to contain up to 6000 ppt PFOS.

A 2009 study found five types of PFAS in bottled water in Bangkok with concentrations between 3.31 – 25.79 ppt. The highest levels exceed the health advisory limit in the US state of Vermont of 20 ppt for PFOA, PFOS, PFHxS, PFHpA and PFNA combined. PFOA was the predominant PFAS found.

Wastewater treatment plants are PFAS pollution sources

A 2011 study found that conventional wastewater treatment processes from seven wastewater treatment plants in Bangkok could not effectively remove PFAS substances. PFOA was the predominant PFAS but other PFAS substances included PFBA, PFHxA, PFHpA, PFNA, PFUnA, and PFOS.

Industrial estates serve many types of industries including textile, electronics, plastics, personal care products, chemicals, glasses etc., mostly belonging to multinational companies. Industrial wastewater treatment plants in central and eastern Thailand contained PFOA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnA, PFDoA, PFHxS and PFOS. Both plants were ineffective at removing PFAS and one plant actually increased PFAS levels. PFAS levels in effluents varied from 662 – 1143 ng/L (ppt). PFOS levels were higher than similar plants in US, Singapore, Switzerland, and Japan. A 2010 study found daily mass PFAS discharges from the studied industrial estate wastewater treatments plant ranged from 1.34–36.6 g/d. The Thai samples from industrial estates showed higher PFAS levels than samples from Japan. Techniques such as aerobic and anaerobic biological treatment, sand filtration, chlorination, ozonation, and activated carbon were all found to be ineffective at removing PFAS substances. The authors hypothesize that multinational companies are shifting PFAS use to developing countries such as Thailand where they are not regulated.

Textile products are contaminated with PFAS

PFAS substances have been found in textile products on the Thai market including diapers, shirts, pants, footwear, towels, uniforms, bags, curtains, upholstery, carpets, blankets, and table cloths. The highest PFOS levels were found in a carpet (0.61 ug/m^2) and the highest PFOA levels were found in bags (14.14 ug/m^2). Both PFOS and PFOA were released into washing water with the highest levels after the first washing. The authors note that, "The data presented in this study showed that textiles could be a significant direct and indirect source of PFOS and PFOA for both human and environmental exposure. Migration of PFOS and PFOA into the human body from textiles through sweat during wearing and the risk assessment of PFOS and PFOA in textiles, should be further studied."

PFAS contaminates food packaging

A 2012 study found PFOA and PFOS in packaging: noodle cup, instant rice porridge cup, microwave popcorn bag, beverage cup, ice cream cup, fried chicken box, fried chicken wrapper, French fries bag, French fries wrapper, French fries box, hamburger wrapper, pretzels box, pretzels wrapper, donut box, donut wrapper, and baking paper. The authors noted that, "there is a potentially significant negative impact on human health from the consumption of food and beverages contained in paper packaging." The authors also noted that PFAS would be released from this packaging when the products become wastes.

Household dust contains PFAS

A 2011 study found eight PFAS substances in household dust samples collected in Bangkok. The highest levels were for EtFOSA (940 ng/g or ppb) – a substance that degrades to PFOS. The authors note that dust may be an important PFAS exposure pathway for young children.

PFAS elimination contributes to the Sustainable Development Goals

Actions to control and phase-out PFAS as a class contribute to achievement of several key Sustainable Development Goals (SDGs) due to the impacts of the substances on health and ecosystems including water pollution. These include SDGs 3, 6, 9, 12, 14, 15, and 16.

Introduction

What are per- and polyfluoroalkyl substances (PFAS)?

PFAS is a large class of more than 4,500 persistent fluorinated chemicals. PFAS are both hydrophobic and lipophobic in nature and extremely persistent due to the strength of the carbon-fluorine bond. They are widely distributed in the global environment due to their high solubility in water, low/moderate sorption to soils and sediments and resistance to biological and chemical degradation. The properties of PFAS have resulted in extensive use as surfactants and surface-active agents in products. Two widely-used members of this class have been perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). As these two substances have come under regulatory pressure, the industry has shifted to other PFAS with similar properties.

Human exposure to PFAS is mainly by ingestion of contaminated food or water. These substances bind to proteins (not to fats) and persist in the body where they are mainly detected in blood, liver and kidneys. Studies indicate that PFOA and PFOS can cause reproductive and developmental, liver and kidney, and immunological effects in laboratory animals. Both chemicals cause tumors in animal studies along with a variety of other effects on infant birth weight, growth, learning, infant behavior, pregnancy, endocrine system, increased cholesterol, and thyroid function. Recent studies have linked a variety of PFAS substances to many human health effects: cardiovascular disease, markers of asthma, damage to semen quality, ovarian insufficiency, altered glucose metabolism, lower testosterone levels in male adolescents, association with shorter birth length in girls, elevated blood pressure, abnormal menstruation, lower birth weight in infants, possible increased risk of female infertility due to endometriosis, and decreased lung function in children with asthma.

The manufacture and use of PFAS and their use in a multitude of products has caused widespread pollution. PFAS are found in wildlife, accumulating in the blood, liver and kidneys of wildlife such as dolphins, polar bears, seals, birds, fish, and other marine wildlife. PFAS substitutes for PFOS and PFOA have been identified as potential global surface water contaminants and they have been found in more than 80% of 30 surface seawater samples from the North Pacific to Arctic Ocean. PFAS use in firefighting foams at military bases and airports is responsible for water pollution and contaminated communities in many countries, including Australia, Canada, China, Germany, Italy, Japan, Netherlands, New Zealand, South Korea, and Sweden.

Safer cost competitive non-fluorinated alternatives for PFAS use in firefighting foams have been adopted by an increasing number of major airports, including Auckland, Copenhagen, Dubai, Dortmund, Stuttgart, London Heathrow, Manchester, and all 27 major airports in Australia. Increasing awareness about the negative characteristics of PFAS has driven efforts to identify and market safer substitutes for other uses. Increasing awareness about the negative characteristics of PFAS has driven efforts to identify and market safer substitutes for other uses. Due to the complexity and negative characteristics of PFAS, there is increasing interest in regulating PFAS as a class rather than as individual substances.

For more information about recent research on the impacts of PFAS, including fluorinated substitutes for PFOS and PFOA, please see Annex 1. Information about the high cost of PFAS pollution cleanup is available in Annex 2. Global regulation of PFAS through the Stockholm Convention and evaluations of its expert committee is discussed in Annex 3.

Actions on PFAS and the Sustainable Development Goals

Actions to control and phase-out PFAS as a class contribute to achievement of several key Sustainable Development Goals (SDGs) due to the impacts of the substances on health and ecosystems including water pollution. These include

Sustainable Development Goal 3: Ensure healthy lives and promote well-being for all at all ages.

Targets under SDG3 include:
3.4: *"reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being"*
3.9: *"substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination."*

Sustainable Development Goal 6: Ensure availability and sustainable management of water and sanitation for all. Targets under SDG6 include:

6.3: *"improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally."*

Sustainable Development Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Targets under SDG9 include:

9.4: *"greater adoption of clean and environmentally sound technologies and industrial processes."*

Sustainable Development Goal 12: Ensure sustainable consumption and production patterns. Targets under SDG12 include:

12.4: *"By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frame works, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment."*
12.5: *"substantially reduce waste generation through prevention, reduction, recycling and reuse."*
12.6: *"Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle."*
12.7: *"Promote public procurement practices that are sustainable, in accordance with national policies and priorities."*

Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Targets under SDG14 include:

14.1: *"By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution."*

Sustainable Development Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. Targets under SDG15 include:
15.1: *"By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements."*
15.5: *"Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species."*
15.9: *"By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts."*

Sustainable Development Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. Targets under SDG16 include:
16.7: *"Ensure responsive, inclusive, participatory and representative decision-making at all levels."*
16.10: *"Ensure public access to information…"*

Scientific studies on PFAS in Thailand

Note that this includes brief English summaries of scientific studies in the Thai language that may not be widely available elsewhere.

No 1.

Title of Paper: Perfluoroalkyl and Polyfluoroalkyl Substances and their Contamination in the Environment of Thailand (In Thai language)
Author: Jira Kongpran
Department of Environmental Health and Technology, School of Public Health, Walailak University,
Published in The Public Health Journal of Burapha University: Vol.13 No.2 July December 2018

Comment
This publication reviews PFAS in two parts: 1) properties, exposure pathways and health effects; 2) the PFAS situation in Thailand. The paper reveals that PFAS water pollution occurs in Thailand.

One study found five types of PFAS in bottled water in Bangkok with concentrations between 3.31 – 25.79 ppt. PFOA was the predominant PFAS found. Ironically, the concentration of PFAS in bottled water was higher than that of tap water. Other PFAS found in tap water include PFBA, PFPA, PFUnDA and PFOS.

A study of wastewater treatment plant processes found that they could not remove PFAS from water as 10 types of PFAS were found with total concentrations ranging between 662 – 1382 ppt – levels that vastly exceed US state drinking water limits for these substances.

The paper also notes that in 2013 – 2014, PFAS were found in the four main rivers. Samples near an industrial complex located in Samut Prakan Province showed high levels of PFOA (12 – 119 ppt) and PFOS (23 – 435 ppt).

PFAS are also found in house dust in Bangkok. Eight type of PFAS were present with a total concentration between 54 – 1310 ppb. EtFOSA was the predominant PFAS found. This substance is a pesticide ingredient and a precursor to PFOS. Other PFAS found include PFOA, PFHxS, PFOS, FOSA, MeFOSA, Me-FOSE, and EtFOSE

PFAS have also been found in air samples. The total concentration of fluorotelomer alcohols (FTOH) ranged between 1690 – 13,030 pg/m^3. With 10:2 FTOH as the predominant substance. PFAS ranged from 4 – 10 pg/m^3. FTOH are used as precursors and in a variety of products including stain repellents.

