AOPs and Regulatory Decisions: Problem Formulation, Development and Acceptance

AOP WORKSHOP 09/04/14
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The views expressed in this presentation are those of the author and do not represent the policy of the U.S. EPA.
So What Is EPA Policy?

- **Science Policy**
  - Defaults, methods, Guidelines
  - *Used when there are data or methodology gaps*
  - Peer reviewed
  - Lots of documentation, which is publicly available

- **Policy based on science**
  - May be set by EPA Executive Level
  - Generally involves regulations or other risk management choices; science is peer reviewed, action involves public comment; May be subject to Federal Advisory Committee Act
  - Lots of documentation; may be docket; publicly available
Examples

- Science policy
  - Cancer Guidelines 2005
  - Set a reference dose for effects which are likely to have a threshold
  - Quantitative adjustment to cancer risk for early life exposure
  - Animal data are relevant to humans unless demonstrated otherwise

These all deal with risk assessment
Risk Assessment

What is Risk Assessment?

A bridge

Risk Management / Risk Assessment Paradigm

Identification of Future Problem, Initiating Event or Public Policy Mandate

Risk Management

Define Risk Management Objectives

Identity and Evaluate Risk Management Options

Risk Management Decision

Implement Option(s)

Develop Measures of Environmental and Public Health Improvement

Monitor Environmental and Public Health Improvement

Reduced Environmental and Public Health Risk

Develop Compliance Assurance Models and Methods

Risk Assessment

Exposure Assessment

Risk Identification Characterization

Define Risk Management Objectives

Identity and Evaluate Risk Management Options

Risk Management Decision

Implement Option(s)

Develop Measures of Environmental and Public Health Improvement

Monitor Environmental and Public Health Improvement

Reduced Environmental and Public Health Risk

Public Health Considerations

Statutory and Legal Consideration

Social Factors

Economic Factors

Political Considerations

Formulate the Problem

Dose-Response Assessment

Hazard Identification

Exposure Assessment

Risk Characterization

Risk Management

Communication

Risk Management
A lot has changed since ‘83

Exposure Science in the 21st Century: A Vision and A Strategy

IPCS FRAMEWORK FOR ANALYSING THE RELEVANCE OF A CANCER MODE OF ACTION FOR HUMANS

World Health Organization

SCIENCE AND DECISIONS
Advancing Risk Assessment

Environmental Decisions in the Face of Uncertainty

Phthalates and Cumulative Risk Assessment
The Tasks Ahead

Toxicity Testing in the 21st Century: A Vision and Strategy

Risk Assessment Forum
Why Do Risk Assessment?

- "... risk assessment should be viewed as a method for evaluating the relative merits of various options for managing risk ..." (Science and Decisions 2009)
- To provide support for decisions to protect public health and the environment.
  - Complex and controversial
  - Risk assessment summarizes the science
TAKE HOME MESSAGE # 1: It’s all about better decisions

- Committee recommends an important extension of the Red Book model—that risk assessment should be viewed as a method for evaluating the relative merits of various options for managing risk rather than as an end in itself.

- Risk assessment should continue to capture and accurately describe what various research findings do and do not tell us about threats to human health and to the environment, but only after the risk-management questions that risk assessment should address have been clearly posed, through careful evaluation of the options available to manage the environmental problems at hand.

Thomas Burke; presentation 09/10
To make risk assessments most useful for risk management decisions, the committee recommends that EPA adopt a framework for risk-based decision-making that embeds the Red Book risk assessment paradigm into a process with initial problem formulation and scoping, upfront identification of risk-management options and use of risk assessment to discriminate among these options.

The Red Book Risk Assessment Paradigm showing by the red dashed lines.
Overarching Considerations

Children’s Environmental Health Protection

Cumulative Risk Assessment

Environmental Justice

Sustainability
Key Considerations for Planning and Scoping

• What decision is to be informed by risk assessment, when is the decision anticipated, and what are the risk management options?

• What legal/statutory requirements affect risk management options and level/type of analysis?

• What other considerations (e.g., environmental justice, life stage, cumulative risk, sustainability) or countervailing risks may influence risk management options and analyses?

• What assessments (e.g., risk, economic) are needed to address decision-making needs?

• What expertise, resources and timelines are available to conduct the assessments(s)?
Problem Formulation

A Generalized Conceptual Model
(adapted from USEPA, 2002; 2003)

<table>
<thead>
<tr>
<th>Sources</th>
<th>Stressors</th>
<th>Exposure Pathways/Routes</th>
<th>Receptors</th>
<th>Endpoints</th>
<th>Risk Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities that generate/release Stressors or types of stressor releases</td>
<td>Chemical, physical or biological agents that cause an effect</td>
<td>Physical processes or interactions by which a stressor is brought into contact with receptor</td>
<td>Populations and/or lifestages exposed to the stressor</td>
<td>Measures of stressor effects or biological systems affected</td>
<td>Metrics by which risk is quantified (e.g., disease cases, hazard quotients, magnitude of effect)</td>
</tr>
</tbody>
</table>
Conceptual Model
Nitrosamines in Drinking Water

Sources
Pathways/
Drinking water disinfection

Stressors
Variable mixture nitrosamines; dependent on treatment & source water.

Exposure
Routes
Ingestion of nitrosamine mixture in drinking water

Receptors
Consumers of drinking water; includes sensitive populations & life stages

Endpoints
Cancer, any site or type

Risk Metrics
Combined risk of cancer from subset nitrosamines in mixture
How high the bar?

