John P. Giesy

“Perfluorinated compounds in the environment: Story of an environmental contaminant”

Exposing ourselves: investigating everyday environments and their health impacts
Saskatchewan Epidemiology Association Symposium 2010

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Example:
Perfluorooctane sulfonate

- PFOS is a fatty acid analogue
- Not metabolized
- Amphiphilic
- Preferentially retained in plasma and liver
  - binds to protein
- Affects membranes
Structure of Perfluorooctane Sulfonate

PFOS: Perfluorooctane sulfonate

C₈F₁₇S - O⁻
# Some PFC Compounds of Interest

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tridecafluoroheptanoate (C7)</td>
<td>C$<em>{6}$F$</em>{13}$COO$^-$</td>
</tr>
<tr>
<td>Pentadecafluorooctanoate (C8; PFOA)</td>
<td>C$<em>{7}$F$</em>{15}$COO$^-$</td>
</tr>
<tr>
<td>Heptadecafluorononoate (C9)</td>
<td>C$<em>{8}$F$</em>{17}$COO$^-$</td>
</tr>
<tr>
<td>Nonadecafluorodecanoate (C10)</td>
<td>C$<em>{9}$F$</em>{19}$COO$^-$</td>
</tr>
<tr>
<td>Perfluoroundecanoate (C11)</td>
<td>C$<em>{11}$F$</em>{21}$COO$^-$</td>
</tr>
<tr>
<td>Perfluorododecanoate (C12)</td>
<td>C$<em>{12}$F$</em>{23}$COO$^-$</td>
</tr>
<tr>
<td>Perfluorooctane sulfonate (PFOS)</td>
<td>C$<em>{8}$F$</em>{17}$SO$_{3}^-$</td>
</tr>
</tbody>
</table>
Compounds Monitored for

PFOS: Perfluorooctanesulfonylic acid potassium salt: C$_{17}$F$_{19}$SO$_3$K
PFHpS: Perfluorooctanesulfonic acid potassium salt:
PFBS: Perfluorobutanesulfonic acid potassium salt:
PFOSA: Perfluorooctanesulphonamide: C$_{17}$F$_{19}$SO$_2$NH$_2$
THPFOS: Tetra Hydro PFOS: C$_8$H$_4$F$_{13}$SO$_3$
PFBA: Perfluorooctanoic acid: C$_3$F$_7$COOH
PFPeA: Perfluoropentanoic acid: C$_4$F$_9$COOH
PFHxA: Perfluorohexanoic acid: C$_5$F$_{11}$COOH
PFHpA: Perfluorooctanoic acid: C$_6$F$_{13}$COOH
PFOA: Pentadecafluoro-octanoic acid: C$_{17}$F$_{15}$COOH (Also C$_{13}$)
PFNA: Perfluorononanoic acid: C$_8$F$_{17}$COOH
PFDA: Perfluorodecanoic acid: C$_9$F$_{19}$COOH
PFUnA: Perfluoroundecanoic acid: C$_{10}$F$_{21}$COOH
PFOA: Perfluorododecanoic acid: C$_{11}$F$_{23}$COOH
N-Et FOSA: Ethyl FOSA Alcohol:
N-MeFOSE: Methyl FOSE Alcohol:
N-Et FOSE: Ethyl FOSE Alcohol:
APFO: Ammonium perfluorooctanate: C$_{17}$F$_{15}$COONH$_3$
4:2FTOH: 1-hydroxyethane-2-perfluorobutane: CF$_3$(CF$_2$)$_3$(CH$_2$)$_2$OH
6:2FTOH: 1-hydroxyethane-2-perfluorohexane: CF$_3$(CF$_2$)$_5$(CH$_2$)$_2$OH
8:2FTOH: 1-hydroxyethane-2-perfluoroctanol: CF$_3$(CF$_2$)$_7$(CH$_2$)$_2$OH
PDFO: Pentadecafluoro-1-octanol: CF$_3$(CF$_2$)$_6$CH$_2$OH
POSF: Perfluorooctanesulphonyl fluoride: C$_{17}$F$_{19}$SO$_2$F
POSF: Perfluorooctanesulphonyl fluoride: C$_{17}$F$_{19}$SO$_2$F
10:2 FT-OH, 1-hydroxyethane-2-perfluorodecanol