The author notes the overall lack of studies on PFAS in Thailand including in food and human blood.

Abstract

Per- and polyfluoroalkyl substances (PFASs) are man-made chemicals which have been produced and used in several industrial and consumer products for more than half a century. PFASs are classified as emerging contaminants due to their ubiquitous contamination in the global environment. They are persistent, bioaccumulative and toxic. Animal experiments and epidemiology studies have shown potential effects of some PFASs to health such as birth outcomes, allergic disease, kidney function, cardiovascular disease, increase of thyroid hormone and cholesterol, and possibly carcinogenic to human etc. Environmental and health concerns have arisen since 2000 results in several researches on PFASs. The production and use of PFASs have been regulated in many countries in order to protect their people. In Thailand, few studies have been conducted only for detection of PFASs in environmental samples including water, house dust and air sample. The results confirm their contamination in the environment which possibly linked to exposure to PFASs in Thai population. Therefore, the study on sources and contamination pathways of PFASs, exposure level in human and related health risk are needed to conduct. Based on these results, the adverse effects of PFASs in Thailand can be regulated.

No 2.

Title of Paper: Levels of perfluorinated compounds (PFCs) in groundwater around improper municipal and industrial waste disposal sites in Thailand and health risk assessment

Authors: Chanidaporn Hongkachok[1], Suwanna Kipati Boontanon[2], Narin Boontanon[3], Shigeo Fuji[4], Shuhei Tanaka[4] and Yuji Suzuki[4]

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Water Sci Technol (2018) 2017(2):457-466

Comment

The authors note that over 50% of industrial waste in Thailand is illegally dumped and these are expected to be PFAS sources for groundwater pollution. The municipal waste disposal sampling sites in Ayutthaya (Bang Chai and Sena) and Chonburi (Map Phai) were chosen due to reports about having a large amount of accumulated waste. Samples were taken directly from faucets connected to a groundwater well.

PFAS substances detected in groundwater near municipal waste dumps included PFHpA, PFOA, PFNA, PFUnA, PFHxS and PFOS. Total PFAS levels ranged from 1.68 – 7.75 ng/L (ppt). The predominant PFAS were PFOS (9% - 78%) and PFOA (22% - 80%).

PFAS were also found near the industrial waste disposal site in Map Phai. Substances included PFOS, PFHpA, PFNA, PFHxS, PFUnA, and PFDA. Levels ranged from 2.6 – 42 ng/L (ppt). The predominant PFAS were PFOA (24% - 87%) and PFOS (8% - 69%). PFHxS was frequently observed in samples taken near the industrial waste disposal site. The authors suggest that this is due to PFHxS serving as an alternative substance for longer chain PFAS such as PFOS.

Levels observed in this study were higher than those reported in Vietnam but less than those reported in China, Japan and USA.

The study estimates cancer and non-cancer risk from drinking ground water and concludes they are "acceptable." However, the carcinogenic risk only included PFOA and the calculations of non-cancer and cancer risk used relatively old US EPA standards established in 2000.

Some of the levels of PFAS observed in groundwater in this study exceed modern health advisory and regulatory standards in US states. For example, currently the US state of Vermont has a health advisory level of 20 ppt for PFOA, PFOS, PFHxS, PFHpA and PFNA combined. Some groundwater samples near the industrial waste dump were more than two times higher than this advisory level.

Abstract:

The aims of this study were to examine the levels of perfluorinated compounds (PFCs) in groundwater around improperly developed municipal and industrial waste disposal sites, including estimating non-cancer risk and cancer risk from ingestion of the groundwater. A total of 27 groundwater samples were collected from two cities in Thailand, Ayutthaya and Chonburi. Seven target compounds were extracted by solid phase extraction (SPE) and analyzed by high-performance liquid chromatography-tandem mass spectrometer (HPLC-MS/MS). The results showed that the total PFCs in groundwater around municipal waste disposal sites (MWDSs) varied from 1.68 to 7.75 ng/L. In groundwater around the industrial waste disposal site (IWDS), total PFCs varied from 2.64 to 42.01 ng/L, which were significantly different from those found in groundwater around the MWDSs at $p < 0.01$. PFOS and PFOA were ubiquitous in both areas, while perfluorohexane sulfonate (PFHxS) was frequently found in the samples around IWDS. The findings

possibly suggest that PFHxS has been introduced for use as an alternative substance for most current C8 and higher due to it having shorter chain length and shorter half-lives. The results for both non-cancer risk and cancer risk in all samples were acceptable.

No 3.

Title of Paper: Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) contamination from textiles

Authors: Phenpimuk Supreeyasunthorn[1], Suwanna K. Boontanon[1] & Narin Boontanon[2]
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J Environ Sci Health A Tox Hazard Subst Environ Eng (2016) 41:472-477

Comment

PFAS have been used in textiles as stain and water repellents. This study examined 32 textile samples of products purchased in Thai stores including diapers, shirts, pants, footwear, towels, uniforms, bags, curtains, upholstery, carpets, blankets, and table cloths.

PFOS and PFOA were found in all samples. The highest PFOS levels were found in a carpet (0.61 ug/m^2) and the highest PFOA levels were found in bags (14.14 ug/m^2). Note that the EU limits PFOS in textiles to 1 ug/m^2. Both PFOS and PFOA were released into washing water with the highest levels after the first washing.

The authors note that, "The data presented in this study showed that textiles could be a significant direct and indirect source of PFOS and PFOA for both human and environmental exposure. Migration of PFOS and PFOA into the human body from textiles through sweat during wearing and the risk assessment of PFOS and PFOA in textiles, should be further studied."

Abstract:

The goals of this study were to determine the concentrations of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in textiles and to determine PFOS and PFOA contamination in textile washing water. Quantification analysis was performed by high performance liquid chromatography coupled with tandem mass spectrometry. Analysis of 32 textile samples by methanol extraction revealed that the average concentrations of PFOS and PFOA were 0.18 μg m(-2) (0.02 to 0.61 μg m(-2)) and 2.74 μg m(-2) (0.31 to 14.14 μg m(-2)), respectively. Although the average concentration of PFOS found in textile samples was below European Union (EU) Commission regulations (<1 μg m(-2)), the average concentration of PFOA was 2.74 μg m(-2), and 68.75% of textile samples had PFOA concentrations exceeding 1 μg m(-2). Thus, based on these results, the concentration of PFOA in products should also be regulated. Experiments on PFOS and PFOA leaching into washing water were conducted. The maximum concentrations of PFOS and PFOA were measured after the first washing; the concentrations gradually decreased with each subsequent washing. PFOS and PFOA migrated from textiles and were released into the

environment, with disappearance percentages of 29.8% for PFOS and 99% for PFOA. The data presented in this study showed that textiles could be a significant direct and indirect source of PFOS and PFOA exposure for both humans and the environment.

No 4.

Title of Paper: Fate and risk Assessment of Perfluoroalkyl substances (PFASs) in water treatment plants and tap water in Bangkok, Thailand

Authors: Wadcharid Tabtong[1], Suwanna Kitpati Boontanon[2], Narin Boontanon[3]
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Procedia Environmental Sciences 2015, 28:750-757

Comment

This study examined PFAS pollution in water treatment plants and tap water in Bangkok. Tap water quality is largely controlled by WHO drinking water guidelines, but the agency has not set standards for PFAS substances. The main tap water source in Bangkok is the Chao Phraya River which is known to contain PFAS substances including 20 – 30 ppt PFOA. Wastewater released into the river is known to contain up to 6000 ppt PFOS. The study sampled each stage of the water treatment process along with tap water.

Conventional wastewater treatment processes could not effectively remove PFAS substances. PFOA was the predominant PFAS but other PFAS substances included PFBA, PFHxA, PFHpA, PFNA, PFUnA, and PFOS. Levels of PFOA in the effluent of the treatment process reached 0.89 ng/L (ppt). However, the authors note that the levels in effluent depend on the levels in the influent.

PFAS found in tap water included PFBA, PFPA, PFHxA, PFOA, PFUnA, and PFOS. Total average levels in a direct faucet were 1.07 ng/L (ppt). In contrast, levels in a household water filter were 0.57 ng/L (ppt).

PFAS were found in all water treatment processes, tap water and drinking water – especially PFOA and PFOS. Reverse osmosis was much more effective at removing PFAS than conventional wastewater treatment methods, however all removal systems depended on the incoming quantity of PFAS. The authors view current conventional water treatment plants to be vulnerable to PFAS pollution in water sources since they were not effective at PFAS removal.

Abstract:

Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs), especially Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonate (PFOS), were found to contaminate the natural water sources serving as a raw material in producing tap water. The main purpose of this study was to measure the quantities of PFASs in both conventional and advanced water treatment processes, and of the PFASs contaminated tap water in various forms, with comparison made between tap water and water

passing through drinking devices. It was found from the investigation that the conventional treatment process using coagulation, sedimentation, filtration and chlorination was incapable of removing PFASs, and that the concentration of effluent increased more than 27% compared to the influent. On the contrary, advanced water treatment process using GAC filter and RO was able to remove more than 86% of PFASs. The tap water was found to contain PFASs at 0.58-1.15 ng/L. However, a comparison between the average of the water passing through drinking devices and direct faucet showed insignificant difference, but the concentration of PFASs decreased by a small amount when passing a filter-equipped device.

