Perfluorooctane Sulfonate (PFOS)

TIER 3
MODERATE CONCERN

MEG SEDLAK,
San Francisco Estuary Institute
(meg@sfei.org)

Quick Summary

Since the late 1940s, PFOS has been widely used as a stain repellant for textiles, furniture, and carpets; as a surfactant in fire-fighting foams and metal finishing processes; as an ingredient in the production of fluoropolymers; and as an insecticide. PFOS repels both water and oil and is highly stable. Consequently, it has been used extensively and has been widely detected in the global environment, including in San Francisco Bay birds and seals and to a lesser extent in fish and bivalves. Bird eggs collected in the southern portion of the Bay in 2006 and 2009 contained levels of PFOS above a threshold for impacts on offspring survival in birds. Fortunately, the most recent PFOS egg results in South Bay (2012) were 70% lower than prior levels and well below this threshold. However, PFOS concentrations in seals do not show similar declines. The pathways by which these compounds enter the Bay are not fully understood.

What Is It?

- PFOS is a fluorine-containing surfactant (chemical that is soluble in both water and oil) that is a very persistent environmental contaminant.
- PFOS is a type of perfluorinated chemical (PFC) – a diverse class of fluorine-containing compounds that are extremely stable in the environment, excellent surfactants, and used in a wide range of applications.
- PFOS accumulates in biota.

What Is It Used For?

- For the last 50 years, PFCs have been used extensively in industrial, commercial, and consumer applications. PFOS has been used as a stain repellent for carpets, textiles, and paper products ("grease-proof" paper); in aqueous film-forming foams (AFFF) used at refineries, airports, and military or industrial facilities to suppress fires; in electronics and metal-finishing; and as a pesticide.
- PFOS was first widely detected in wildlife throughout the world in 2000 (Giesy and Kannan 2001). At the same time, it was also found to be a pervasive contaminant in human blood in the US (Hansen et al. 2001). As a result, the major US manufacturer of PFCs voluntarily withdrew PFOS and other structurally similar compounds, and its use in North America and Europe was restricted. Despite use reductions, PFOS continues to be detected in the environment as a result of the continued use of PFOS precursors that degrade to PFOS, historic reservoirs of these chemicals in products and the environment, PFOS impurities in other PFCs, and the continued production of PFOS and PFC precursors in other parts of the world, such as China.

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How Is It Getting Into the Bay?

- The sources and pathways of PFOS to the Bay are not fully understood.
- Research in the Great Lakes and elsewhere suggests that wastewater effluent and urban tributaries are important pathways. Also potentially significant are point sources such as contaminated sites where PFOS has been directly released to the environment (e.g., as a result of the use of AFFF to fight fires, spills from production sites, and the land application of biosolids).
- Municipal wastewater treatment plant (WWTP) effluent is a major pathway. Uses in consumer, commercial, and industrial products result in transport to WWTPs. WWTPs are not effective at removing PFCs and in some instances promote the formation of PFOS from precursors (Schultz et al. 2006, Becker et al. 2008).
- In a recent RMP study, the average concentration in effluent from six Bay Area WWTPs was 24 nanograms per liter (ng/L) (Sedlak and Allen in prep). This value is on the low end of the range of concentrations commonly seen in effluent nationally (Plumlee et al. 2008). Concentrations from WWTPs receiving industrial wastewater are typically higher.
- Urban stormwater, which flows directly into the Bay untreated, is another potential source of PFOS to the Bay.
  - In a survey of three Bay Area tributaries, PFOS concentrations ranged from below detection to 14 ng/L (Sedlak and Allen in prep). These values are in the range observed in other Bay Area studies and nationally (Plumlee et al. 2008, Houtz and Sedlak 2012).
  - Unknown precursors in tributaries may be converted to PFOS (Houtz and Sedlak 2012).
- Rain can be a pathway for PFOS. Concentrations of PFOS in Bay Area rainwater have not been measured.
- Other possible point sources are facilities that may use AFFF such as refineries and airports, or facilities where these materials are discarded such as landfills. PFC concentrations at such point sources have not been monitored in the Bay Area.
- Shorter-chained fluorinated compounds are being substituted for PFOS. Perfluorobutanesulfonate (PFBS), one of the substitutes, has been detected in Bay effluents and tributaries at relatively low concentrations (10 ng/L). Shorter-chained compounds such as PFBS are believed to be less toxic and less bioaccumulative.
- Precursors that degrade to PFOS may be another source (Higgins et al. 2005).