Note: Must purify and separate straight-chain and branched isomers
Papers coated with PFOS-based fluorochemicals
Scotchguard-Major Use
Uses of Fluorinated Surfactants

Adhesives: Wetting agents
Antifogging: Glass surfaces
Antistatic agents: Microchip manufacture
Cement additives: Reduce shrinkage of cement
Cleaners for hard surfaces: Floor Polishes
Coatings: Paint additives, waxes
Cosmetics: Hair-conditioning
Electronics: Insulators, microchips
Electroplating: Chromium, copper and nickel
Etching: Glass
Fire-Fighting Foams: Formulated to float on flammable liquids
Herbicides and Insecticides: Wetting agents
Leather: Provide water and oil repellency
Paper: Oil and water repellency
Textiles: Polyester etc. to impart soil, oil and water repellency.

Major use is in carpeting.
How Did We Get Here?

- PFFAs were persistent and bioaccumulative
- PFFAs were primarily used in polymers and thought to be inert and were not expected to enter the environment and be accumulated in biota
- PFFAs were thought to be nontoxic
- PFFAs have a fundamentally different environmental profile than chlorinated hydrocarbons
- There were no suitable methods or standards to allow for monitoring of the environment
How Did We Get Here?

- **1950** – Large scale production begins with many uses.
- **1976** - Dr. Travers (UR) confirms earlier UR studies, tentatively identifies PFOS in human blood.
- **Early 1990s** - 3M uses advanced mass spectrometry to scan worker’s blood - detects with MDL of 0.5 mg/l (ppm).
- **1993** - Univ. Minnesota reports no effects in PFOS-exposed workers. Elsewhere PFOS linked to cancer in rodents and changes in reproductive hormones in humans.
How Did We Get Here?

• 1997 - Researchers at Michigan State University (MSU) report finding organic fluorine compounds in water, air and soil and eagle blood

• May, 1998 - 3M advises US EPA that it found organic fluorine in blood bank samples - decides to move away from this chemistry

• Sept. 1998 - 3M reports to US EPA results of studies in which offspring of rats die within days

• February, 2000 - MSU reports PFOS found in a variety of wildlife species from many locations around the world
How Did We Get Here?

- March, 2000 - 3M and US EPA discuss latest finding, including chronic studies of reproduction in monkeys
- May 16, 2000 - 3M and US EPA announce that the company will voluntarily phase out manufacture and use of PFOS
- 2000-2004 – Improvements in methods for abiotic and abiotic matrices
- 2000-2004 – MSU, 3M and EPA conduct toxicity studies to determine mechanisms of action and thresholds for effects of PFOS
- 2003-2004 – Many laboratories around the world begin to report concentrations of PFFAs in biota, water and air
Potential Mechanism of Movement

PolyAcrylate/Methacrylate Copolymers

Potential Sources?

Residual

Degradation

Carpet Treatment

S. Maybery et al, 2001
Global Circulations

- Mid-latitudes: Seasonal cycling of deposition and evaporation
- Long-range atmospheric transport
- Long-range oceanic transport
- Low latitudes: Evaporation > deposition
- POP migration processes
- Global distillation with fractionation according to global mobility
- High mobility
- Relatively high mobility
- Relatively low mobility
- Low mobility
- "Grasshopping"
Likely Mechanisms of Dispersion

- Methyl- and Ethyl-FOSE alcohols are more volatile and likely moved in atmosphere
- Released during manufacture as well as 1-3% residual in products
- Accumulated into aquatic organisms and into predators and transformed into PFOS
SUMMARY - Environmental Fate

PFOS is ubiquitous in the global environment in both urban and remote locations

PFOS accumulates into human and wildlife tissues

PFOS can be toxic to invertebrates and vertebrates under laboratory conditions

Issue: Are current concentrations of PFOS in the environment expected to cause any adverse effects on wildlife
Uncouple oxidative phosphorylation
Inhibit Gap junctional intercellular communication
Peroxisome proliferation and organ-specific DNA Damage
Induce liver microsomal carboxylase RL4

PFOS, PFOSA
PFOA, PFDA, PFOS
PFOA, PFDA, PFBA
PFOA, PFDA, PFOS

PFOA: Perfluorooctanoate; PFDA Perfluorodecanoate; PFBA: Perfluorobutyric acid; PFOS: Perfluorooctane sulfonic acid
Toxicity Summary - 2

