NEWMOA Ecological Risk Assessment Workshop

Westford, MA & Danielson, CT

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Principles of Ecological Risk Assessment

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Introduction to Your Instructor

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- Principal Ecologist with AMEC Earth & Environmental
- Professional Wetland Scientist
- BS in Wildlife Ecology, MA in Biology
- 25 years as an environmental consultant in the Northeastern United States
- Completed Ecological Risk Assessments at over 50 CERCLA/RCRA sites and countless major state-lead sites

Why Ecological Risk Assessments?

- Not all hazardous waste sites have human exposure components
- Ecological receptors behave much differently than human receptors
- HHRA addresses a single, well studied receptor; whileERA addresses multiple receptors, which are often not well studied
- When to conduct ecological risk assessments?
Ecological Risk Assessment

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

EPA, 1992
Stressors

- Chemical
- Physical
- Biological

Ecological Risk Assessment

- Multi-disciplinary process for collecting, organizing and analyzing information to estimate the probability of adverse impacts to ecological receptors
- Tiered approach
  - Lower tiers protective, higher tiers predictive
  - Lower tiers use conservative assumptions, higher tiers use site-specific data and mechanistic models
  - Evaluate each tier to decide if the next is needed
  - Objective is to progressively reduce uncertainty
Unique Aspects Of Ecological Risk Assessment

- Focus of ERA should be primarily on the population, community or ecosystem rather than the individual, unless receptor is endangered species
- Some routes of exposure are unique to nonhuman species
- Nonhuman organisms may be indirectly affected by loss of food or habitat associated with chemical exposure
Problem Formulation Phase

PROBLEM FORMULATION
- Source and Exposure Characteristics
- Ecological Effects
- End Points
- Analysis Plan
- Conceptual Model

ANALYSIS

Problem Formulation Analysis Risk Characterization

Planning (Risk Assessor/Risk Manager Dialogue)

As Necessary: Acquire Data, Iterate Process, Monitor Results
Problem Formulation

- Defines the nature of the problem and the characteristics of the risk assessment needed to solve it
  - Identify ecosystem at risk
  - Identify potential ecological effects
  - Select assessment/measurement endpoints
  - Conceptual Site Model
- Considers established management goals for site
- Risk assessors’ first opportunity to incorporate “perspectives” into the assessment
- First evaluation of comparative risks at a site

Problem Formulation (Questions Asked)

- What are the stressors?
- What is the area of concern?
- Who are the interested parties?
  - Responsible parties
  - Governments – Federal, State, Local
  - Tribes
  - NGOs
  - Local interests
Identification of Stressors

- Chemical
  - Site uses and sources of contamination
  - Primary sources
  - Secondary sources
- Physical
  - Construction
  - Fire
  - Invasive species
- Biological
- Combination

Assessment Endpoints

- Neutral expressions of the actual environmental goals to be protected
- Not management goals
- Defined by:
  - Ecological entity (species, species groups, community, ecosystem)
  - Attributes of the ecological entity (growth, survival, species diversity)
Assessment Endpoints

- **Ecosystem**
  - Productive capability

- **Population**
  - Extinction
  - Abundance
  - Yield/production
  - Age/Size class structure

- **Community**
  - Sport value
  - Recreation quality
  - Biological stability
  - Desirability

Measurement Endpoints (Measures of Effects)

- **Ecosystem**
  - Biomass
  - Productivity
  - Nutrient dynamics

- **Population**
  - Occurrence
  - Abundance
  - Age/class structure
  - Reproductive success

- **Community**
  - Number of species
  - Dominance
  - Diversity

- **Individual**
  - Death
  - Growth
  - Fecundity
  - Behavior
Selection of Endpoints

- **Assessment Endpoints**
  - What component of the environment is at risk?
  - How should efforts be defined
    - Legal
    - Regulatory
    - Public concerns

- **Measurement Endpoints**
  - Directly related to assessment endpoints
  - Consistent relationship

Characteristics of Good Endpoints

- Social relevance
- Biological relevance
- Unambiguous
- Measurable or predictable
- Susceptible to the hazard
- Logically related to the decision process
Conceptual Site Model

