Endocrine Disrupting Chemicals in King County Surface Waters – Survey Results

Deb Lester, Richard Jack, Dana Walker and Fran Sweeney
King County Department of Natural Resources and Parks
Overview

• Overview of EDC issue and associated challenges
• Purpose of Survey
• Survey Design and Methods
• Results
• Conclusions and Discussion
Endocrine Disrupting Chemical - Definition

• “An external compound that interferes with or mimics natural hormones in the body that are responsible for the maintenance, reproduction, development and/or behavior of an organism” (EPA 1997)
EDC’s - Why the increased concern?

• 1996 publication of “Our Stolen Future” - increased public awareness;

• Reports of feminization/altered reproduction of fish downstream of STPs in Europe and US;

• 2002 USGS survey detected EDCs or pharmaceuticals in 80% of nationwide surface waters tested;

• Increasing scientific literature linking EDCs with effects on fish, other aquatic life, and humans;

• Altered reproductive status of English Sole observed in Elliott Bay (NOAA and WDFW).
EDCs represent wide variety of household and industrial compounds

- Natural and Synthetic Hormones
- Pesticides
- Metals
- Industrial Chemicals
- Personal Care Products
Examples of Some EDCs

**Industrial/Household Chemicals**
- 4-Nonylphenol
- Bisphenol-A
- PBDEs
- PCBs, Dioxins
- Phthalates
- Parabens

**Sex and Steroidal Hormones**
- Natural and synthetic hormones (e.g., estrogen, ethinylestradiol)

**Pesticides**
- Atrazine
- Carbofuran
- Vinclozolin
- Endosulfan, Lindane
- DDT, DDE
- Aldicarb

**Metals**
- Hg, Cd, Pb, As, Tributyltin
Pharmaceuticals and Personal Care Products vs. EDCs

- PPCPs and EDCs not synonymous;
- Subset of PPCPs are known EDCs (synthetic hormones);
- Primary sources - municipal and hospital effluent;
- Examples of PPCPs include:
  - human and veterinary drugs, diagnostic agents
  - antibacterial compounds, surfactants, other compounds in soap and shampoo and consumer products
EDCs - Potential Ecological Effects

• Reproductive,
• Developmental,
• Abnormalities,
• Immune response,
• Behavior, etc.
EDC Effects- Vitellogenin Induction

- VTG - protein precursor to egg production in **female** fish;
- EDC exposure induces VTG in **male** fish;
- Depressed VTG in female fish exposed to EDCs;
- Ecological relevance unclear; potential stressor.
EDC Effects – Skewed Sex Ratio

White Sucker

![Graph showing sex ratio upstream and downstream of WWTP effluent](image)

**Endocrine-Active Wastewater Constituents in Boulder Creek**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Concentration</th>
<th>Endocrine Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>17β-Estradiol</td>
<td>2.4 ng/L</td>
<td>Estrogenic</td>
</tr>
<tr>
<td>17α-Estradiol</td>
<td>24 ng/L</td>
<td>Estrogenic</td>
</tr>
<tr>
<td>Estradiol</td>
<td>3.1 ng/L</td>
<td>Estrogenic</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>5.6 ng/L</td>
<td>Estrogenic</td>
</tr>
<tr>
<td>4-Nonylphenol</td>
<td>240 ng/L</td>
<td>Estrogenic</td>
</tr>
<tr>
<td>Total</td>
<td>200 ng/L</td>
<td></td>
</tr>
<tr>
<td>Nonylphenoxyethoxycarboxylates</td>
<td>200 ng/L</td>
<td></td>
</tr>
</tbody>
</table>

* Murphy et al. 2003 and Larry Barber, pers. comm.
Challenge of Evaluating EDCs

- Variety of chemical classes,
- “Standard” analyses not developed for some compounds,
- Low analytical detection limits required,
- Chemical potencies vary significantly,
- Complexity of hormonal effects,
- Evidence of synergism.
King County EDC Surface Water Survey
Purpose of Surface Water Survey