No 5.

Presentation paper: PFOS substances and their use in various industries
Nucharin Ramankul, Environment Research Unit, National Metal and Materials Technology Center (MTEC), December 2015

- Knowledge about PFOS and PFC, PFOS by OECD Policy, Situation of PFOS in Asia and some findings in Thailand's tap water and dust in houses:
- Types of PFOS Use in industries:
  - Textile protection,
  - Carpet protection and leather protection (for surface treatment)
  - Metal plating,
  - Paper & Packaging protection,
  - Firefighting foam (ex: Fluoroprotein foam, Aqueous film forming foams (AFFF) (Fluorocarbon + Synthetic foaming agents + solvents + other ions), Film forming fluoroprotein foam, Alcohol resistant aqueous film forming foams (AR-AFFF), Alcohol resistant film forming fluoroprotein foams)
  - Cleaning agents (examples of household use - rinse aid, levelling agents, wetting agent, surface coating, polishing. Examples of industrial use - additive, wetting agent, waxing, antifreeze, soil suspension, foaming agent, etc.)
  - Enamel and Additives
  - Photo industry
  - Photolithography
  - Agricultural chemical production industry
  - Medical device and material production industry
  - Mining & oil surfactants
  - Fire retardants
  - Adhesives
  - Etc.

- Examples of PFOS used in food packaging materials
  - Liner board, packaging materials for fast food, multiwall bags, mold pulp products, flexible packaging, flexible light weight papers, mainly paper mill industries.

No 6.

Title of Paper: Occurrence of Perfluorooctane Sulfonate in the Water Environment of Bangkok, Thailand

Authors: Suwanna Kitpati Boontanon[1], Chinagarn Kunacheva[2], Narin Boontanon[3], Natchuda Musirat[1], Shigeo Fujii[4], Shuhei Tanaka[4]

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Jour Environ Engin (2013) 139:588-593

Comment

The study notes widespread PFAS water pollution, but the lack of information in developing countries including Thailand. The research focused on PFOS in the greater Bangkok water system including the Chao Phraya and Bang Pakong Rivers, tap water, bottled drinking water, and industrial wastewater.

In the Chao Phraya River, PFOS levels ranged up to 20 mg/L (ppt) and PFOS ranged from 0.7 – 20 ng/L (ppt). Levels increased from the upstream area to the outlet and the highest levels were found at the port where one of Bangkok's wastewater treatment plants discharges effluents. Lower levels were observed in the Bang Pakong River which runs through an agricultural area with a much smaller population area. The authors note that, "urbanization has a significant effect on water contamination by PFOS and PFOA."

Industrial wastewater contained PFOS with average levels of 264 ng/L (ppt) and reaching 6,200 ng/L (ppt) – a very high level. The authors suggest that the data indicates that industrial wastewater is one of the major sources of PFOS contamination in the water system in Bangkok. Tap water from industrial zones contained PFOS levels 69-fold higher than residential zones, largely because industrial wastewater flows into surface water which is then used to generate tap water. Ironically, bottled water had higher PFOS levels than tap water.

PFOA levels in the Chao Phraya River were higher than levels reported in rivers in Hanoi and Taipei and lower than those from Johor Bahru, Shenzhen, Singapore, and Osaka. PFOS levels in the Chao Phraya were much higher than those in Hanoi but lower than in other countries.

Abstract

Persistent organic pollutants (POPs) are organic substances that have characteristics of persistence in the environment; transboundary movement, or the ability to travel long distances through air and water; toxicity; and bioaccumulation in living things. Perfluorooctane sulfonate (PFOS), a toxic chemical that never breaks down, was added to the Stockholm Convention on POPs and was listed in the Annex B restrictions with many exemptions to continue using PFOS. This study focused on the

occurrence of PFOS in the water system of Bangkok, Thailand, including the Chao Phraya and Bang Pakong Rivers, tap water in industrial zones and residential areas, drinking water, and industrial wastewater. Seasonal effect of PFOS between dry season and wet season was also observed for more than 3 years. Solid phase extraction (SPE) coupled with HPLC-ESI-MS/MS was used for the analysis of these compounds. PFOS was detected in most water samples. The average concentration of PFOS in the Chao Phraya River (urban area) was 1.70 ng=L, whereas lower concentrations were detected in the Bang Pakong River (suburban area), residential tap water, and bottled drinking water, with averages of 0.7, 0.4, and 0.5 ng=L, respectively. Higher concentrations (an average of 25.1 ng=L) were found in industrial tap water, whose sources were from surface water near the industrial zones. Much higher concentrations were detected in industrial wastewater, with the maximum of 6,100.8 ng=L. These results indicated that industrial wastewater was one of the major sources of PFOS contamination in the water system of the city of Bangkok. This study provided data on the spatial occurrence, its seasonal effect, and distribution of PFOS in the water environment of Bangkok and surrounding areas, which need continuous attention to this emerging contaminant.

No 7.

Title of Paper: Determination of perfluorooctane sulfonate and perfluorooctanoic acid in food packaging using liquid chromatography coupled with tandem mass spectrometry

Authors: Somrutai Poothong[1], Suwanna Kitpati Boontanon[1], NarinBoontanon[2]
[1] Department of Civil and Environmental Engineering, Faculty of Engineering, Mahidol University, Phutthamonthon, Nakorn Pathom, Thailand
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J Hazard Mater (2012) 205 – 206:129-143

Comment

This investigated PFOS and PFOA in food packaging. Samples were fresh packages that had never been used to contain food products. The 34 samples included 10 instant food cups, 3 microwave popcorn bags, 3 beverage cups, 2 ice cream cups, 8 fast-food containers, 7 dessert containers, and 1 baking paper. PFOS and PFOA were detected in almost all samples.

PFOA was found in the following types of packaging: noodle cup, instant rice porridge cup, microwave popcorn bag, beverage cup, ice cream cup, fried chicken box, fried chicken wrapper, French fries bag, French fries wrapper, French fries box, hamburger wrapper, pretzels box, pretzels wrapper, donut box, donut wrapper, and baking paper. The highest levels of PFOA in methanol were in an ice cream cup (16.91 ng/dm^2). The highest levels of PFOA extracted into a saliva simulant were in a French fries box (41.71 ng/dm^2).

PFOS was found in the following types of packaging: noodle cup, instant rice porridge cup, microwave popcorn bag, beverage cup, ice cream cup, fried chicken box, fried chicken wrapper, French fries bag, French fries wrapper, French fries box, hamburger wrapper, pretzels box, pretzels

wrapper, donut box, donut wrapper, and baking paper. The highest levels of PFOS in methanol were in an fried chicken box (92.48 ng/dm^2). The highest levels of PFOS extracted into a saliva simulant were in a hot cup (10.26 ng/dm^2).

The study found that thicker samples had higher levels of PFAS. These included products such as fried chicken boxes and French fries boxes. The authors noted that, "there is a potentially significant negative impact on human health from the consumption of food and beverages contained in paper packaging." The authors also noted that PFAS would be released from this packaging when the products become wastes.

Abstract
This research aimed to monitor the amounts of PFOS and PFOA in food packaging and study the migration of PFOS and PFOA from food packaging, using a saliva simulant and pressurized liquid extraction (PLE) technique. Liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS) was employed to determine residues of PFOS and PFOA by using a gradient reversed-phase method with ammonium acetate/acetonitrile buffer. A good linearity was established for PFOS and PFOA in a range of 0.05-10 µgL(-1), with R2 ≥ 0.9998. Of the samples extracted by methanol, the highest concentration of PFOS was found in fast-food container samples, at a level of 92.48 ng dm(-2). For PFOA, the highest concentration in samples extracted by methanol was found in ice cream cup samples, at a level of 16.91 ng dm(-2). The amounts of PFOS and PFOA that migrated from food packaging samples through contact with saliva simulant were 4.80 and 4.55 ng dm(-2), respectively. Saliva simulant could leach PFOS and PFOA from the group of the thickest paper samples (≤1 dm2 g(-1)) at levels of 7.01 and 6.41 ng dm(-2), respectively, indicating that paper with greater thickness and less area might release larger quantities of coated/added PFOS or PFOA.

No 8.

Title of Paper: Determination of perfluorinated compounds (PFCs) in solid and liquid phase river water samples in Chao Phraya River, Thailand

Authors: Chinagarn Kunacheva, Shuhei Tanaka, Shigeo Fujii, Suwanna Kitpati Boontanon, Chanatip Musirat and Thana Wongwattana
Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan

Water Sci Technol (2011) 64:684-692

Comment
This study examined PFAS pollution in the Bangkok area of the Chao Phraya River in both water and sediments during 2006 – 2008. The Chao Phraya River covers 160,000 km^2 (30% of Thailand's area) and supplies water to millions of people.

PFAS were found in all samples with PFOA as the dominant substance (48%) along with significant frequencies of PFPA (18%) and PFOS (10%). Other detected PFAS included PFHxA, PFHpA, PFNA, PFDA, PFUnA, PFDoA, and PFHxS.

In 2008, the highest levels of PFOS (37 ng/L or ppt) and PFOA (13 ng/L or ppt) were found where an industrial zone and a port were located. This location also yielded the highest contamination levels in 2006 and 2007. Average loadings were PFPA (94.3 g/day), PFOA (284.6 g/day) and PFOS (93.4 g/day). The study also revealed that PFAS is better at dissolving in water than adsorbing onto suspended solids.