- Describes predicted relationships among stressors, exposure, and assessment endpoint responses
- Identifies potential sources
- Identifies complete and incomplete exposure pathways
- Identifies potential receptors (primary and secondary)

Elements of a CSM

- Source
- Stressor
- Response
- Measurable Change in Endpoint Attribute
Analysis Phase

As Necessary: Acquire Data, Iterate, Process, Monitor Results

RISK CHARACTERIZATION

Problem Formulation

Analysis

Risk Characterization

PROBLEM FORMULATION

Characterization of Exposure

Characterization of Ecological Effects

Measures of Exposure

Measures of Ecosystem and Receptor Characteristics

Measures of Effects

Exposure Analysis

Ecological Response Analysis

Exposure Profile

Stressor-Response Profile

Figure 1A

Aquatic Conceptual Site Model for the Mississippi River Ecological Risk Assessment
Saugatuck River RIFs SSP
Saugatuck Area 2 Sites Group
Analysis

- Exposure Characterization/Assessment
  - Stressor characterization

- Effects Assessment
  - Use of limited data on ecological effects can result in highly uncertain and overly conservative risk estimates
  - Safety factors for taxonomic extrapolations
  - Agencies prefer use of most conservative values

Analysis (continued)

- “Top down” evaluation can complement the results of a “bottom up” effects assessment

- Exposure assessment becomes the primary mechanism for reducing the uncertainty of the effects assessment
  - Site-specific information
  - Reasonably definable
Exposure Characterization

- Type: Chemical, physical, or biological
- Intensity: Concentration
- Duration: Acute (short-term) or chronic (long-term)
- Frequency: Single event, episodic or continuous
- Timing: Relative to ecological/biological cycles
- Occurrence: Homogenous or heterogeneous
- Scale: Geographic extent

Tools for Conducting Exposure Assessments

- Chemical data from site-related matrices
- Tissue residue data
- Bioaccumulation/food web modeling
- Biomarkers
- Life history information
Effects Assessment

- Determination of the nature of the effects and their magnitude as a function of exposure

- Assessments made using
  - Literature studies/review
  - Laboratory toxicity tests
  - Ambient media toxicity tests
  - Field studies
  - Biological surveys
Risk Characterization

• Characterize type, nature, extent and the strength of adverse ecological risks associated with chemicals identified at your site based on evaluation of data collected in Analysis phase

• Statistically compare data from area of concern with data from reference area

• Compare toxicological benchmarks with representative estimated doses

• Evaluate stressor-response relationships

Uncertainty Evaluation

• Built into discussions on measures of exposure and effects

• Subject to professional judgment and scrutiny

• Often qualitative

• Provides perspective on soundness of lines of evidence
ERA Process for Superfund - Objectives

- Document whether actual or potential ecological risks exist at a site
- Identify which contaminants present at a site pose an ecological risk
- Generate data to be used in evaluating cleanup options

Eight Step Process

- Screening-Level Ecological Risk Assessment
  - Step 1 – Screening Level Problem Formulation/Effects Evaluation
  - Step 2 – Screening Level Exposure Estimate/Risk Characterization*
SMDP’s

- Scientific Management Decision Points
- Points in the ERA process at which the risk assessor and risk management team are required to meet
- Purpose is to reach agreement between all parties on the approach and activities necessary for that stage of the ERA process

Eight Step Process (Continued)

- Baseline Ecological Risk Assessment (BERA)
  - Step 3 – Problem Formulation
  - Step 4 – Study Design/Data Quality Objectives
  - Step 5 – Field Verification of Sampling Design
  - Step 6 – Site Investigation and Analysis of Exposure and Effects
  - Step 7 – Risk Characterization
  - Step 8 – Risk Management

* - SMDP
Screening Level Ecological Risk Assessment (SLERA)

- Objectives
  - Eliminate endpoints/exposure routes/media
  - Eliminate contaminants of no concern
  - Focus study on short list of contaminants
  - Cost-effective

- Actions
  - Chemical analyses
  - Comparison of data to benchmarks
  - Focus future study on short list of contaminants
  - Survey of biological resources
  - Development of species/site-specific toxicity benchmarks
  - Food web evaluation

