Trends and Perspectives of Ecological Risk Assessments for Dioxin-Like Compounds in the Great Lakes Basin

Efficacy of Predicted vs. Measured Exposure and Effects Assessments

International Conference on Ecotoxicology
Trends and Perspectives
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Wisla, Poland
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Chair Professor at Large Dept. Biology and Chemistry City University of Hong Kong Concurrent Professor School of the Environment Nanjing University
Objectives of presentation

- Present historical, geographical, and ecological background of Great Lakes Basin
- Discuss risk assessment as a decision making tool
- Describe the site-specific multiple lines of evidence approach
- Compare the goals and outcomes of the site-specific approach to ERA’s completed for the same locations
The lakes contain about 23,000 km³ of water. Covers a total area of 244,000 km². The Great Lakes are the largest system of fresh, surface water on earth, containing roughly 18 percent of the world supply. Outflows from the Great Lakes are relatively small (less than 1 percent per year).
Ecological Risk

The likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors

United States Environmental Protection Agency
A Risk Assessment Provides:

- Clear and consistent risk characterization of valued endpoints
- Systematic means of quantifying, comparing and prioritizing risks (and solutions)
- Basis for risk-benefit and risk management and sustainable development decisions
Exposure characterization

Effect characterization

Exposure characterization

Risk Characterization

Problem Formulation and Hazard Identification

Laboratory toxicological studies

Extrapolation methods

Measurements of exposure and dose

Epidemiology and population-level studies

Research needs identified

Development of regulatory options

Identification of mitigation options

Evaluation of public health, environmental, economic, social, and political consequences of regulatory options

Regulatory decision

Risk communication

Planning
Field Studies in Support of a Baseline ERA

Aquatic Toxicology Laboratory
Michigan State University

Dr. Matthew Zwiernik
Dr. John Giesy
Jeremy Moore
Dusty Tazelaar
Tim Fredricks
Sarah Coefield
Rita Seston
Mike Fales
Lori Williams
David Hamman
Emily Koppel
Melissa Palmer
The MSU-ATL Approach

- Answer the question of ecological risk directly with site-specific data
- Select surrogate or sentinel species when possible
- Utilize multiple lines of evidence
- Conduct the process in an open and transparent manner
- Involve stakeholders and utilize local assets
Tittabawassee River Ecological Studies

- Song birds
- Fish eating birds
- Raptors
- Migratory waterfowl
- Mink
Multiple lines of evidence

- Dietary exposure assessment
- Tissue based exposure assessment
- Laboratory Dose response
- Population health measurements

Exposure X Effects = RISK

Population Health and Sustainability

Risk to Population Health

Exposure

Toxicity

Frequency

Concentration
Uncertainty vs. Data

More Uncertainty

Protective

Assumptions

Data

More Certainty

Predictive

Assumptions

Data
Dietary exposure

- Stomach content
- Scat analysis
- Prey Remains
- Visual Observations
Dietary exposure

Tittabawassee River Mink
- Fish: 52%
- Crayfish: 19%
- Muskrat: 8%
- Small Mammals: 8%
- Amphibians: 9%
- Vegetation: 4%

Tittabawassee River Kingfisher
- Fish: 82%
- Crayfish: 13%
- Amphibians: 5%
Sampling Dietary Items
### Dietary exposure

<table>
<thead>
<tr>
<th>Prey item</th>
<th>95% UCL TEQ\textsubscript{WHO-mammalian}</th>
<th>conc. (ng/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reference</strong></td>
<td><strong>Target</strong></td>
<td></td>
</tr>
<tr>
<td>Sediment</td>
<td>0.69</td>
<td>14.5 - 714</td>
</tr>
<tr>
<td>Forage fish</td>
<td>0.45</td>
<td>28.8 - 72.4</td>
</tr>
<tr>
<td>Muskrat</td>
<td>0.16</td>
<td>7.79 - 11.9</td>
</tr>
<tr>
<td>Crayfish</td>
<td>0.24</td>
<td>13.2 - 96.7</td>
</tr>
<tr>
<td>Small mammals</td>
<td>1.69</td>
<td>75.6 - 115</td>
</tr>
<tr>
<td>Vegetation</td>
<td>0.81</td>
<td>1.84 - 4.27</td>
</tr>
<tr>
<td>Amphibian</td>
<td>0.64</td>
<td>16.9 - 119</td>
</tr>
</tbody>
</table>
Dietary exposure for Mink

LOAEL to NOAEL HQ of 95% UCL Dietary Exposure

Hazard Quotient

Tittabawassee River

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

Sanford Smith’s Crossing Tittabawassee Twp. Park Freeland Festival Park Imerman Park
Tissue Based Exposure

- Eggs
Tissue Based Exposure

- Eggs
- Plasma
Tissue Based Exposure

- Eggs
- Plasma
Tissue Based Exposure

- Eggs
- Plasma
Tissue Based Exposure

- Eggs
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- Plasma
Tissue Based Exposure

- Eggs
- Plasma
Tissue Based Exposure

- Eggs
- Plasma
Tissue Based Exposure

- Eggs
- Plasma
- Tissues
Tissue Based Exposure
Mink

Mink liver TEQ, WHO-mammalian (ng/kg)

- Sanford
- Chippewa Nature Center
- Tittabawassee
- Upstream Smiths Crossing
- Tittabawassee Township Park
- Freeland Festival Park
- Imerman Park
Exposure Assessment Comparison
Mink