Abstract

Perfluorinated compounds (PFCs), especially perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), are fully fluorinated organic compounds, which have been used in many industrial applications. These chemicals have contaminated surface water all over the world even in developing countries like Thailand. The previous study showed the contamination in Chao Phraya River in 2006 and 2007. The purposes of this field study were to determine the solid and liquid phase of PFCs contamination in Chao Phraya River and to compare the changes of PFC concentration in 2008. Surveys were conducted in the lower reach of Chao Phraya River in the industrialized area. A solid phase extraction (SPE) coupled with HPLC-ESI-MS/MS were used for the analysis for ten PFCs. Ten PFCs were analyzed to identify the contamination in both solid and liquid phases. PFCs were detected in both the solid and liquid phase in every sample. PFOA was the most dominant PFC while PFPA and PFOS were also highly detected in most samples. The average loadings of PFPA, PFOA and PFOS in Chao Phraya River were 94.3, 284.6 and 93.4 g/d, respectively. PFOS concentrations did not show differences between 2006 and 2008. However, PFOA concentrations were higher in 2008/5/26, while comparing other samplings. The ratio of solid : liquid PFPA (2.1 : 1.0) [(ng/g)/(ng/L)] was lower than PFOA (13.9 : 1.0) [(ng/g)/(ng/L)] and PFOS (17.6 : 1.0) [(ng/g)/(ng/L)]. The shorter chain (more hydrophilic) PFC was better to dissolve in water rather than adsorb onto suspended solids. PFOS also showed more potential to attach in the suspended solids than PFOA.

No 9.

Title of Paper: Mass flows of perfluorinated compounds (PFCs) in central wastewater treatment plants of industrial zones in Thailand

Authors: Chinagarn Kunacheva, Shuhei Tanaka, Shigeo Fujii, Suwanna Kitpati Boontanon, Chanatip Musirat, Thana Wongwattana, Binaya Raj Shivakoti

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Chemosphere (2011) 83:737-744

Comment

This study focuses on PFAS flows in industrial wastewater treatment plants in Thailand. One objective is to determine how well processes used in these plants remove PFAS substances. The authors note the importance of understanding PFAS pollution from using industries as well as producing industries.

Industrial wastewater treatment plants in central and eastern Thailand contained PFOA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnA, PFDoA, PFHxS and PFOS. Both plants were ineffective at removing PFAS and one plant actually increased PFAS levels. At one plant the influent contained a total PFAS concentration of 847 ng/L (ppt) and an effluent level of 662 ng/L (ppt). At the other plant the influent contained 673 ng/L (ppt) PFAS and the effluent, 1143 ng/L (ppt). The authors suggest that increases in PFAS levels could be due to degradation of PFAS precursors. PFOS was the dominant PFAS in both plants but the amounts of individual PFAS varied, reflecting different industrial inputs. PFOS levels were higher than similar plants in US, Singapore, Switzerland, and Japan.

Abstract:
Perfluorinated compounds (PFCs) are fully fluorinated organic compounds, which have been used in many industrial processes and have been detected in wastewater and sludge from municipal wastewater treatment plants (WWTPs) around the world. This study focused on the occurrences of PFCs and PFCs mass flows in the industrial wastewater treatment plants, which reported to be the important sources of PFCs. Surveys were conducted in central wastewater treatment plant in two industrial zones in Thailand. Samples were collected from influent, aeration tank, secondary clarifier effluent, effluent and sludge. The major purpose of this field study was to identify PFCs occurrences and mass flow during industrial WWTP. Solid-phase extraction (SPE) coupled with HPLC–ESI–MS/MS were used for the analysis. Total 10 PFCs including perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), perfluoropropanoic acid (PFPA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), perfluorohexane sulfonate (PFHxS), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnA), and perfluorododecanoic acid (PFDoA) were measured to identify their occurrences. PFCs were detected in both liquid and solid phase in most samples. The exceptionally high level of PFCs was detected in the treatment plant of IZ1 and IZ2 ranging between 662–847 ng L^{-1} and 674–1383 ng L^{-1}, respectively, which greater than PFCs found in most domestic wastewater. Due to PFCs non-biodegradable property, both WWTPs were found ineffective in removing PFCs using activated sludge processes. Bio-accumulation in sludge could be the major removal mechanism of PFCs in the process. The increasing amount of PFCs after activated sludge processes were identified which could be due to the degradation of PFCs precursors. PFCs concentration found in the effluent were very high comparing to those in river water of the area. Industrial activity could be the one of major sources of PFCs contamination in the water environment.

No 10.

Title of Paper: Levels, temporal trends, and tissue distribution of perfluorinated surfactants in freshwater fish from Asian countries

Authors: Michio Murakami, Nozomi Adachi, Mahua Saha, Chiaki Morita, Hideshige Takada "Wisdom of Water", Suntory, Corporate Sponsored Research Program, Organization for Interdisciplinary Research Projects, The University of Tokyo, Japan

Arch Environ Contam (2011) 61:631-644

Comment
The PFAS content of freshwater fish was measured in samples of carp, snakehead, and catfish from India, Japan, Vietnam, Malaysia, and Thailand. Samples from Thailand were catfish from Kohn Kaen. In muscle, PFOS was not detected but PFUA was found at approximately 0.1 ng/g wet weight. Higher levels were found in fish from Vietnam.

Abstract
Perfluorinated surfactants (PFSs) in Asian freshwater fish species were analyzed to investigate tissue distribution, temporal trends, extent of pollution, and level of PFS exposure through food intake. Freshwater fish species, namely carp, snakehead, and catfish, were collected in Japan, Vietnam, India, Malaysia, and Thailand, and 10 PFSs, including perfluorooctanesulfonate (PFOS) and perfluorooctanoate, were analyzed by liquid chromatography-tandem mass spectrometry. PFSs in carp in Tokyo were more concentrated in kidneys (Σ10 PFSs = 257 ± 95 ng/g wet weight [ww]) and livers (119 ± 36 ng/g ww) than in ovaries (43 ± 2 ng/g ww) and muscles (24 ± 17 ng/g ww). Concentrations of PFOS and its precursor, perfluorooctane sulfonamide, in livers of carp and in waters in Tokyo showed a dramatic decrease during the last decade, probably because of 3 M's phasing-out of the manufacture of perfluorooctanesulfonyl-fluoride-based products in 2000. In contrast, continuing contamination by long-chain perfluorocarboxylates (PFCAs) with ≥ 9 fluorinated carbons was seen in multiple media, suggesting that these compounds continue to be emitted. PFS concentrations in freshwater fish species in tropical Asian countries were generally lower than those in developed countries, such as Japan, e.g., for PFOS in muscle, Vietnam < 0.05-0.3 ng/g ww; India < 0.05-0.2 ng/g ww; Malaysia < 0.05-0.2 ng/g ww; Thailand < 0.05 ng/g ww; and Japan (Tokyo) = 5.1-22 ng/g ww. Daily intake of short-chain PFCAs with ≤ 8 fluorinated carbons from freshwater fish species in Japan was approximately one order of magnitude lower than that from drinking water, whereas daily intake of PFOS and long-chain PFCAs with ≥ 9 fluorinated carbons from freshwater fish species was comparable with or greater than that from drinking water. Because the risk posed by exposure to these compounds through intake of fish species is a matter of concern, we recommend the continued monitoring of PFS levels in Asian developing countries

No 11.

Title of Paper: Perfluoroalkyl compounds in dust from Asian, Australian, European, and North American homes and UK cars, classrooms, and offices
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Environ Int (2011) 37:86-92

Comment
This study investigated PFAS contamination of house dust in homes located in Australia, Canada, France, Germany, Kazakhstan, Thailand, UK, and US and in UK cars classrooms and offices. Target

PFAS substances included PFOS, PFOA, PFHxS, FOSA, MeFOSA, EtFOSA, MeFOSE, and EtFOSE. Twenty samples from Thailand were taken in Bangkok and Nakhonsrithammarat.

Dust samples from Thailand contained all eight PFAS substances measured. The highest levels were for EtFOSA (940 ng/g or ppb) – a substance that degrades to PFOS. The highest levels for other PFAS substances were PFOS (130 ppb), PFOA (290 ppb). PFHxS (84 ppb), MeFOSA (13 ppb), FOSA (41 ppb), MeFOSE (140 ppb), and EtFOSE (350). Average concentrations of these substances in Thai dust was lower than that observed in other countries. The authors note that dust may be an important PFAS exposure pathway for young children.

Abstract

Perfluoroalkyl compounds (PFCs) were measured in dust from Australian, Canadian, French, German, Kazahkstani, Thai, UK, and US homes, and UK cars, classrooms, and offices. Most PFCs were significantly lower in Kazahkstan and Thailand than elsewhere; 2-(N-methylperfluoro-1-octanesulfonamido)-ethanol (MeFOSE) and 2-(N-ethylperfluoro-1-octanesulfonamido)-ethanol (EtFOSE) were significantly lower in Canada than in the UK and the US; perfluoro-1-hexanesulfonate (PFHxS) was significantly lower in Canada than in the UK, and N-ethylperfluoro-1-octanesulfonamide (EtFOSA) was significantly higher in Australia than in the UK. High EtFOSA concentrations in some samples may be consistent with its use as an insecticide. Perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), PFHxS, and MeFOSE were significantly higher in classrooms than in cars, homes, and offices; N-methylperfluoro-1-octanesulfonamide (MeFOSA) was significantly lower in classrooms than in homes and offices, and perfluoro-1-octanesulfonamide (FOSA) was significantly lower in classrooms than in cars, homes, and offices. While homes are usually the most important vector of dust exposure (typically > 60%), offices and classrooms make important contributions. While diet is usually the main exposure pathway for UK adults and children (~1-6 years) for PFOS, PFOA, and PFHxS; dust ingestion can be significant under high dust ingestion scenarios. Even under high-end exposure scenarios for dust and diet, PFOS and PFOA exposures are well within the European Food Safety Authority tolerable daily intakes.