What Happens to It in the Bay?

General Properties

- Longer-chained PFCs (with eight carbons or more) can degrade to PFOS, which is not known to undergo further degradation in the environment.
- Unlike legacy contaminants such as PCBs and DDT that accumulate in fatty tissues, PFOS binds to proteins and is most frequently detected in blood and liver.

Patterns of Occurrence in the Bay and in Other Aquatic Ecosystems

- Bay sediment concentrations ranged from 0.4 to 3.2 parts per billion (ppb) (Sedlak and Allen in prep). The highest concentrations were observed in the South Bay.
  - These values are consistent with prior studies of San Francisco Bay and are within the range of concentrations observed nationally in estuaries and lakes. For example, concentrations from Lake Ontario were higher on average (26 ppb) (Myers et al. 2012).
- Average PFOS concentrations in Bay surface water in 2009 were 7 ng/L. These were generally lower than other urban water bodies such as Tokyo Bay (0.3-58 ng/L) and Lake Ontario (3.6-38 ng/L), but exceed concentrations measured in more pristine environments.
- PFOS accumulates in Bay birds and seals to levels that may be of concern (FIGURES 1 AND 2). Bay seal and bird egg concentrations have been some of the highest observed worldwide.
- Cormorant eggs have been collected from three Bay sites on three occasions: 2006, 2009 and 2012. Average PFOS concentrations in eggs from the South Bay in 2006 (1,300 ppb) and 2009 (1,200 ppb) exceeded a threshold of 1,000 ppb, above which adverse outcomes have been observed for survival. In 2012, PFOS in South Bay bird eggs was substantially lower (385 ppb).
- Concentrations of PFOS in seal blood have remained relatively constant over time. Similar to birds, the highest concentrations were observed in the South Bay (1,000 ng/mL, parts per billion (ppb) followed by Central Bay (80 ppb)). Background concentrations observed in seals from Tomales Bay in the Point Reyes National Seashore were much lower (12 ppb).
- PFOS was infrequently detected in sport fish tissues. Of the 21 fish analyzed in 2009, PFOS was detected in four samples (leopard shark, anchovies, and white sturgeon) with a maximum concentration of 18 ppb. There are no California thresholds for evaluating risks to humans from PFOS concentrations in Bay sport fish. The State of Minnesota has established a sport fish threshold of 40 ppb for one serving of fish per week.
- PFCs do not appreciably bioaccumulate in mussels. As part of a larger California survey and a RMP special study, PFOS was monitored in mussels at 13 Bay sites in 2010. PFOS was detected in two samples from the South Bay at concentrations of 35 ng/g dw and 76 ng/g ww.

Trends in the Bay and Nationally

- No trend data for Bay sediment and water are available.
- PFOS was lower in the most recent sampling of Bay bird eggs, but no sign of a trend has been observed in Bay seals (FIGURES 1 AND 2).

Is There a Risk of Harm in the Bay?

- In mammals, PFOS exposure has been associated with compromised immune systems, reproductive and developmental defects, neurotoxicity, and cancer (DeWitt et al. 2012).