Hypophagia, weight loss, bradycardia, hypothermia and reduced motor activity

Reduced T3 and T4 concentrations

Induction of cytochrome P450; ECOD, Acylglycerophosphochocholine

Acyltransferase, acyl CoA-hydratase

Induced liver phospholipase C’

Inhibited phosphochocholine

PFOA: Perfluorooctanoate; PFDA Perfluorodecanoate; PFBA: Perfluorobutyric acid; PFOS: Perfluorooctane sulfonic acid
Toxicity Summary - 3

- Decreased serum cholesterol: PFOA, PFOS
- Increased fatty acid and acyl CoA binding proteins in rat liver: PFDA
- Increased Protein kinase C activity, decreased Acyl CoA synthase activity: PFOS

PFOA: Perfluorooctanoate; PFDA Perfluorodecanoate; PFBA: Perfluorobutyric acid; PFOS: Perfluorooctane sulfonic acid
Membrane Effects

• Structure of Perfluorinated compounds: Similarity to endogenous fatty acids

• Physico-chemical Properties of Perfluorinated Compounds: Surface Active Agents

• Effects of Perfluorinated Compounds:
  • GJIC
  • Bioassay interactions

…… all suggest membrane related effects.
Alterations in Membrane Properties by PFOS
Effects on Gap Junctions
What is Gap Junction Intercellular Communication?
Why Study GJIC?

• Gap Junctional Intercellular Communication (GJIC) plays an important role in the maintenance of normal cell growth and function.
• Previous studies showed that perfluorinated fatty acids (PFFAs) with 7-10 carbons caused significant inhibition of GJIC in a dose-dependent manner.
• Down regulation of GJIC has been considered as one of the mechanisms of non-genotoxic carcinogens.
Experimental Design

Chemicals:
PFOS (C8), PFOSA (C8), PFHS (C6), PFBS (C4).

Two cell lines:
WB ---- rats liver epithelial cell line;
CDK ---- dolphin kidney epithelial cell line;

Three experiments:
dose response experiment
time course experiment
recovery experiment
Experimental Design *In vitro*

GJIC measured by scrape loading dye technique

1. Cell grow to confluence (monolayer)
2. Expose to PFOS
3. Apply lucifer yellow dye
4. Make scrapes with blade
5. Discard dye after 3 min
6. Observe under fluorescent microscope
7. Analyze image with gelexpert
WB cell Solvent Control

WB cell exposed to 12.5 μM PFOS

WB cell exposed to 50 μM PFOS

WB cell exposed to 160 μM PFOS
WB cells Solvent Control

WB cells exposed to PFOS for 2 min

WB cells exposed to PFOS for 5 min

WB cells exposed to PFOS for 10 min
IN VIVO GJIC measured by dye loading

Experimental Design *In vivo*

1. Expose to PFOS
2. Remove & score liver
3. Apply lucifer yellow dye to liver
4. Discard excess dye and wash
5. Fix, slice and prepare liver sections for microscopy
6. Observe under fluorescent microscope
7. Analyze image with gelexpert
In vivo inhibition of GJIC by PFOS

Control

PFOS, 5mg/kg/d for 21 days
PFOS inhibits GJIC in a dose-dependent fashion;
The length of the carbon chain, but not the functional group determines the GJIC inhibitory potency.
The inhibitory effect is neither species- nor tissue-specific.
The inhibition of GJIC by PFOS occurred in a short period of time, and is rapidly reversible.
Post-transcriptional modification of gap-junctional protein(s) may be involved.
No evidence that PFOS is a complete carcinogen.
DNA Microarrays
Peroxisomal Fatty Acid β Oxidation

Membrane

- Fatty acyl-CoA synthetase (1.5X)
- Acyl-CoA dehydrogenase (2X)
- Enoyl-CoA hydratase (6.5X)
- Hydroxyacyl-CoA dehydrogenase (6.5X)
- 3-Ketoacyl-CoA thiolase (10X)
- Acetyl-CoA + acyl-CoA

Mitochondrial Fatty Acid β Oxidation

Membrane

- Fatty acyl-CoA synthetase (1.5X)
- Carnitine AT I (1X)
- Carnitine AT II (1.2X)
- Acyl-CoA dehydrogenases (1.1X)
- Enoyl-CoA hydratase (1.2X)
- Hydroxyacyl-CoA dehydrogenase (1.2X)
- 3-Ketoacyl-CoA thiolase (1.5X)
- Acetyl-CoA + acyl-CoA