No 12.

Title of Paper: Occurrences and behavior of perfluorinated compounds (PFCs) in several wastewater treatment plants (WWTPs) in Japan and Thailand

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J Environ Monit (2010) 12:1255-1264

Comment

This study examined PFAS in wastewater treatment plants due to concerns that they can be a major pollution point source due to discharge of wastewater effluents, septic discharges or application of sludge to farmland. Samples were from five industrial wastewater treatments from industrial estates in the Bangkok area. These industrial estates serve many types of industries including textile, electronics, plastics, personal care products, chemicals, glasses etc., mostly belonging to multinational companies. The five industrial estates examined in this study serve 316, 270, 196, 200, and 398 companies.

Some PFAS substances were found in all samples, sometimes at very high levels more than 1000 ng/L (ppt). Data from different parts of the plant operation showed that the plants failed to remove PFAS. Daily mass discharges from each industrial estate wastewater treatment plant ranged from 1.34–36.6 g/d. The highest levels in Thailand were several thousand ppt.

The Thai samples from industrial estates showed higher PFAS levels than samples from Japan. In addition, the specific PFAS substances were different. PFOA, PFNA and PFOS were the main PFAS found in Japan while PFUuS, PFOA, and PFHxA were the main PFAS in Thai wastewater treatment plants. Techniques such as aerobic and anaerobic biological treatment, sand filtration, chlorination, ozonation, and activated carbon were all found to be ineffective at removing PFAS substances.

The authors hypothesize that multinational companies are shifting PFAS use to developing countries such as Thailand where they are not regulated.

Abstract

This study examines occurrences of 11 perfluorinated compounds (PFCs) in several wastewater treatment plants in Japan and Thailand. Surveys are conducted in eight wastewater treatment plants (WWTPs) in Japan and central WWTPs of five industrial estates (IEs) in Thailand. Samples are collected from all major treatment processes in order to understand the behavior of PFCs in WWTPs. PFCs are detected in all WWTPs in Japan and Thailand. Concentrations of PFCs even exceed several thousands ng/L in some WWTPs. PFOS, PFOA, and PFNA are mainly detected in WWTPs in Japan, while PFBuS, PFOA, and PFHxA are mainly detected in WWTP of IEs in Thailand. Even though some of the investigated WWTPs utilize biological treatment processes coupled with chlorination, ozonation, or activated carbon adsorption, they are found ineffective to remove PFCs. During the treatment process, PFCs are found to accumulate at exceptionally high concentration levels in the activated sludge of an aeration tank and returned activated sludge. Overall, the estimated total daily mass of discharged PFCs is 124.95 g/d (PFASs: 49.81 g/d; PFCAs: 75.14 g/d) from eight WWTPs in Japan and 55.04 g/d (PFASs: 12 g/d; PFCAs: 43.04 g/d) from five WWTPs in Thailand. Although the presented data are from a single observation in each WWTP, the results indicate that certain industries using PFCs in manufacturing processes could be the principle point source, while domestic activities could be releasing PFCs at detectable levels causing environmental concern.

No 13.

Title of Paper: Contamination of perfluorinated compounds (PFCs) in Chao Phraya River and Bangpakong River, Thailand

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Water Sci Technol (2009) 60:975-982

Comment

This study examined PFAS pollution in Thai surface waters in the Chao Phraya River (urban area) and Bangpakong River (semi-urban area) with an objective of examining the impact of three industrial estate discharges.

PFOS and PFOA were found in all samples. In the Chao Phraya River, the dominant PFAS substances were PFOA (40%), PFOS (22%), PFNA (17%) and PFHxS (10%). In the Bangpakong River, the dominant PFAS substances were PFOA (36%), PFOS (34%), PFDA (17%), and PFNA (9%). In the effluent of the industrial estates, the dominant PFAS were PFOA (78%) and PFOS (16%).

The average concentrations of PFOS and PFOA were 1.9 and 4.7 ng/L (ppt), respectively in Chao Phraya River, while lower concentrations were detected in Bangpakong River with the averages of 0.7 ng/L (ppt) for both PFOS and PFOA.

PFAS levels in the Chao Phraya River increased closer to the outlet at the Gulf of Thailand. The average loading from the river was calculated to be 112 g/day for PFOS and 409 g/day for PFOA. PFAS levels in the Bangpakong River were far lower and loading was calculated to be 19 g/day PFOS and 13 g/day PFOA.

The wastewater treatment plants of the industrial estates receive discharges from many types of factories including chemical, electronics, coating, and clothing industries. PFOS levels ranged from 12.8 – 50.6 ng/L (ppt) and PFOA levels varied from 20.7 – 316.3 ng/L (ppt). Twenty industrial estates are located in this area.

The authors note that PFOS, PFOA and other PFAS are released daily from these rivers into the Gulf of Thailand “where many important sea food sources for domestic use and exports are located.”

Abstract

Perfluorinated compounds (PFCs) have been used for many years, and are distributed all over the world. This study focused on occurrences of PFCs, especially perfluorooctane sulfonate (PFOS) and perfluorooctonoic acid (PFOA) in Thai rivers and industrial estate discharges, while comparing

results with rivers of other Asian countries (Japan, China, and Malaysia). Surveys were conducted in Chao Phraya River, Bangpakong River and three industrial estates. A solid phase extraction (SPE) and HPLC-ESI-MS/MS were used for the analysis of these chemicals. The average concentrations of PFOS and PFOA were 1.9 and 4.7 ng/L, respectively in Chao Phraya River, while lower concentrations were detected in Bangpakong River with the averages of 0.7 ng/L for both PFOS and PFOA. Higher concentrations were detected in all industrial estate discharges with the averages of 64.3 ng/L for PFOA and 17.9 ng/L for PFOS., Total loadings from three industrial estates were 1.93 g/d for PFOS and 11.81 g/d for PFOA. The concentration levels in Thai rivers were less than rivers in Japan, China, and Malaysia. However, PFCs loading rate of Chao Phraya River was much higher than Yodo River (Japan), due to the higher flow rate. The other six PFCs were found above the Limit of Quantification (LOQ) in most samples. PFHxS and PFNA were also highly detected in some river samples.

No 14.

Title of Paper: Study on Contamination of Perfluorinated Compounds (PFCs) in Water Environment and Industrial Wastewater in Thailand

Authors: Chinagarn Kunacheva, Department of Urban and Environmental Engineering,
Graduate School of Engineering, Kyoto University, Japan

September 2009
Kyoto University Dissertation

Abstract

PFCs are used in a wide variety of industrial and commercial applications for more than 50 years. Among variation of PFCs, Perfluorooctane sulfonate (PFOS) (CF3(CF2)7SO3-) and perfluorooctanoic acid (PFOA) (CF3(CF2)6COO-) are the most dominant PFCs. In May 2009, PFOS, its salts and perfluorooctane sulfonyl fluoride (PFOSF) are designated as new Persistent Organic Compounds (POPs) which are resistant, bio-accumulating, and having potential of causing adverse effects to humans and environment (IISD, 2009). However, products containing PFCs are still being manufactured and used, which could be the main reason why they are still observed in the environment and biota (Berger et al., 2004; Saito et al., 2003; Sinclair et al., 2004).

The study is focused on the PFCs contamination in water and industrial wastewater around the Central and Eastern Thailand, where is one of the major industrialized areas in the country. The samplings were conducted in major rivers, Chao Phraya, Bangpakong and Tachin River. PFCs were contaminated in all rivers. The average total PFCs were 15.10 ng/L, 18.29 ng/L and 7.40 ng/L in Chao Phraya, Bangpakong and Tachin River, respectively. PFOS and PFOA were the predominant PFCs in all samples. The total of 118.6 g/d PFOS and 323.6 g/d PFOA were released from the three rivers to the Gulf of Thailand. The survey was also conducted in small rivers, reservoirs, and coastal water around Eastern Thailand, where many industrial zones (IZ) are located. The geometric mean (GM) concentration of each PFC was ranged from 2.3 to 107.7 ng/L in small rivers, 2.2 to 212.2 ng/L

in reservoirs, and 0.8 to 41.1 ng/L in coastal water samples. The higher PFCs contaminations were detected in the surface water around the industrial zones, where might be the sources of these compounds. Field surveys were also conducted in ten industrial zones (IZ1 – IZ10) to identify the occurrences of PFCs from in industries. The recovery rates of PFCs in the samples indicated that the matrix interference or enhancement was an important problem in PFCs analysis. The elevated concentrations were detected in electronics, textile, chemicals and glass making industries. Total PFCs concentrations in the influent of WWTP were ranged from 39.6 to 3,344.1 ng/L. Ten industrial zones released 188.41 g/d of PFCs. All of the treatment processes inside industrial zones were biological processes, which were reported that they were not effective to remove PFCs. The influence of industrial discharges was affected not only the rivers and reservoirs but also in the coastal water. The PFCs in rivers and reservoirs were discharged to the Gulf of Thailand, which is the important food source for Thai people and exports.

Due to the problems in industrial wastewater analysis, several optimizing options were applied in PFCs analytical method especially in Solid Phase Extraction (SPE) procedure. The combination of PresepC-Agri and Oasis®HLB was the better option for analyzing PFCs in water samples. The optimum flow rate for loading the samples was 5 mL/min. Methanol (2 mL) plus Acetronitrile (2 mL) was the effective way to elute PFCs from the cartridges. The specific solvent percentages to elute each PFCs were identified for both water and industrial wastewater samples. The matrix removal methods by using Envi-Carb and Ultrafilter were effective for different types of industrial wastewater samples.