Several continua

- Increasing cost - economic, social
  - Lower → Higher
- Voluntary action → Command and control
- Information → Regulation
- Prioritizing research → Required testing

- Less evidence → Lots of evidence
- AOP seems plausible → "Validated"

Application to Levels of Organization Based on Source to Outcome

Molecular Initiating Event → Cellular Effects → Individual → Population → Community

Toxicity Pathway

Mode of Action

Adverse Outcome Pathway

Source to Outcome Pathway
Uses of AOP -- Hazard ID

- Relevance of animal data: e.g. α2µ globulin

**α2u-Globulin**

- The main story
  - Protein produced by male rats
  - MOA – functional changes in epithelial cells of proximal tubules

  - Hyaline droplets accumulate
  - Tubule cell degeneration
  - Regenerative cell proliferation
  - Expansion of initiated renal tubule cells

8/27/2014
Uses of AOP -- Hazard ID

- Prediction of AO from early step in AOP
  - Genotoxic carcinogens
  - ER binding

“We propose that the ability of a chemical to interfere with hormone action is a clear predictor of adverse outcome, much like mutagenicity is a predictor of carcinogenicity.” p. 4099

“Environmental chemicals that interfere with any aspect of hormone action should be presumed to cause adverse effects.” p. 4107. (Zoeller et al. 2012.)
Uses of AOP -- Hazard ID

- Conditions under which agents produce toxicity
  - Route of exposure
  - High dose only?
  - Life stage

- Prioritizing
  - For testing
  - For assessment
Uses of AOP Dose Response

- Quantitative KER in Biologically Based Dose Response models (BBDR)
Mutagenic MOA for Cancer: AFB1-induced HCC

IME = Initial Molecular Event
MIE = Molecular Initiating Event
KE = Key Event
AO = Adverse Outcome

IME
Hepatic metabolic activation

MIE
Pro-mutagenic DNA adducts formation

KE1
Insufficient/Mis-repair of pro-mutagenic DNA adducts

KE2
Induced mutation in critical gene(s)

KE3
Cellular proliferation and clonal expansion of mutant cells (pre-neoplastic lesions)

AO
Hepatocellular carcinoma

DRAFT: 6/6/2014
Oltipraz is a chemoprotective agent that increases GST activity in cells. Oltipraz also appears to increase nucleotide excision repair, the primary error-free DNA repair mechanism that acts on both types of AFB1-DNA adducts. Kensler suggested the use of aflatoxin-albumin adducts as a biomarker of AFB1 exposure and demonstrated the oltipraz administration reduced both albumin adducts and HCC incidence. Scholl derived a relationship between albumin adducts in rats as a function of cumulative AFB dose. That relationship is:

\[
Adduct\; Burden\left(\frac{\text{pg LYS} - \text{AFB1}}{\text{mg Albumin}}\right) = 0.3 \cdot \text{dose}^2 + 39.6 \cdot \text{dose}
\]

where dose = µg AFB1 / kg BW

It may be possible to use the relationship between AFB1 albumin adducts and mutations based on the work of Scholl et al. (2006).
Uses of AOP Dose Response

- Choice of POD
- Choice of extrapolation method
- Life Stage adjustment?
Use of AOP Grouping

- For Cumulative Risk Assessment
- By MOA, AOP
Use of AOP Grouping

- For cumulative risk assessment
- By common adverse outcome

Cumulative Risk Assessment Broadly Viewed

Why Should This Only Apply to Reductions in Androgen?

- “To cite another example, EPA could evaluate combined exposures to lead, methylmercury and polychlorinated biphenyls because all contribute to the cumulative risk of cognitive deficits associated with IQ reductions in children, although the deficits are produced by different mechanisms of action.”
For most real-world applications, AOP networks are the functional unit of prediction.

Key events shared by multiple AOPs

KERs shared by multiple AOPs

Dan Villeneuve
Use of AOP Grouping

- Cumulative risk assessment
  - For scoping, qualitative assessment
  - For regulation, clean up
- Prioritize for testing
- Prioritize for assessment
What Does “Validation” Mean?

- “Validating New Tools/Assays Against Carcinogenicity AOPs to Support Regulatory Decisions”
- Some meanings are defined by statute or court
- Often means comparison to a standard set of results
  - Comparison of HTP assays to lifetime assay results
    - Specificity and sensitivity
Validated biomarkers

Jarabek et al. 2009
Validation in OECD Handbook

AOP Evaluation

- AOP assessment is an important aspect of formal AOP description

Assessment of the AOP

Users’ handbook supplement to OECD guidance document for developing and assessing AOPs.

Domain of applicability of the AOP
- Life stage
- Sex
- Taxa

Support for essentiality of each KE

Weight of evidence for each KER

Quantitative understanding for each KER

Assessment of confidence of the overall AOP

OECD “validation”

Approval process for AOPs

- Approved AOP
  - Submitted for declassification
  - WNT and TF HA

- Joint Meeting
  - Submitted for information
  - WNT and TF HA

Submits completed AOP for approval

Extended Advisory Group on Molecular Screening and Toxicogenomics

AOPD Workplan:
- AOP Development
- AOP Knowledge Management Tools
- AOP Application Case Studies
- AOP Guidance
Use of Default Options

The Guidelines emphasize analysis of all the data before use of default options.

- Analyze the available data
- Is there too much uncertainty or is critical information lacking?
  - **Y**: Invoke a default option*
  - **N**: *“The primary goal of EPA actions is public health protection, accordingly, as an agency policy, the defaults used in the absence of scientific data to the contrary should be health protective (SAB 1999).”*
Conclusions

- Progress in changing basis for regulation can move at glacial speed
  - Glacier melting appears to be accelerating
  - Bad for climate change; maybe good for acceptance of new approaches
- Most terms have meaning only when defined in a particular context
  - e.g. “validate”
- Problem formulation, planning and scoping is critical for any assessment
- Knowledge beats information beats data