Electron transport chain → ATP
Gene Expression Conclusions

• PFOS alters expression of peroxisomal but not mitochondrial fatty acid metabolism

• However, PFOS does not induce all genes characteristic of true “Peroxisome proliferators”

• Other genes also affected but not a consistent number in a specific pathway
Ecotoxicological Assessment For PFOS:
Rationale for Testing

Discovery of PFOS in environmental Samples

Reliable, sensitive analytical methods now available

Generate hazard data for environmental risk evaluation
Approach

- Determine Toxicity Reference Values (TRVs) based on standard practices
- Calculate threshold water concentrations for protection of aquatic life based on the US EPA-GLI methods and OECD, PNEC
- Determine tissue concentrations to protect predatory birds and mammals
- Compare measured concentrations in water or tissues to TRVs

\[ HQ = \frac{\text{Concentration}}{\text{TRV}}; \quad \text{MOS} = \frac{1}{HQ} \]
Threshold Screening Concentrations for the Protection of Aquatic Life

- GLI used to calculate acute & chronic concentrations
- Semi-probabilistic approach
- Requires acute and chronic toxicity results for aquatic species of various orders and families
- Uses species and genus geometric means
- Uses Acute to Chronic Ratios
- Can calculate Tier I and Tier II GLI values
- Similar to method of Stephan et al (1985)
- Conservative (Protective)
Threshold Screening Concentrations for the Protection of Aquatic Life

• Aquatic Plants relatively tolerant
  – NOAEC values from 5.3 to 150 mg PFOS/l
• GLI Tier I value could not be calculated due to insufficient number of families and especially chronic data
• Secondary Chronic Value (SCV) = 1.2 ug PFOS/l (1,200 ng/l, ppTr)

Northern Bobwhite (Colinus virginianus)

- Order Galliformes, Family Odontophoridae
- Ground-dwelling upland game bird
- Feeds primarily on weeds, woody plants and grasses. Adults and chicks also consume insects and other invertebrates
Mallard (Anas platyrhynchos)

- Order Anseriformes, Family Anatidae
- Surface feeding dabbling duck (waterfowl)
- Feed primarily on aquatic plants and aquatic insects
Northern Bobwhite Reproduction Study
Final NOAEL & LOAEL Values

<table>
<thead>
<tr>
<th>Measures of PFOS Exposure</th>
<th>ADULT MALES</th>
<th>NOAEL</th>
<th>LOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose (mg PFOS/kg in Feed)</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>ADI (mg PFOS/kg body weight/day) over 21-wk period</td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum (mg PFOS/mL) at study termination (21-wks)</td>
<td>140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver (mg PFOS/g) at study termination (21-wks)</td>
<td>88</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures of PFOS Exposure</th>
<th>ADULT FEMALES</th>
<th>NOAEL</th>
<th>LOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose (mg PFOS/kg in Feed)</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>ADI (mg PFOS/kg body weight/day) over 21-wk period</td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum (mg PFOS/mL), pre-reproductive phase (5-wks)</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum (mg PFOS/mL), reproductive phase, (21-wks)</td>
<td>8.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver (mg PFOS/g) at study termination (21-wks)</td>
<td>4.9</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Measures of PFOS Exposure</th>
<th>OFFSPRING</th>
<th>NOAEL</th>
<th>LOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yolk (mg PFOS/mL)</td>
<td>62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^A\) LOAEL was based on a decrease in the 14-d old survivability of offspring

All concentrations are reported on a wet weight basis
## Mallard Definitive Reproduction Study

