Modeling Dietary Human Exposures to Mercury and Methylmercury Using a Probabilistic Source-to-Dose Approach

Presented at U.S. EPA Region 2 Modeling Seminar
Evaluating Fish Consumption Guidelines: A Qualitative and Quantitative Approach for High Risk Ethnic Groups
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Presentation Overview

• Brief overview of MENTOR-4M*
  • A probabilistic framework for source-to-dose exposure and risk assessments; individual-based and population-based options
  • Dynamic linking of biologically-based modules with environmental, microenvironmental, and human activity modules

• A case study of modeling human exposures to Hg and MeHg through dietary pathway
  • Required Databases: food consumption patterns, food residue data, auxiliary data, etc.
  • 10,000 “virtual individuals” in Oswego County, New York
  • PBTK modeling for estimating target tissue concentrations of MeHg
  • Comparison with available biomarker measurements (NHANES, NHEXAS)

*Modeling ENvironment for TOtal Risk studies (MENTOR) for Multiple co-occurring contaminants and Multimedia, Multipathway, Multiroute exposures (4M)
Modeling ENvironment for TOtal Risk Studies (MENTOR): A Probabilistic Framework for Source-to-Dose Modeling

Figure adapted from Furtaw, E.J. 2001. An overview of human exposure modeling activities at the USEPA’s National Research Exposure Laboratory. Toxicology and Industrial Health 17:302-314.
Some Issues and Uncertainties Related to Dietary Mercury Exposure/Dose Modeling

Environmental Modeling
- Atmospheric emissions
  - Natural: Forest fires, volcanoes
  - Industrial: Power plants
- Deposition to aquatic ecosystem
- Ground water transport
  - Natural & industrial sources

Human Activity Modeling
- Population Diet Uncertainties:
  - Amounts consumed
  - Fish species consumed
  - Fish preparation etc.

Regional Economy Uncertainties:
- Local vs. imported fish
- Pricing and availability
- Processing, storage etc.

Season Uncertainties:
- Fish species
- Fish maturation
- Fish size etc.

PBTK & BBDR Modeling
- Absorption, Distribution Metabolism, Elimination & Toxicity (ADMET) Modeling Uncertainties:
  - Age, gender, lifestyle differences
  - Physiological variability
  - Physicochemical and biochemical variabilities
  - Health status, activities
  - Pregnancy/nursing
  - Genetic susceptibilities

Dietary Ingestion

Fish Uptake of MeHg

Target Tissue Dose
- Brain
- Kidney
- Breast milk
- Fetus/fetal brain

Toxicity/Adverse Effect
- Neurological
- Renal
- Cardiovascular
- (Genomic/Cytomic)
A Case Study of Modeling Human Exposure to Hg and MeHg through Dietary Pathway for the General Population in Oswego County, NY

10,000 “virtual individuals” were generated to match the demographic characteristics of Oswego County, NY. (Data source: US Census Survey 2000)
## Data Sources Used for Dietary Exposure Modeling

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<tr>
<th>Type of Data</th>
<th>Database</th>
<th>Source</th>
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<td><strong>Food Consumption Patterns</strong></td>
<td>Continuing Survey of Food Intakes by Individuals (CSFII) 1994-98</td>
<td>USDA</td>
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<td>National Health &amp; Nutrition Examination Survey (NHANES) Annual Data</td>
<td>CDC</td>
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<td><strong>Food Residue</strong></td>
<td>Total Diet Study (TDS) 1991-2003</td>
<td>USFDA</td>
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<td>National Marine Fisheries Survey (NMFS) 1978</td>
<td>NOAA</td>
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<td>Mercury in Fish Monitoring Program 1990-2003</td>
<td>USFDA</td>
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<td>National Listing of Fish Advisories</td>
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<td>Great Lakes Fish Consumption Advisories</td>
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<td><strong>Mapping of Food Consumption to Food Residue</strong></td>
<td>Food Commodity Intake Database (FCID)</td>
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<td>Mapping Profile of TDS Foods to CSFII Food Codes</td>
<td>USFDA</td>
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Example: MeHg Concentrations for Selected Species of Fish Most Commonly Consumed in the U.S. Commercial Seafood Market

Long-Term Dietary Exposure Modeling

• Food consumption surveys (e.g. CSFII) only provide dietary consumption rates for short-term periods (24-h recall data)
  • Underestimate lower percentiles of dietary intake distribution
  • Overestimate higher percentiles of dietary intake distribution
• Food frequency questionnaires (e.g. NHANES data from 1999 onwards) provide eating patterns over a longer time period (such as 30 days)
  • Food consumption details are not collected (e.g., quantity, ingredients, and preparation method)
• The following approach was used to bridge data from above two surveys for estimating longitudinal (usual) dietary intake distribution [Tran et. al., 2004]
  • Estimating distributions of fish/shellfish intake per eating occasion
  • Estimating month-long (30 day average) daily fish/shellfish intake
Fish Intake Distributions for Selected Fish Species for Two Susceptible Populations in U.S.:
women 16-49 yrs of age (child-bearing age) and children 1-5 yrs of age

Fish Consumption Frequencies* of Selected Fish Species for Two Susceptible Populations in U.S.: women 16-49 yrs of age (child-bearing age) and children 1-5 yrs of age

Data Source: CDC’s NHANES 2001-2002

* Reported as total number of consuming occasions in past 30 days
Cumulative MeHg Dietary Exposure Distributions for Two Susceptible Groups of Oswego County, NY Calculated by the MENTOR-4M Population Based Model
PBTK* modules of MENTOR incorporate age/gender specific parameter distributions and are designed to support probabilistic assessments of cumulative and aggregate exposures/doses.

*PBTK: Physiologically-Based Toxicokinetics
Cumulative Distributions of MeHg Target Tissue Concentrations for the Susceptible Group of Women in Childbearing Age in Oswego County, NY Calculated by the MENTOR-4M Population Based Model
Comparison of Predicted and Observed Cumulative Distributions of MeHg Blood Concentrations from MENTOR-4M Calculations* and NHANES-2002 Measurements

* MENTOR-4M calculations were conducted for the two susceptible age groups (women 16-49 yrs of age (child-bearing age) and children 1-5 yrs of age) in Oswego County, NY
Comparison of Predicted and Observed Cumulative Distributions of MeHg Hair Concentrations from MENTOR-4M Calculations* and NHEXAS-Region V Measurements

* MENTOR-4M calculations were conducted for the two susceptible age groups (women 16-49 yrs of age (child-bearing age) and children 1-5 yrs of age) in Oswego County, NY
Conclusions and Discussion

• The case study of dietary exposure to Hg and MeHg showed that
  - The one-month simulation results provide more reliable estimates for the upper and lower tails of the MeHg dietary intake distribution
  - The predicted distributions of MeHg biomarker (blood and hair) concentrations calculated from MENTOR-4M are comparable to the observed ones (NHANES-2002, NHEXAS-V)

• On-going/future efforts
  - Assemble/organize and evaluate available (geo)databases in different scales (from national to regional/local)
  - Perform focused case studies to characterize
    o Exposures of the general population
    o Exposures of selected subpopulations (e.g. Chinese residents in NYC)
Acknowledgements

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