PFCs were detected in surface waters, which are the sources of tap and drinking water for the people in Central and Eastern Thailand. The surveys were conducted in Bangkok city. Samples were collected from water treatment plants (WTPs), tap water, and drinking water. PFCs were detected in all tap water and drinking water samples. PFOS and PFOA concentrations in raw water of WTP were found 4.29 ng/L and 16.54 ng/L, respectively. The average PFOS and PFOA concentrations in tap water were detected 0.17 and 3.58 ng/L, respectively. The tap water results also showed that PFOS and PFOA concentrations were not similarly detected in all area in the city. PFOA were detected higher in the western area, while PFOS concentration was quite similar in all areas. Overall, it can be concluded that the current treatment processes were not completely remove PFCs. Nevertheless, PFCs in particulate phase were effectively removed by the primary sedimentation and rapid sand filtration.

Elevated PFCs were found in the industrial zones (IZ2 and IZ5). To understand the distribution and fate of PFCs during industrial wastewater process, PFCs mass flows were studied. Higher PFCs in adsorbed phase were detected only in activated sludge and

some influent samples. In IZ2, PFOA loading in the dissolved phase increased after activated sludge process by 5%. There was no degradation of PFOA inside the polishing pond. The highest loading to the treatment plant was PFOS with the loading of 2,382 mg/d and 1,529 mg/d in dissolved and adsorbed phase, respectively. Unlike PFCAs that showed no removal in the treatment process, PFOS were decreased during the treatment processes with 36% in the activated sludge process and 36% in the polishing pond. The predominant in this IZ5 was PFOS. The increasing of PFOS was also found in this treatment plant dissimilar to IZ2. PFOS was increasing by 45% in dissolved phase and 47% in adsorbed phase. All of PFCs in this industrial zone were detected higher in the effluent, indicated that PFCs' precursors should be the major effects of this contamination.

No 15.

Project Title: Presence of PFOS and PFOA and their Relationship to Pollutants in Surface Water: A Case Study of Downstream Chao Phraya River

Investigator: Dr. Suwanna Kitpati Boontanon, Civil and Environmental Engineering Department, Faculty of Engineering, Mahidol University

Project Period: July 2, 2007 – July 1, 2011

Abstract

Perfluorooctane Sulfonate (PFOS) was added to the Stockholm Convention on Persistent Organic Pollutants (POPs) and listed in Annex B restriction in 2009. Another important chemical is Perfluorooctanoic Acid (PFOA). Both PFOS and PFOA have been used in numerous applications of industries for more than 50 years. They are persistent in the environment, transboundary movement, toxic and bioaccumulated in living things. The contamination in environment of these chemicals have been in concerns since 2000 This research aims to investigate the contamination of PFOS and PFOA in the lower part of Chao Phraya River in order to understand the spatial and seasonal effect to the PFOS and PFOA contamination, including their relation to basic water quality indices. More than 300 samples from 6 times monitoring with 31 sampling sites were investigated. Solid phase extraction (SPE) couple with HPLC-ESI-MS/MS was used for the analysis of these compounds. PFOS and PFOA were detected in all samples. The concentrations were varied in the range of <LOQ – 20.1 ng/L for PFOS and 0.7 – 20.4 ng/L for PFOA with the average of 1.6 and 3.5 ng/L for PFOS and PFOA, respectively. Land uses of residential and commercial area and industrial area affected to the contamination of PFOS and PFOA resulting the highest contamination found at the central of Bangkok city. The concentration gradually increased from the upstream to the river outlet. Higher concentration found in the eastern part of Chao Phraya River rather than the western part where land use is high in agricultural purpose. No seasonal variations were apparent for PFOS, while PFOA showed seasonally affected. The positive relations of PFOS and PFOA with ammonia nitrogen and conductivity were observed, indicating higher water contamination, higher PFOS and PFOA concentration. Contamination of PFOS and PFOA in Chao Phraya River of Thailand presented

lower level than of Malaysia, China, Singapore Taiwan and Japan except Vietnam (Hanoi), reflecting the urbanization and industrialization effect to the level of PFOS and PFOA contamination.

Recommendations

National recommendations

1. Specific regulations are needed to prohibit PFAS production, use, import, and export (including PFOA and PFOS). To avoid costly mistakes, PFAS should be banned as a class.
2. Make information about PFAS releases (including PFOA and PFOS) publicly available in a national PRTR inventory
3. Require effective wastewater treatment processes that remove all PFAS for all factories in industrial parks / industrial estates.
4. PFAS monitoring should be conducted to identify hotspots near industrial areas and other relevant locations.
5. A complete inventory of PFAS (including PFOA and PFOS) needs to be carried out including in suspected products and process in order to develop a regulatory, institutional framework for sound management of these chemicals. There is hardly any information available in the country on the use of the chemical in various sectors and this data is needed for control of use and waste management.
6. To prevent PFAS pollution and subsequent costly remediation, Thailand should promptly make an inventory of firefighting foam stocks and replace PFAS-containing foams with fluorine-free foams as soon as possible.
7. The export and import data for PFAS substances should have precise global and national HS codes to permit sectoral use and help Customs identify trade flows.
8. Identify methods to assess and manage existing stockpiles of contaminated items and contaminated sites.
9. Creation of more information and data generation to understand the use of these chemicals in various products. This will help prevent contamination as a result of substances being dumped into a landfill.
10. Conduct assessments on alternatives to PFOS, PFOA and other PFAS substances used in different applications and approving the most sustainable alternative/s within the process of sustainable consumption and production.
11. A no-allowable-residues policy should be established for PFAS in clothing articles, imported or otherwise. In order to offer adequate protection, the limit should cover the entire PFAS class

and be set for limits of detection in laboratory tests with the potential for this to be reduced further in the future, as technology improves.

Recommendations for Stockholm Convention COP9

1. PFOA should be listed in Annex A with no specific exemptions. If exemptions are granted, they should be for specific products and the listing should require labeling new products that contain PFOA so that Parties can fulfill requirements under Article 6 as done previously for HBCD (SC-6/13).
2. Due to the costly, highly polluting nature of firefighting foams, and the availability of cost-effective, technically feasible non-fluorinated alternatives, no specific exemptions should be adopted either for PFOS or PFOA production and/or use in firefighting foams.
3. Specific exemptions or acceptable purposes for the following 11 uses of PFOS should be ended: photo-imaging, photo-resist and anti-reflective coatings for semiconductors; etching agent for compound semiconductors and ceramic filters; aviation hydraulic fluid; certain medical devices; photo masks in semiconductor and LCD industries; hard metal plating; decorative metal plating; electric and electronic parts for some color printers and color copy machines; insecticides for control of red imported fire ants and termites; and chemically-driven oil production.
4. The following 3 acceptable purposes should be converted into specific exemptions: metal plating (hard metal plating only in closed loop systems); firefighting foams; insect bait for control of leaf-cutting ants from *Atta* spp. and *Acromyrmex* spp. Sulfluramid should be named in the PFOS listing and its use sharply limited to cultivation of specific crops.

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Annex 1. PFAS toxicity

The Stockholm Convention expert committee (please see Annex 3) evaluated the toxicity characteristics of PFOS in 2007 and PFOA in 2017. Since then, more scientific information has emerged for both these substances along with some of the shorter-chain PFAS aggressively promoted by the industry as substitutes.

Recent research shows the harmful impacts of PFAS

Recent studies have linked PFAS substances to a variety of human health effects: cardiovascular disease, markers of asthma, damage to semen quality, ovarian insufficiency, altered glucose metabolism, lower testosterone levels in male adolescents, association with shorter birth length in girls, elevated blood pressure, abnormal menstruation, lower birth weight in infants, possible increased risk of female infertility due to endometriosis, and decreased lung function in children with asthma.

The chemical industry promoted perfluorohexane sulfonate (PFHxS) as a substitute for PFOS. In 2018, the Stockholm Convention expert committee concluded that it "warrants global action." PFHXS is found in 2 – 4 month-old infants and associated with damage to semen quality. The Stockholm Convention expert committee found that PFHxS has been detected in human blood and breast milk in many regions, and is together with perfluorooctane sulfonic acid (PFOS), perfluorooctanoic acid (PFOA) and perfluorononanoic acid (PFNA) one of the most frequently detected and predominant PFASs in human blood. The Committee noted that the fetus is exposed to PFHxS via umbilical cord blood and that animal studies show impacts on reproduction, liver function, thyroid hormone levels, and lipid and lipoprotein metabolism.