### Final NOAEL & LOAEL Values

<table>
<thead>
<tr>
<th>Measures of PFOS Exposure</th>
<th>NOAEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADULT MALES</strong></td>
<td></td>
</tr>
<tr>
<td>Dose (mg PFOS/kg body weight)</td>
<td>10</td>
</tr>
<tr>
<td>ADI (mg/PFOS/kg body weight per day) over 21-wks</td>
<td>1.5</td>
</tr>
<tr>
<td>Serum (μg PFOS/ml) at study termination (21-wks)</td>
<td>87</td>
</tr>
<tr>
<td>Liver (μg PFOS/ml) at study termination (21-wks)</td>
<td>61</td>
</tr>
<tr>
<td><strong>ADULT FEMALES</strong></td>
<td></td>
</tr>
<tr>
<td>Dose (mg PFOS/kg body weight)</td>
<td>10</td>
</tr>
<tr>
<td>ADI (mg/PFOS/kg body weight per day) over 21-wks</td>
<td>1.5</td>
</tr>
<tr>
<td>Serum (μg PFOS/ml) pre-reproductive phase (5-wks)</td>
<td>77</td>
</tr>
<tr>
<td>Serum (μg PFOS/ml) at study termination (21-wks)</td>
<td>17</td>
</tr>
<tr>
<td>Liver (μg PFOS/g) at study termination (21-wks)</td>
<td>11</td>
</tr>
<tr>
<td><strong>OFFSPRING</strong></td>
<td></td>
</tr>
<tr>
<td>Yolk (μg PFOS/ml)</td>
<td>53</td>
</tr>
</tbody>
</table>

^A All concentrations given on a wet weight basis
Derivation of Toxicant Reference Values (TRVs)

- Bird TRVs based on whole-life in vivo studies with bobwhite and mallards
- Mammalian TRVs (mink etc) based on pup weight reduction in rats
- Application of uncertainty factors
## Uncertainty Factors for a Generic Trophic Level 4 Predator Exposed to PFOS

US EPA Great Lakes Initiative (GLI) methods

<table>
<thead>
<tr>
<th>UNCERTAINTY FACTORS (UF)</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-taxon Extrapolation ($U_{FA}$)</td>
<td>6</td>
</tr>
<tr>
<td>Exposure Duration ($U_{FS}$)</td>
<td>3</td>
</tr>
<tr>
<td>Toxicological Endpoint ($U_{FL}$)</td>
<td>2</td>
</tr>
</tbody>
</table>

UF for TRV

\[ UF = (6 \times 3 \times 2) = 36 \]
Derivation of Uncertainty Factors to Calculate a Predicted No Effect Concentration (PNEC) for Avian Species Exposed to PFOS

OECD methods

- Final uncertainty factor (UF) based on:
  - Chronic reproduction studies conducted with two avian species  UF= 30
  - NOAEL values were not determined for the most sensitive toxicological endpoint in bobwhite quail.  UF = 2
- UF = 30 x 2 = 60
# Avian Threshold Doses for PFOS

<table>
<thead>
<tr>
<th>Threshold Dose</th>
<th>Average Daily Intake (mg PFOS/kg/d)</th>
<th>Serum (μg PFOS/ml)</th>
<th>Liver (μg PFOS/g, wet wt)</th>
<th>Egg Yolk (μg PFOS/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOAEL</td>
<td>0.77</td>
<td>35</td>
<td>21</td>
<td>62</td>
</tr>
<tr>
<td>TRV</td>
<td>0.021</td>
<td>1.0</td>
<td>0.6</td>
<td>1.7</td>
</tr>
<tr>
<td>PNEC</td>
<td>0.013</td>
<td>0.6</td>
<td>0.35</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- **Threshold dose for each end point is based on the geometric mean of female and male values.**
- **The LOAEL based on the 10 ppm PFOS treatment in the bobwhite reproduction study.**
- **Average daily intake in units of mg PFOS/kg body weight per day**
- **TRV calculation based on an overall uncertainty factor (UF) of 36**
- **PNEC calculation based on an overall uncertainty factor (UF) of 60**
Derivation of a NOAEL Water Concentration: PFOS/Birds
Derivation of Safe Water Concentrations for the Protection of Wildlife

\[ WV = \frac{TD}{UF \times BAF} \]

- \( WV \) = Wildlife Value in ng PFOS per liter (ng/L)
- \( TD \) = Threshold dose (mg PFOS/kg bw/day)
- \( UF \) = Uncertainty Factor
- \( BAF \) = BCF x BMF x food consumption
# Biomagnification Factor for PFOS in Avian Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Feed (ug PFOS/g)</th>
<th>Liver (ug PFOS/g)</th>
<th>BMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mallard</td>
<td>10</td>
<td>61</td>
<td>6.1</td>
</tr>
<tr>
<td>Quail</td>
<td>10</td>
<td>88</td>
<td>8.8</td>
</tr>
</tbody>
</table>

**Geometric mean**: 7.3

- BMF values calculated from the dietary chronic studies.
- Geometric mean of mallard and bobwhite quail BMFs used in the calculation of wildlife values. **BMF = 7.3**
- All measured values reported on a wet weight basis.
Accumulation of PFOS by birds from water

![Diagram showing the accumulation of PFOS from water to food to threshold dose.]