• Determine if EDC’s present in KC surface waters;
• Better understand issue and magnitude of any potential problem;
• If detected, determine general spatial distribution – Is there an obvious area/chemical of concern?
• Need for KCEL to develop capability to analyze these compounds;
• Use data to guide future monitoring.
• Not intended to provide a comprehensive assessment of EDCs in surface waters.
“New” Compounds Evaluated

**Hormones**
- Estrone (E1), Ethynylestradiol (EE2), Estradiol (E2), Methyltestosterone, Progesterone and Testosterone;

**Plasticizers**
- Phthalates (7), Bisphenol A (BPA);

**Surfactants**
- Total 4-Nonylphenol (NP);

**Pesticide**
- Vinclozolin.
Surface Water Sampling Locations

- **Stream locations** – 63 (42)
- **Lake locations** – 25
  - Lake Union - 3
  - Lake Washington - 11
  - Lake Sammamish - 11
- **Marine locations** - 5
  - Multiple depths
- In general, samples collected quarterly
- Additional EDC data associated with other studies also included (Sammamish River, Snoqualmie River and smaller streams)
Storm Water Samples

- Limited samples collected as part of 2 separate efforts;
  - Evergreen Point Floating Bridge (SR 520) (3 downspouts);
  - 4 discharges into Sammamish River (Redmond area);
- All samples 100% storm water – not mixed with surface waters.
Results – General Overview

- Of 16 compounds analyzed, 11 detected at least once; 5 never detected (estrone, progesterone, testosterone, methyltestosterone and vinclozolin);

- Concentrations of most compounds highest in stormwater;

- Highest frequency of detection (FOD) and levels of BPA, NP, EE2 and E2 detected in streams/rivers.

- Blank contamination problem for phthalates, BPA and NP; limited data availability;
Weather Influence?

• Some compounds detected in streams at higher levels and greater FOD during wet and dry conditions:
  – Wet - NP, BPA
  – Dry - E2, EE2

• However - Sample size for wet/dry not balanced, greater number of samples collected during dry weather.
## Surface Water– Frequency of Detection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Marine</th>
<th>Lakes</th>
<th>Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisphenol A</td>
<td>*0% (n=6)</td>
<td>*8.4% (n=47)</td>
<td>*26% (n=98)</td>
</tr>
<tr>
<td>Total 4-Nonylphenol</td>
<td>*3.2% (n=31)</td>
<td>*5.6% (n=71)</td>
<td>*16.2% (n=130)</td>
</tr>
<tr>
<td>Ethynylestradiol</td>
<td>0% (n=48)</td>
<td>22% (n=83)</td>
<td>26% (n=183)</td>
</tr>
<tr>
<td>Estradiol</td>
<td>16.7% (n=48)</td>
<td>11% (n=83)</td>
<td>35.9% (n=184)</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl) Phthalate</td>
<td>*100% (n=1)</td>
<td>*100% (n=3)</td>
<td>*100% (n=19)</td>
</tr>
</tbody>
</table>

* Blank qualified data not included in summary statistics
## Surface Water- Max Concentrations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Marine</th>
<th>Lakes</th>
<th>Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisphenol A (µg/L)</td>
<td>ND (MDL 0.095) (n=6*)</td>
<td>0.046 (n=47*)</td>
<td>0.934 (n=98)</td>
</tr>
<tr>
<td>Total 4-Nonylphenol (µg/L)</td>
<td>0.25 (n=31*)</td>
<td>0.149 (n=71*)</td>
<td>0.836 (n=130)</td>
</tr>
<tr>
<td>Ethynylestradiol (ng/L)</td>
<td>ND (MDL 0.3) (n=48)</td>
<td>0.9 (n=83)</td>
<td>4.0 (n=183)</td>
</tr>
<tr>
<td>Estradiol (ng/L)</td>
<td>ND (MDL 0.2) (n=48)</td>
<td>0.6 (n=83)</td>
<td>1.1 (13) (n=184)</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl) Phthalate (µg/L)</td>
<td>40.5 (n=1*)</td>
<td>13.1 (n=3*)</td>
<td>15.8 (n=19*)</td>
</tr>
</tbody>
</table>

ND – Not detected above the method detection limit (MDL)
* Blank qualified data not included in summary statistics
## Stormwater- Frequency of Detection