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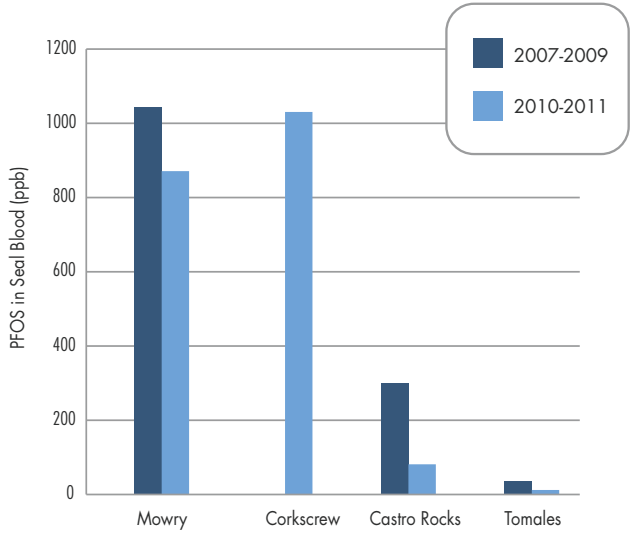

FIGURE 1
PFOS accumulates in Bay seals and birds to levels that may be of concern and are among the highest observed worldwide. Concentrations of PFOS in seal blood have remained relatively constant over time. The highest concentrations were observed in the South Bay (1,000 ng/mL, parts per billion (ppb)) followed by Central Bay (80 ppb). Background concentrations observed in seals from Tomales Bay in the Point Reyes National Seashore were much lower (12 ppb).

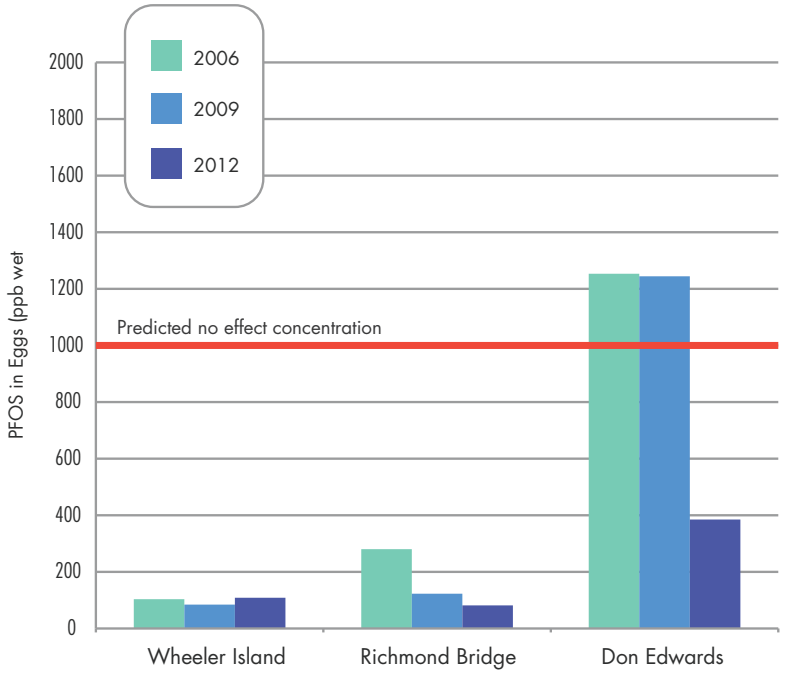

FIGURE 2
Average PFOS concentrations in cormorant eggs from the South Bay in 2006 (1,250 ppb) and 2009 (1,240 ppb) exceeded a threshold of 1,000 ppb, above which adverse outcomes have been observed for embryo survival. In 2012, PFOS concentrations in South Bay eggs were substantially lower (385 ppb).

Footnote: Each bar represents the average of three composite samples, with seven eggs in each composite.

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- A predicted no effect concentration for PFOS has been developed for bird eggs of 1,000 ppb (Newsted et al. 2005). Concentrations in Bay cormorant eggs have exceeded this threshold, but the most recent data from 2012 were substantially below this threshold.
- In a study of California sea otters (Kannan et al. 2006), PFOS concentrations similar to those observed in Bay harbor seals were associated with a higher incidence of disease and mortality.

Key Information Gaps

- Few studies have evaluated the effects of PFOS exposure in seals.
- The sources of PFCs to Bay biota are not well understood.
- Little is known regarding the presence and pathways by which precursors form PFOS in the Bay.
- Manufacturers are shifting to fluorinated compounds that are expected to be less toxic and less likely to accumulate in biota. It will be important to monitor to ensure that these are not accumulating in the Bay or in Bay biota.

Management Timeline