Temporal trends in perfluorinated alkylated substances (PFASs) in North Atlantic seawater and pilot whales

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Perfluorinated Surfactants (PFOX, X=S/A)

Perfluorooctane sulfonate (PFOS)

Perfluorooctanoate (PFOA)

Fluorophilic = (Hydro + Oleo)phobic
PFOS elicits the most dramatic immune suppression ever observed for an environmental toxicant.

Children from the Faroe Islands

50% Reduction in antibody concentrations for each doubling of PFASs

Grandjean et al., 2012
Composition of manufactured PFASs has changed dramatically since 2002.

Tonnes per year

PFOS and precursors

PFCAs

C-11
C-9
C-8
Understanding fate of environmental contaminants

Tools: Global 3-D Models for the Atmosphere & Ocean

Satellite Data

MITgcm with ecology

Biological Exposures & Health Outcomes
Major Source of PFOS to Oceans is Wastewater

Wastewater treatment plants (WWTP)

River basins

Oceans

Zhang et al., in. prep.

\[ E_{\text{WWTP}} \, (\mu g/d) = 0.21 \times 10^{0.44 \pm 0.09} \times P_{\text{WWTP}}^{1.24 \pm 0.09} \]
Biogeochemical processes of PFOS in the ocean

\[
[HX + X^-]_{aq} \cdot EF \cdot Flux_{droplet} \cdot A
\]

Negligible

\[
[HX]_{aq} \leftrightarrow [X^-]_{aq}
\]

\[
K_1 = 10^{PH-pKa}
\]

\[
K_2 = K_{OC}[POC]
\]

\[
[X_P]_{ng/L}
\]

\[
[P OC]_{kg/L}
\]

Zhang et al., in prep.
Temporal Trends in North Atlantic Inputs (t/a)

PFOS Inputs to North Atlantic

PFOS Inputs to Arctic

Seawater Depth (m)

Zhang et al., in. prep.
North Atlantic PFOS Concentrations (10 m)

PFOS (pg/L)

(a) 1980  
(b) 1990  
(c) 2000  
(d) 2010  
(e) 2020  
(f) 2030

Zhang et al., in. prep.
How quickly do changing seawater concentrations influence biological trends?

- Whales exhibit high degree of site fidelity
- Examine muscle of juvenile males ages 7-12, spanning 1986-2013

PFOS Seawater (ng/L)

Whale telemetry data

Zhang et al., in. prep.

Mikkelsen, unpublished data

Sunderland, 8/20/15
Pilot Whale Muscle 1986-2013

- PFOSA is a volatile precursor of PFOS
- PFOSA >> PFOS concentrations in whale
- PFOSA << PFOS in seawater
- Suggestive of atmospheric exposure pathway

\[ \text{Dassuncao et al., in. prep.} \]

\[ \text{PFOS:PFOSA} \]
\[ 1985-2000 = 16\% \]
\[ 2011-2013 = 63\% \]

Sunderland, 8/20/15
Conclusions

- Large decline in wastewater PFOS inputs to North Atlantic have resulted in substantial declines in seawater concentrations.
- Concentrations are spatially heterogeneous depending on proximity to sources and ages of water masses.
- PFOS in whale muscle likely to follow seawater trend lagged by age of individuals (7-12 years).
- PFOSA in pilot whale muscle >> PFOS and temporal patterns are suggestive of an atmospheric pathway for exposure.
“The Island and the Whales”

KICKSTARTER