<table>
<thead>
<tr>
<th>Parameter</th>
<th>520 Bridge Runoff</th>
<th>Sammamish Stormwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisphenol A</td>
<td>100% (n=11)</td>
<td>*100% (n=6)</td>
</tr>
<tr>
<td>Total 4-Nonylphenol</td>
<td>73% (n=11)</td>
<td>50% (n=16)</td>
</tr>
<tr>
<td>Ethynylestradiol</td>
<td>Not Measured**</td>
<td>100% (n=16)</td>
</tr>
<tr>
<td>Estradiol</td>
<td>Not Measured**</td>
<td>81% (n=16)</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl) Phthalate</td>
<td>*100% (n=7)</td>
<td>*0% (n=0)</td>
</tr>
</tbody>
</table>

* Blank qualified data not included in summary statistics
** Matrix interference, not analyzed
### Stormwater - Max Concentrations

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<thead>
<tr>
<th>Parameter</th>
<th>520 Bridge Runoff</th>
<th>Sammamish Stormwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bisphenol A ($\mu g/L$)</td>
<td>9.14 (n=11)</td>
<td>1.57 (n=6)*</td>
</tr>
<tr>
<td>Total 4-Nonylphenol ($\mu g/L$)</td>
<td>44.2 (n=11)</td>
<td>8.9 (n=16)</td>
</tr>
<tr>
<td>Ethynylestradiol (ng/L)</td>
<td>Not Measured**</td>
<td>5.9 (n=16)</td>
</tr>
<tr>
<td>Estradiol (ng/L)</td>
<td>Not Measured**</td>
<td>1.2 (n=16)</td>
</tr>
<tr>
<td>Bis(2-ethylhexyl) Phthalate ($\mu g/L$)</td>
<td>20.3 (n=7)*</td>
<td><em>ND (n=0)</em>**</td>
</tr>
</tbody>
</table>

* Blank qualified data not included in summary statistics  
** Matrix interference, not analyzed  
***All samples blank qualified
Locations Where Bisphenol A Detected in Surface Waters
Bisphenol A – Literature Based Effect Values
Locations Where Nonylphenol Detected in Surface Waters
Nonylphenol – Literature Based Effect Values
Locations Where Estradiol Detected in Surface Waters
Ethynylestradiol – Literature Based Effect Values
Locations Where Ethynylestradiol Detected in Surface Waters
Estradiol – Literature Based Effect Values
Surface water locations where concentrations of at least one of these three chemicals (NP, E2, EE2) may warrant additional investigation.
Non-Detected Chemicals

• Analytical detection limits compared to literature based effect values:
  – Estrone – all toxicity values below MDLs;
  – Methyltestosterone - most toxicity values above, a few below;
  – Vinclozolin - all toxicity values above MDLs;
  – Testosterone - all toxicity values above MDLs:
  – Progesterone - limited toxicity data to evaluate.
Conclusions

• 11 of 16 “new” compounds detected;
• Generally high spatial variability - however, most compounds detected in each water type – suggesting multiple sources;
• Concentrations were relatively low; many below most significant effect levels identified in literature;
• Greatest concern – EE2 and NP in streams.
Conclusions

• Limited detections in vicinity of WW outfall;
• Highest levels of most compounds detected in undiluted stormwater – suggests significant source to surface waters;
• Most concentrations similar to those found by others in North America.
Questions???

Deborah.Lester@metrokc.gov
Richard.Jack@metrokc.gov
EDCs- How do they reach the environment?

- Natural/synthetic hormones excreted and discharged via wastewater;
- Some household products contain EDCs and are washed down the drain;
- WW treatment not designed to remove some EDCs;
- WW treatment can increase toxicity of some EDCs;
- Pesticides and other EDCs transported to environment via stormwater;
- Wildlife/Agriculture – animals source of hormones to surface waters.
Analytical Methods

- Required KCEL to identify and develop expertise in EDC analysis;
- Two types of analytical methods used – GC/MS and an immunoassay (ELISA) for estradiol and ethynylestradiol;
- Detection limits decreased over the course of the monitoring period;
- Matrix interference was a problem for some stormwater samples.