Studies showing the toxicity, environmental fate, and occurrence of PFAS in current use include:

Perfluorobutanoic acid (PFBA)

- Effects on thyroid and developmental delays in offspring exposed during pregnancy
- Similar toxicity to liver as PFOA
- Associated with damage to semen quality
- Found in home-produced eggs
- Found in the Arctic
- Efficiently translocated into plants
- Taken up by corn
- Found in fruits and vegetables
- Contaminates fish
- Found in humans in a community with known drinking water contamination
- Found in consumer products

Perfluorobutane sulfonate (PFBS)

- Associated with damage to semen quality
- Disrupts pancreas formation in zebrafish
- Associated with cardiovascular disease in humans
- Associated with markers of asthma in humans

- Increases fatty tissue formation in laboratory studies
- Impairs visual function in fish
- Damages thyroid function in fish in subsequent generations
- Induces reproductive toxicity in animal studies
- Found in 2 – 4 month-old infants
- Found in humans in community with known drinking water contamination
- Found in children
- Found in the Arctic
- Found in consumer products

Perfluorohexanoic acid (PFHxA)

- Similar toxicity to liver as PFOA
- Associated with damage to semen quality
- Negatively associated with testosterone levels in adolescent humans
- Alters zebrafish behavior
- Modulates immune response in vitro
- Contaminated drinking water linked to human body burden
- Alters amphibian embryogenesis
- Exposes the human fetus vis presence in amniotic fluid
- Found in human milk
- Found in house dust
- Found in US wildlife preserves
- Found in the Arctic
- Contaminates fish
- Found in Indo-Pacific humpback dolphins and finless porpoises
- Efficiently translocated into plants
- Resistant to sewage treatment
- Found in US wastewater treatment plants

Perfluoroheptanoic acid (PFHpA)

- Alters amphibian embryogenesis
- Exposes the human fetus via presence in amniotic fluid
- Found in human milk
- Manufacturing sites, military fire training, and wastewater treatment plants are predictors of pollution
- Use in airport firefighting foams pollutes groundwater, lakes, soils, and fish
- Found in remote mountain snow
- Bioaccumulates in plankton
- Contaminates fish
- Efficiently translocated into plants

PFAS in people

Numerous studies show PFAS contamination in people. For example, in one study of 299 infants, PFOS was found in the blood of 297 of them and PFOA was found in all of them.

The Stockholm Convention conducts global monitoring of substances listed in the treaty as part of its effectiveness evaluation. The most recent data is from a series of regional monitoring reports published in 2015.

In Africa, the treaty monitoring study noted that PFOS was detected in mothers' milk from all 11 countries that submitted samples with levels varying from 1 – 34 ppt. The report notes that, *"Assuming that there is no industrial production of PFOS in the region, exposure of humans to PFOS and related chemicals might probably come from different kinds of waste, releases from industrial applications in firefighting and the various consumer products."*

The monitoring report for the Asia-Pacific region notes that only a few countries reported data. The report shows PFOS in air in Fiji, Hong Kong, Japan and in blood including maternal plasma in Japan. PFOS was also measured in marine areas in China, Hong Kong, Japan, Macao and rivers and lakes in Philippines, South Korea, and Thailand.

In Central and Eastern Europe, the Stockholm Convention monitoring report notes that data on water monitoring are scarce and data for the presence of PFOS in human tissues is even more limited.

Stockholm Convention monitoring in Latin America and the Caribbean showed that only Uruguay reported data on PFOS in air and the report notes that at this time (2015) there was no formal monitoring program in the region for determination of PFOS.

In Western Europe and Other States, monitoring data also includes the Arctic where PFOS and PFOA in air were measured. The report notes that phaseouts of PFOS and PFOA are reflected in declining concentrations but that fluorinated substitutes show increasing levels in Arctic air. The study also reveals that of all the measured POPs, PFOS was the predominant substance in human plasma, with the highest level of 470 ppt reported in an Inuit resident of the Arctic.

Recent scientific studies show the widespread presence PFAS in humans. Data include the following:

- Perfluorohexane sulfonate (PFHxS), perfluorononanoate (PFNA), perfluorodecanoate (PFDA), perfluoroundecanoate (PFUnDA), and perfluorotridecanoate (PFTrDA) in human milk in Sweden
- PFOS, PFOA, PFNA, PFDA, PFUnA and PFHxS in maternal sera, placentas, and fetuses.
- PFOS, PFOA, PFHxS, and PFNA in New Zealand adults
- PFOS, PFDoDA, PFUnDA and PFTrDA in pregnant Japanese women
- PFOS, PFOA, PFHxS in >94% of community residents with drinking water contaminated by a former US Air Force base.
- 10 long-chain PFAS in California women.
- PFOS< PFOA< PFHxS, PFNA, PFUnDA, PFHpS found in maternal plasma in Norway.
- PFAS in amniotic fluid in Denmark.
- Prenatal exposure to PFOS, PFHxS, PFHpS, PFNA, and PDFA in Denmark.

- Prenatal exposure to PFBS, PFHxS, PFUA in China.
- Six PFAS in middle-aged US women.
- PFNA, PFDA, PFUnDA, PFHxS, PFOA, and PFOS in more than 99% of sampled pregnant Swedish women.
- PFAS in maternal and cord blood in mothers exposed to the US World Trade Center disaster during pregnancy.
- PFOA, PFOS, PFNA, PFHxS in cord blood of Slovak infants.
- PFOS, PFOS and 6:2 CL-PFESA in cerebrospinal fluid in China indicating ability to cross the blood-CSF barrier.
- PFOS, PFOA, PFNA, and PFHxS in children.
- PFOA, PFOS< PFNA, and PFHxS in pregnant US women.
- PFOS< PFOA< PFHxS and PFNA in maternal serum in the UK.
- PFOA, PFOS, and PFHxS in Chinese women.
- PFOA and PFNA in US children.
- PFAS in Alaska Natives.
- PFHxS, PFOA< PFOA, PFNA, PFDA, PFUdA, PFDoA, and PFTrDA in >85% of sampled pregnant women in China.
- PFAS in pregnant Chinese women.

Manufacturers knew PFAS were harmful

Recently obtained documents indicate that the original manufacturers of PFOS and PFOA knew about the harmful characteristics of both substances decades ago.

A lawsuit filed by the US State of Minnesota against 3M produced internal company documents that demonstrated that the company knew PFOS and PFOA were accumulating in people for more than 40 years. 3M had previously withheld required documents from US regulators which resulted in a USD$1.5 million fine in 2006. In 1975, university researchers found a fluorinated substance in human blood and 3M confirmed that it was PFOS. Subsequent company testing found PFOS levels in 3M personnel at levels 50 – 1000 times higher than normal levels. In 1978, tests on monkeys feed PFOS resulted in all the animals dying and those given PFOA developed lesions on their spleen, lymph nodes, and bone marrow, all relevant to a functioning immune system. By 1989, the company knew that PFOS suppressed the immune system, caused tumors in animals, and that rates of cancers of the digestive organs and prostate were elevated in its own workers. The company proceeded to produce the substance anyway.

Internal company documents reveal that DuPont knew decades ago that PFOA affected the livers of dogs and humans, encouraged the growth of testicular tumors in rats, and appeared to result in endocrine disorders and kidney cancer in workers. In 1978, the company documented immunotoxicity and other adverse effects in tests on monkeys exposed to PFOA and PFOS. By 1984, DuPont knew that PFOA was toxic, didn't break down, accumulated in blood, transferred from mothers to the fetus, and polluted drinking water supplies. DuPont decided to keep producing it anyway as it became incorporated into a multitude of products and processes. The company's real attitude about the consequences of PFOA production is revealed in its internal documents as "the material 3M sells us that we poop to the river and into drinking water."

DuPont was fully aware of PFOA's hazards, but a study of the company's decision-making processes noted that DuPont made a calculated, rational decision to pollute anyway. The authors estimate that for DuPont, "it was value-maximizing to pollute if the probability of getting caught was less than 19%." In reality the probability was much less than that and now communities and governments bear the burden of that private sector decision.

Annex 2. The high cost of PFAS cleanup

PFAS manufacturing and use in a multitude of products such as firefighting foams has resulted in widespread pollution – especially in water due to the solubility of PFAS substances. PFAS-contaminated sites have been identified in Australia, Canada, China, Germany, Italy, Japan, Netherlands, New Zealand, South Korea, Sweden, and the US, including a large number of military bases that contribute to 172 PFAS contamination sites in 40 states. In 2018, the US State of Minnesota entered into an agreement with 3M for the company to pay the state USD$850 million for costs associated with cleanup of PFAS including PFHxS due to manufacturing and releases by the company.

Clean up of PFAS pollution is difficult and costly. According to the Polluter Pays Principle, and sound economic policy, these types of external costs should not be borne by taxpayers, the state or national treasury, or by any other third party. Rather, these costs should be internalized within producer industries to avoid market distortion. As noted by UN Environment in 2012, "The vast majority of human health costs linked to chemicals production, consumption and disposal are not borne by chemicals producers, or shared down the value-chain. Uncompensated harms to human health and the environment are market failures that need correction."

Examples of estimated and actual cleanup costs for PFAS pollution include:

- Recent US government agency estimates for the cost PFAS clean-ups and associated monitoring due to use of firefighting foams at US military bases are more than USD$2 billion. There are also expensive clean up costs and estimates in a variety of US states including Alaska, New Jersey, New York (see also here and here), Vermont, Virginia, and Washington.
- The World Bank estimates that if just 20% of fluorinated firefighting foam in China is used for training or fire extinguishing, remediation costs would exceed USD$800 million.
- Remediation of PFAS-containing firefighting foam at the Düsseldorf Airport in Germany will take years or even decades. Cleanup costs cited by the European Chemicals Agency exceed €100 million. There are additional documented remediation costs due to PFAS pollution in Germany – see here, here, and here.
- Clean up due to use of 3M's "Light Water" firefighting foam containing PFOS and PFHxS at 18 military bases in Australia is estimated to cost hundreds of millions of dollars. The cleanup of just a single firefighting training college in Australia is estimated to cost AUS$80 million.
- To clean up groundwater polluted by PFAS around firefighting areas in Norway costs €3.5-5.5 million per training site.
- Firefighting training sites are the main sources of PFAS pollution in Sweden leading to €1 million in annual costs for charcoal filtering of water in Uppsala and a new water supply in Ronne costing €3 million. Extrapolated estimates for advanced cleaning of all waste water treatment plants in Sweden would only moderately remove fluorinated compounds but still cost USD$230 million per year.
- New Zealand has budgeted NZE$1 million to investigate cleanup of PFAS associated with firefighting foam use by military bases.