Liver and Dietary HQs (TEQ)

- **Dietary Based HQs**
- **Liver Based HQs**

HQ

- Sanford
- Chippewa Nature Center
- Tittabawassee Upstream
- Smiths Crossing
- Tittabawassee Township Park
- Freeland Festival Park
- Limerik Park
# Population Health
## Mink

## Mink Morphological Data

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>N=20</td>
<td>N=14</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Body Weight (Male)</strong></td>
<td>872 g</td>
<td>917 g</td>
</tr>
<tr>
<td><strong>Body Weight (Female)</strong></td>
<td>482 g</td>
<td>517 g</td>
</tr>
<tr>
<td><strong>Body Length (Male)</strong></td>
<td>56.3 cm</td>
<td>57.5 cm</td>
</tr>
<tr>
<td><strong>Body Length (Female)</strong></td>
<td>18.7</td>
<td>19.6</td>
</tr>
<tr>
<td><strong>Age (Male)</strong></td>
<td>1.8 yrs</td>
<td>2.2 yrs</td>
</tr>
<tr>
<td><strong>Age (Female)</strong></td>
<td>2.3 yrs</td>
<td>2.7 yrs</td>
</tr>
<tr>
<td><strong>Liver Weight (Male)</strong></td>
<td>51.3 g</td>
<td>51.7 g</td>
</tr>
<tr>
<td><strong>Liver Weight (Female)</strong></td>
<td>26.4 g</td>
<td>28.7 g</td>
</tr>
<tr>
<td><strong>Nutritional Status</strong></td>
<td>1.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

(3=excellent, 1=poor)

No significant difference between sites at (p=0.05)
Additional Parameters

- Brain weight
- Liver wt. to brain wt. ratio
- Baculum length
- Male to female ratio
- Placental scars
- Histology
  - Liver
  - Kidney
  - Brain
  - Jaw

No significant difference between sites at p=0.05
### Population Health Mink

#### Habitat Suitability and Abundance

<table>
<thead>
<tr>
<th>Habitat Suitability</th>
<th>Pine River</th>
<th>Chippewa River</th>
<th>Tittabawassee River</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% = Excellent</td>
<td>70%</td>
<td>59%</td>
<td>51%</td>
</tr>
<tr>
<td>0% = Poor</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| # Mink / km | 1.46 | 0.44 | 0.96 |

Study areas have appropriate habitat and support mink year round.
Goal: To provide decision makers with the information necessary to make informed decisions
TITTABAWASSEE RIVER
AQUATIC ECOLOGICAL RISK ASSESSMENT

POLYCHLORINATED DIBENZO-P-DIOXINS
POLYCHLORINATED DIBENZOFURANS

Submitted to: Michigan Department of Environmental Quality,
Remediation & Redevelopment Division,
Saginaw Bay District Office

October 2003

Submitted by: Galbraith Environmental Sciences LLC.,
Newfane, Vermont
Dietary exposure of the Red Fox and American Robin on the Kalamazoo River

![Graph showing predicted versus measured plant PCB concentrations in mg/kg. The graph compares the predicted values (3.5) with the measured values (0.000018).]
Red Fox and American Robin Exposure on Kalamazoo River

<table>
<thead>
<tr>
<th>Origin of Plant Tissue</th>
<th>Red Fox HQ</th>
<th>Robin HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted</td>
<td>85</td>
<td>42</td>
</tr>
<tr>
<td>Re-predicted</td>
<td>42</td>
<td>23</td>
</tr>
<tr>
<td>Site specific</td>
<td>0.7-0.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Hazard quotient (HQ) decreases with use of site-specific information the greatest change was due to reductions in uncertainty.
Tittabawassee River
Modeled vs. Measured:

- Predicted invertebrates: 705 TEQs (ng/kg, ww)
- Measured terrestrial invertebrates: 41.9 TEQs
- Measured earthworms: 76.5 TEQs
Modeled vs. Measured: 100 fold decrease

TEQs (ng/kg, ww)

12000
10000
8000
6000
4000
2000
0

predicted small mammals
measured small mammals

12063
83.4
Mink dietary exposure on the Tittabawassee River

Mink hazard quotient (HQ) decreases with use of site-specific information

<table>
<thead>
<tr>
<th>Diet</th>
<th>Toxity Reference Value</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumed - 100% fish</td>
<td>1 ng/kg</td>
<td>78</td>
</tr>
<tr>
<td>Site specific - 52% fish, 19% muskrat, 9% vegetation, 8% crayfish, 8% small mammal, 4% amphibian</td>
<td>1 ng/kg</td>
<td>44</td>
</tr>
<tr>
<td>Site specific</td>
<td>54 ng/kg</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Uncertainty vs. Data

More Uncertainty

Protective

Assumptions

Data

More Certainty

Predictive

Population Health Threshold
Summary

- Wildlife are key indicators of ecological health
- Wildlife integrate stressor exposure and accumulation over time and space (bioavailability)
- The selection of surrogate or sentinel species can streamline the process
- Site-specific, multi-year, multi-line of evidence studies effectively reduce uncertainties
ERAs move from protective to predictive as uncertainty is reduced.

Ecological risk assessments provide for a systematic means of quantifying, comparing and prioritizing risks, solutions.

Ecological risk assessments can be effective tools for risk-benefit, cost-benefit and sustainable development decisions.
Thank You

Questions?

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