Probabilistic Approach to Deriving Human Health-Based Water Quality Criteria (HHWQC)

ARCADIS
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Goals today

• Typical process for deriving HHWQC
• Introduction to probabilistic risk assessment (PRA)
  • Defining distributions
  • How does PRA generate distributions of risk
• Using PRA to derive HHWQC
• Critical role of risk management decisions
• Key elements of the ARCADIS PRA Tool
HHWQC: Three Elements

Health Protection Target
(cancer risk or hazard quotient)

Substance Toxicity
(risk specific dose or reference dose)

Exposure Scenario
(water concentration, body weight, intake, bioaccumulation, exposure duration, cooking loss, etc.)

HHWQC
HHWQC: Fundamental Equation to Estimate Risk

- Risk = \( C_w \times (D_I + (F_I \times BAF)) / (B_W \times RSC \times Toxicity) \)
  - \( C_w \) = concentration in water
  - \( D_I \) = drinking water intake
  - \( F_I \) = fish intake
  - \( BAF \) = bioaccumulation factor
  - \( B_W \) = bodyweight
  - \( RSC \) = relative source contribution (only non-cancer)
  - Toxicity = RfD, POD/UF, or 1/CSF

- Also need to consider implicit parameters
  - Relative bioavailability, catch location factor, life history factor, proportion of lipid, cooking loss, exposure duration
## Typical Exposure Scenario

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Value</th>
<th>Location in Range of Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explicit Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bodyweight</td>
<td>70 kg</td>
<td>Near Mean</td>
</tr>
<tr>
<td>Water Intake</td>
<td>2 L/day</td>
<td>Upper End</td>
</tr>
<tr>
<td>Fish Consumption</td>
<td>17.5 g/day</td>
<td>Upper End</td>
</tr>
<tr>
<td>Relative Source Contribution</td>
<td>20%</td>
<td>Arbitrary Floor</td>
</tr>
<tr>
<td><strong>Implicit Parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooking Loss</td>
<td>0%</td>
<td>Minimum Possible</td>
</tr>
<tr>
<td>Exposure Duration</td>
<td>70 years</td>
<td>(Extreme) Upper End</td>
</tr>
<tr>
<td>Exposure Concentration</td>
<td>At HHWQC 100% of the time</td>
<td>Maximum Possible</td>
</tr>
<tr>
<td>Relative Bioavailability</td>
<td>1</td>
<td>Maximum Possible</td>
</tr>
</tbody>
</table>
What is Probabilistic Risk Assessment (PRA)?

• Simply put: It is the same as the typical risk assessment approach, except it uses a distribution of values for the parameters that determine risk
• The result is a distribution of exposure and risk
• The key is in defining and combining the distributions
  • Users do the defining
  • Excel add-ins (@Risk, Crystal Ball) do the combining
Define Distributions

• Based upon data or professional judgment
• State-wide HHWQC should be representative of entire population
• Called probability density functions
• Varying shapes
• Most common (in risk assessment)

- Lognormal
- Normal
- Uniform
- Triangular
How Probabilistic Risk Assessment Creates a Distribution of Risk

- Iterates the standard equation
- Concentration \times (\text{Water Ingestion} + (\text{Fish Ingestion} \times \text{Bioaccumulation})) / \text{Bodyweight} \times \text{Slope Factor} = \text{Cancer Risk}
- After one iteration
How Probabilistic Risk Assessment Creates a Distribution of Risk (cont.)

- Concentration x (Water Ingestion + (Fish Ingestion x Bioaccumulation)) / Bodyweight x Slope Factor = Cancer Risk
- After ten iterations
How Probabilistic Risk Assessment Creates a Distribution of Risk (cont.)

- Concentration $\times$ \((\text{Water Ingestion} + (\text{Fish Ingestion} \times \text{Bioaccumulation})) / \text{Bodyweight} \times \text{Slope Factor} = \text{Cancer Risk}\)
- After one thousand iterations
Using Probabilistic Risk Assessment to Derive HHWQC

• When using PRA, can’t rearrange the equation and solve “backward” for HHWQC corresponding to an allowable risk

• Two approaches:
  • Systematic linear derivation
  • Iterations (trial and error)

• Example of iterations approach
Using Probabilistic Risk Assessment to Derive HHWQC (cont.)

**Input Parameters**
- Cw
- DI, ED, BW, AT
- RBA, CL, RSC, Toxicity
- FI, CLF, LHF, BAF, Lipid

**Output**
- Distribution of Risk

**Change Cw**
- **No**
- **Yes**
  - Allowable Risk at Selected Percentile(s)?
  - HHWQC = Cw
Using Probabilistic Risk Assessment to Derive HHWQC (cont.)

Step 1: Choose initial test value for $C_w (C_{w_1})$. Evaluate risk distribution.
Step 2: Adjust $C_w (C_{w_{0.1}})$. Evaluate risk distribution.
Step 3: Adjust $C_w (C_{w_{0.5}})$. Evaluate risk distribution.
Protecting Different Segments of the Population

- It’s not just about good science
- Need good science plus risk management decisions
- We are all different, making equal protection of everyone impossible
- How does protection vary among different members of a population?
- A hypothetical example using two distributions
  - Fish consumption rate
  - Source of fish
Hypothetical Distributions

• Fish consumption rate
  • 50th percentile = 13 grams/d
  • 95th percentile = 60 grams/d
  • 99th percentile = 175 grams/d

• Source of fish
  • 50th percentile = 0.25 (25%) locally caught
  • 95th percentile = 0.50 (50%) locally caught
  • 99th percentile = 0.95 (95%) locally caught
Other Factors Affecting HHWQC Remain Point Estimates and Conservative

- Duration of exposure (70 years)
- Cooking/preparation loss (zero)
- Water column concentration (always equal to HHWQC)
- Bioaccumulation (fish assumed to be constantly exposed)
- Body weight (average)
- Toxicity factors (upper bound, several safety factors)
Keep in mind that protection is greater (risk is lower) due to conservative toxicity values and exposure assumptions (exposure duration, lack of cooking loss, water concentrations equal to HHWQC).
What if the goal is to protect the 50th percentile at $1 \times 10^{-6}$? But because of the other conservative assumptions any actual risks are much lower.
PRA Calculator for Deriving HHWQC

- Uses the fundamental equations employed by the USEPA to derive HHWQC, including all explicit and implicit parameters
- User may derive HHWQC with either deterministic or probabilistic methods
- Now evaluating fourth beta release of calculator
  - Probabilistic Ambient Water Quality Criteria Calculator (PAWQCC)
- Validation using Florida input distributions and proposed criteria
- Does not contain default policy risk assumptions
  - Risk protection elements – users decide
  - Substance toxicity elements – default to EPA’s IRIS values
  - Exposure elements – users decide
- Characterizes risk for all segments of the population
Real Time Demonstration of PAWQCC

- Requires Excel and @Risk
- @ Risk and PRA primer
- Setting up PAWQCC
- Elements and features of PAWQC
- Example derivation of HHWQC
- Demonstration
Some Closing Reminders

- HHWQC are determined by all the assumptions that affect exposure and risk, not any single assumption.
- PRA allows use of all information (e.g., distributions instead of point estimates) that affect exposure and risk.
- PRA can characterize risk for the whole population.
- PRA better separates risk assessment from risk management than deterministic (point estimate) approaches.
- PRA alone is not sufficient to establish protective and practical HHWQC.
- Risk managers will have to make important risk management decisions.
Imagine the result