Annex 3. PFAS and the Stockholm Convention

The Stockholm Convention objective is to protect human health and the environment from persistent organic pollutants. Persistent organic pollutants (POPs) are a class of highly hazardous chemical pollutants that are recognized as a serious, global threat to human health and to ecosystems. Substances can be added to the Stockholm Convention after evaluation and recommendation by the POPs Review Committee (POPRC). Thailand signed and ratified the treaty in 2005.

PFOS

Governments added PFOS to the treaty list at the 4th Conference of the Parties in 2009 and subsequently adopted a series of guidance documents on PFOS alternatives
When PFOS was listed in Annex B of the treaty in 2009, a very large number of loopholes accompanied its listing that permitted continued production and use. At COP9 in April/May 2019, Parties will determine if these loopholes are still needed or if some can be ended. The decision will focus on 6 time-limited ones (specific exemptions) and 8 time-unlimited ones (known as acceptable purposes). The POPRC recommended the following changes to the PFOS listing in the Convention:

End loopholes for 11 PFOS uses: photo-imaging, photo-resist and anti-reflective coatings for semiconductors; etching agent for compound semiconductors and ceramic filters; aviation hydraulic fluid; certain medical devices; photo masks in semiconductor and LCD industries; hard metal plating; decorative metal plating; electric and electronic parts for some color printers and color copy machines; insecticides for control of red imported fire ants and termites; and chemically-driven oil production.

Convert two time-unlimited exemptions to time-limited exemptions: metal plating (hard metal plating only in closed loop systems) and firefighting foams. This gets the clock running on ending these uses in five years. On the firefighting foams, the Committee recommended stopping production and only allowing use for class B fires (ones involving solvents, oil etc.) and only in installed systems. The Committee also noted that, *"a transition to the use of short-chain per- and polyfluoroalkyl substances (PFASs) for dispersive applications such as fire-fighting foams is not a suitable option from an environmental and human health point of view…"* This is extremely important since the fluorinated alternatives are persistent, toxic and readily pollute drinking water.

Continue time-unlimited exemption for one use: insect bait for control of leaf-cutting ants from *Atta* spp. and *Acromyrmex* spp. This vaguely-worded listing actually refers to a pesticide called sulfluramid that degrades to PFOS. The POPRC recommended naming sulfluramid in the treaty under the PFOS listing and narrowing its use to agriculture.

IPEN recommendations for PFOS

Specific exemptions or acceptable purposes for the following 12 uses of PFOS should be ended: photo-imaging, photo-resist and anti-reflective coatings for semiconductors; etching agent for compound semiconductors and ceramic filters; aviation hydraulic fluid; certain medical devices; firefighting foams, photo masks in semiconductor and LCD industries; hard metal plating; decorative metal plating; electric and electronic parts for some color printers and color copy machines; insecticides for control of red imported fire ants and termites; and chemically-driven oil production.

If a specific exemption is allowed for use in firefighting foams, the POPRC recommendations should be adopted.

The following 2 acceptable purposes should be converted into specific exemptions: metal plating (hard metal plating only in closed loop systems); and insect bait for control of leaf-cutting ants from *Atta* spp. and *Acromyrmex* spp. Sulfluramid should be named in the PFOS listing and its use sharply limited to cultivation of specific crops.

PFOA

PFOA is extremely persistent and does not degrade under relevant environmental conditions. It bioaccumulates in air-breathing land and marine mammals, including humans. PFOA is found in water, snow, air, sediment and biota at remote locations including the Arctic. In 2017, the Stockholm Convention POPs Review Committee noted the link between PFOA and serious illnesses in humans, including diagnosed high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer and pregnancy-induced hypertension. PFOA is transferred to the fetus through the placenta and to infants via breast milk. PFOA-related compounds such as fluorotelomer alcohols, fluoropolymers and fluorotelomer-based polymers must be included in actions designed to eliminate PFOA releases since they can degrade to PFOA.

In 2018, the POPRC recommended that governments list PFOA and related substances in Annex A of the Stockholm Convention for global elimination.

Ten time-limited exemptions accompany the PFOA listing recommendation, however, many of these are not justified.

Proposed PFOA Exemption	Comment
5 years	
3 exemptions connected to semiconductor manufacturing (equipment or plant infrastructure, legacy equipment, photo-lithography, etch process)	Alternatives without PFOS or PFOA are available for photolithography and etch processes. For example, IBM eliminated both in 2010. The other proposals are not sufficiently defined.
Photographic coatings applied to films	Obsolete use of PFOA replaced by digital imaging, including in developing and transition countries.
Textiles for oil and water repellency for workers	Proposal relies on industry claims and does not state what specific products the exemption would cover or how worker protection can be achieved without relying on a toxic chemical-impregnated textile.

Invasive medical devices	Alternative medical devices made without PFOA have passed all regulatory requirements, are available on the market, and in use.
Implantable medical devices	Alternative medical devices made without PFOA have passed all regulatory requirements, are available on the market, and in use.
Firefighting foams	Cost-effective non-fluorinated alternatives are in use at major airports and military installations and perform as well as PFAS-containing foams.
10 years For manufacture of semiconductor or related electronic devices; refurbishment parts containing fluoropolymers and/or fluoroelastomers with PFOA for legacy equipment or legacy refurbishment parts	See above for manufacturing. Legacy equipment proposal is not specific and include thousands of unnamed parts. Retrofitting with parts that do not contain PFOA should be utilized, instead of continuing PFOA production and use.
Until 2036 To use PFOI (a PFOA-related substance) to make PFOB for producing pharmaceutical products *"with a review of continued need for exemptions."*	In 2015, more than 100 governments agreed that environmentally persistent pharmaceutical products are an emerging policy issue of global concern in the SAICM process. A global exemption should not be adopted on behalf of a single company (Daikin) and exemptions for environmentally persistent pharmaceutical products should not be recommended.

IPEN recommendations for PFOA

PFOA should be listed in Annex A with no specific exemptions. If exemptions are granted, they should be for specific products and the listing should require labeling new products that contain PFOA so that Parties can fulfill requirements under Article 6 as done previously for HBCD (SC-6/13). In addition, due to the costly, highly polluting nature of firefighting foams, and the availability of technically feasible, high-performing non-fluorinated alternatives, no exemption should be granted for this use.

PFHxS

PFHxS and related compounds are persistent in water, soil and sediment and unlikely to undergo degradation in the environment including hydrolysis, aqueous photolysis or under anaerobic conditions. PFHxS biomagnification factors (BMF) greater than 1 have been observed in food chains including Arctic bird/fish, Arctic polar bear/ringed seal, dolphin/fish, and fish/zoo plankton among others, indicating bioaccumulation. PFHxS has the longest half-life in humans determined for any PFAS. PFHxS undergoes long-range transport and is found in Arctic air, sediment, snow, ice, soil, sediment and biota (including humans) and in Antarctic biota and snow. *In vivo* and epidemiological studies show that PFHxS negatively affects liver function, thyroid, and the developing immune system resulting in reduced effects of vaccines and higher incidences of infections and asthma in children. A significant association between PFHxS exposure and breast cancer has been found in Greenlandic Inuit women. PFHxS is widely found in breast milk and is one of the most frequently detected and predominant PFAS in human blood, including maternal and infant cord blood. In September 2018, the POPRC determined that PFHxS "warrants global action" and moved the substance to the third and final evaluation during 2018 – 2019.

PFAS use in firefighting foams

There are many uses of PFAS, but one of the most highly polluting is in firefighting foams. This pollution occurs where the foam is used and quickly contaminates water and moves. Airports and military bases are common sources of PFAS pollution.

PFOS and PFOA were the original components in firefighting foams, but after regulatory pressure in the US, many companies switched to shorter-chain substances such as PFHxS, PFBA, PFBS, PFHxA, and PFHpA. These substances also are persistent and have hazardous properties. Some are found in the Arctic, suggesting ability to undergo long-range transport. Recently, IPEN assembled a group of fire safety experts who produced a detailed report on issues involving firefighting foams and the technical feasibility of fluorine-free firefighting foams. Safer cost competitive non-fluorinated alternatives to PFAS in firefighting foams have been adopted by major airports, including Auckland, Copenhagen, Dubai, Dortmund, Stuttgart, London Heathrow, Manchester, and all 27 major airports in Australia.

In September 2018, the POPRC recommended severe restrictions on the use of PFOS and PFOA in firefighting foams. In addition, the Committee also made an extremely important recommendation **not** to use the fluorinated alternatives to PFOA and PFOS, *"due to their persistency and mobility as well as potential negative environmental, health and socioeconomic impacts."*

The recommended restrictions on firefighting foams containing PFOA, PFOA-related substances, or PFOS include:

- No production.
- Use for 5 years only for liquid fuel vapor suppression and liquid fuel fires (Class B fires) already in installed systems.
- No import or export, except for environmentally-sound disposal.
- No use for training or testing purposes.
- By 2022, restrict use to sites where all releases can be contained.

- Ensure that all firewater, wastewater, run-off, foam and other wastes are managed in accordance with the treaty.

IPEN recommendations on PFAS use firefighting foams

Due to the costly, highly polluting nature of firefighting foams, and the availability of technically feasible, high-performing alternatives, no exemption should be granted for this use. IPEN supports the POPRC recommendation that fluorinated alternatives to PFOA and PFOS should not be used.