- BAF: 14,556
- BCF: 1,994 *
- BMF: 7.3

* BCF based on geometric mean of rainbow trout (BCF=1,100) and bluegill (BCF=3,614)
Effects Ranges: Birds/Water

3,797 ng PFOS/L – Lethal to Adults

1,725 ng PFOS/L – Subtle effects on testes without any effects on survival, growth or reproduction of quail (LOAEL)

TRV: 50 ng PFOS/L – No effects, includes safety factor of 36 (EPA GLI)

PNEC: 30 ng PFOS/L – No effects, includes safety factor of 60 (OECD)
Assessment of Current Concentrations of PFOS

• Water concentrations compared to:
  – Protection of aquatic life
  – Protection of predatory birds and mammals

• Tissue concentrations
  – Blood
  – Liver
  – Egg
Bird Eggs (N = 60)

**Species:**
Cormorant, Skua, Herring Gull, Great Horned Owl, Adelie Penguin, Caspian Tern, Guillemot, Tree Swallow, Ring Billed Gull

**Locations:**
Michigan, Antarctica, Canada, Sweden, Faroe Islands, Poland, Germany, Italy
Bird Egg

Minimum = 0.008
Maximum = 3.35
Geomean = 0.127

MOS
Minimum = NIL (0.51)
Geomean = 13.38

Exceedence
Cormorant, MI
G.H. Owl, MI
Caspian, Tern MI
Bird Liver (N = 219)

Species:

Locations:
USA:  Or, TX, MT, CA, IL, LA, MO, OH, SC, FL, NC
Poland, Germany, Italy, Japan, Korea, Canada, Greenland, Faroe Islands, Antarctica
Bird Liver

Minimum = 0.001
Maximum = 1.740
Geomean = 0.0697

MOS
Minimum = NIL (0.34)
Geomean = 8.61

Exceedence
Bald Eagle, MI
B. Pelican, MS
C. Loon, NC
R.T. Loon, NC
B.B. Gull, NC
G. Egret, FL
B.C.N.H. ,CA
Osprey, FL
Cormorants, Japan

PFOS (mg/kg ww)

N=219
TRV= 0.6
Bird Serum/Plasma (N = 61)

**Species:**
Bald Eagle, Laysan Albatross, Black-footed Albatross, Cormorant
Herring Gull, Sea Eagle

**Locations:**
USA: Midway Islands, SC, MI, MN, WI, AL
Italy

*Only Serum or Plasma data used*
Bird plasma

Minimum = 0.001
Maximum = 2.57
Geomean = 0.108

MOS
Minimum = NIL (0.38)
Geomean = 8.98

Exceedence
Bald Eagles
AL, WI, SC

PFOS (mg/kg, ww)
Water Data (N = 357)

**Types:**
Surface water, rain water, freshwaters, marine waters

**Locations:**
USA: FL AL GA TN

Japan, Canada, S. Korea, Sweden, Finland, Iceland, Faroe Islands, Denmark, Norway
Water vs. Bird TRV

Minimum = 0.00004
Maximum = 2210
Mean = 17.87

MOS
Minimum = NIL (0.022)
Mean = 2.80

Exceedence
FL, AL
Lake Ontario, Canada

TRV = 50.0
Concentrations of PFOS & PFOA in Lake Shihwa, Korea
General Conclusions Water/Birds

- Concentrations less than 100 ng PFOS/L pose no environmental hazard to birds

- Values greater than 1,000 ng PFOS/L would require site-specific assessments, including sampling to confirm exposures and population-level effects to birds or biomarkers

- Concentrations greater than 5,000 ng PFOS/L are likely to cause adverse effects to fish-eating birds
General Conclusions

• Concentrations in water or tissue are generally less than the thresholds
• Thresholds are exceeded only in a few industrial areas
• Thresholds are conservative (protective) such that exceedences do not necessarily indicate the potential for population level effects
Questions ????????
Thank You

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