PFAS Bioaccumulation in Ecosystems

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Mission: Provide scientific support and tools for decision-making and communication through collaborative efforts.

Sedlak et al., 2017 *Chemosphere*
PFAS Bioaccumulation in the Bay Food Web

Bioaccumulation
An organism’s net contaminant accumulation from all sources
• Air
• Water
• Sediment
• Food

PFOS in SF Bay Bird Eggs

PFOS is most abundant
- Developmental toxicity
- PNEC 1000 ng/mL (yolk)

Similar levels observed in other urban areas near PFAS sources
PFOA and Long-chain Carboxylates

South Bay Cormorant Eggs

Sum PFCA Concentration (ng/g wet weight)

- PFOA
- PFNA
- PFDA
- PFUnDA
- PFDaDA
- PFCA

2009
2012
2016
2018
PFAS in SF Bay Harbor Seal Serum

From a wide range of 8:2 fluorotelomer-based substances in bacteria, rodents and sh (Butt et al., 2014).

The range of PFOS concentrations reported in the most recent (2014) Bay seal samples (12.6e796 ng/g) are similar to or lower than those observed in urbanized areas from other parts of the world. For example, four stranded seals collected in 2007 from the German Bight contained blood PFOS concentrations ranging from 48 to 887 ng/g (average 349 ng/g) (Ahrens et al., 2009b). These levels are considerably higher than PFOS concentrations in seals from more remote regions, which are typically in the range of a few to tens of ng/mL or ng/g (Kannan et al., 2001; Butt et al., 2007; Rotander et al., 2012; Riget et al., 2013; Routti et al., 2014).

PFOS concentrations reported in this study and a prior SF Bay study were not statistically correlated to sex or age (2-sided unpaired Wilcoxon rank-sum for sex, Kruskal-Wallis for age, p > 0.05). Sex and age correlations appear to vary by species and study with no definitive trends (Fair et al., 2012). For example, no gender or age difference were observed in studies of PFOS concentrations in Canadian seals (Butt et al., 2008); however, in a recent study of dolphin from Charleston North Carolina adult males were observed to have higher PFOS concentrations than females (Fair et al., 2012).

Several researchers have observed higher PFOS concentrations in seal pups versus adult females suggesting maternal transfer of PFASs (Shaw et al., 2009).

South Bay seals contained substantially higher PFOS concentrations than Castro Rocks seals (1-sided Dunn's Test, Bonferroni adjustment for multiple comparisons, p < 0.01). Both the Central and South Bays are urbanized and industrialized areas. A plethora of possible PFAS sources such as airports, historic landfills, and former military facilities exist throughout the SF Bay region. Independent of specific PFAS sources, one of the major differences between Central and South Bays is the degree of hydraulic flushing that occurs at each site. The Central Bay receives approximately 90 percent of the freshwater flows coming into the Bay via the Sacramento and San Joaquin Rivers. In contrast the South Bay receives approximately 10 percent of the annual river flow (Conomos, 1979).

Hydraulic residence times in the embayments near the Castro Rocks/Richmond Bridge site are on the order of days, as compared to months in the South Bay (Walters et al., 1985). It is possible that the reduced flushing of the South Bay is a factor in the higher levels of PFOS contamination observed in resident wildlife.

3.2. PFAS occurrence in bird eggs

Similar to seals, PFOS was the dominant PFAA over all time points (Fig. 3; Table S8; range 36.1e466 ng/g) and the highest concentrations were observed in the South Bay. Concentrations of other PFAAs are in general an order of magnitude lower than PFOS.

PFOS concentrations observed in SF Bay are in the range reported from other urbanized estuaries and contaminated sites (Houde et al., 2006, 2011). Concentrations in cormorant eggs collected in 2009 from nests on the Elbe River downstream of Hamburg, Germany, ranged from 100 ng/g to 1451 ng/g ww (mean 540 ng/g) (Rudel et al., 2011). Custer et al. (2013) observed elevated PFOS concentrations in the eggs of piscivorous Great Blue Heron near a St. Paul PFAS manufacturing site in MN in the early 1990s. In 1993, concentrations of PFOS were as high as 940 ng/g ww (range of 608e1453 ng/g); more recent results indicate a decline, averaging...
PFOS in Prey Fish

Canada’s Federal Environmental Quality Guidelines for PFOS in Wildlife Diet

• To protect birds: 8.2 ng/g ww (whole prey fish)
• To protect mammals: 4.6 ng/g ww (whole prey fish)

SF Bay small (prey) fish: up to 240 ng/g ww
PFOS in Sport Fish

Figure 7: Concentrations of PFOS in Sport Fish. Each point represents an individual fish (carp or bass from Artesian Slough) or composite fish (all other species, including striped bass composites from San Pablo Bay, and Central Bay). Fish that did not contain PFASs above detection limits are not included. The San Francisco Bay fish were collected in 2014; Artesian Slough fish were collected in 2015.

2.4 PFASs in San Francisco Bay Double-crested Cormorant Eggs

The RMP has monitored Double-crested cormorant (Phalacrocorax auritus) eggs to assess contaminant exposure from the open water habitats of the Bay. Cormorants are year-round avian residents that forage for food in shallow, open waters, close to shore. Their feeding range can be quite large; they are known to forage in an approximately 20-mile radius from their nesting sites (Melwani et al. 2012). As such, they are excellent regional integrators of contaminants. Since 2006, the RMP has monitored cormorant eggs for 13 PFASs from three Bay sites (Figure 8): the Central Bay (at the Richmond Bridge), the South Bay (at Don Edwards Pond or the South Bay Towers), and in the Delta-influenced Suisun Bay (at Wheeler Island). At each site, three composites of seven eggs are collected and analyzed for 13 PFASs including PFOS, PFOA, and a PFOS precursor, PFOSA (Appendix Table 7).
Uncertainties: Occurrence and Impacts of Many More PFAS, Alone and in Mixtures

Fluorine mass balance:

- PFOS dominates but...
- Dozens more PFAS are present, including many not routinely measured

What are the impacts of these mixtures?

(Spaan et al. 2019)
Take-home Messages

PFAS are widespread in Bay food web
PFOS is most abundant

• May pose risks to wildlife,
  though levels are declining

Occurrence, impacts of many other PFAS unknown

SF Bay Research Priorities:
• Stormwater, wastewater monitoring
• Bay water, sediment monitoring
• Fluorine mass balance on Bay wildlife
• Research to promote greener substitutes
Thank you

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