Baseline Ecological Risk Assessment (BERA)

- Full weight of evidence risk characterization
- Additional matrix sampling
- Biological sampling
- Ecological community/population survey/assessment
- Toxicity testing
Step 1 – Screening Level Problem Formulation/Effects Evaluation

- Identify environmental setting and known/suspected contaminants
- Evaluate potential contaminant fate and transport
- Identify mechanisms of toxicity and likely categories of receptors that can be affected
- What are the complete exposure pathways?
- Select endpoints to screen

SLERA Problem Formulation Assumptions

- Total concentration is bioavailable
- Diverse community is present
- Healthy populations are present
- Use conservative ecological risk criteria to screen risks
- Exposure scenario is worst case
- Chemical exposure and effects data can be used to evaluate potential ecological risks
Step 1 – Screening Level Problem Formulation/Effects Evaluation

- Identification of screening ecotoxicity values
  - Conservative thresholds for determining adverse ecological effects
- Should represent lowest effect values
- Look at toxicity data
  - Exposure duration
  - Exposure route
  - Field versus laboratory data
- Population level ecological effects (reproduction/survivorship)

Step 2 – Screening Level Exposure Estimate/Risk Characterization

- Maximum concentrations (also use a central statistic)
- Conservative Exposure Factors
- AUF & SUF – 100%
- Bioavailability – 100%
- Body weight/food ingestion
  - Minimum body weight
  - Maximum food ingestion
- Dietary composition – 100% consists of the most contaminated dietary component
Step 2 – Screening Level Exposure Estimate/Risk Characterization

- Hazard Quotient
  - HQ = Exposure Concentration/Benchmark
- HQs less than one indicate the potential for an adverse ecological risk is minimal
- HQ of one or greater is not confirmation of an impact, just indication of the potential for an adverse ecological risk

SLERA Activities

- Identify Type and Extent of Stressors
  - Chemical sampling for COPECs
  - Surface water
  - Surface soil
    - Grid versus biased sampling
  - Surface sediment – BAZ
    - Depositional areas
    - Single line sampling
    - Transect sampling
    - Deep sampling
SLERA Activities (Continued)

- Define site setting and ecological resources
- Lines of evidence
  - Simple screening of chemical data against benchmarks
    - Benchmarks are values that if exceeded suggest the potential for an ecological effect – measure of effect
  - Conservative food chain modeling

Step 3 – BERA Problem Formulation

- Refine preliminary contaminants of concern
- Further characterize ecological effects of contaminants
- Review and refine information on contaminant fate and transport, exposure pathways, ecosystems at risk
  - Refine ecological setting, magnitude/distribution of contaminants
  - Degradation, ionization, adsorption, erosion, volatilization
- Select additional assessment endpoints
- Refine conceptual site model
Step 4 – Study Design and Data Quality Objective Process

- Establish measurement endpoints
- Complete the conceptual model
- Establish the study design for field work to support the BERA
  - Lines of evidence?
  - Bioaccumulation studies/tissue studies?
  - Toxicity testing?
  - Population/community evaluations
- Establish the data quality objectives

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Step 4 – Study Design and Data Quality Objective Process (Continued)

- DQO process
  - Series of planning steps
  - Clarify the study objectives
  - Determine the most appropriate time for data collection
  - Establishing quantity and quality of data
- Results of Step 4
  - Work Plan (WP)
  - Sample and Analysis Plan (SAP)
    - Field Sampling Plan (FSP)
    - Quality Assurance Project Plan (QAPP)
ERA Work Plan

- Introduction
- Description of Ecological Risk Assessment Process
- History of Site Investigations
- Problem Formulation
  - Ecological Setting
  - Conceptual Site Model (CSM)
  - Selection of COPECs
  - Identification of Receptors and Endpoints
  - Assessment and Measurement Endpoints
- Analysis
  - Ecotoxicological Benchmarks
  - Wildlife Toxicological Benchmarks
- Risk Characterization
- Uncertainty Analysis
- Conclusions

BERA Final Steps

- Step 5 – Field Verification of Sampling Design
- Step 6
  - Site Investigation – Implementation of study
  - Analysis of ecological exposure and effects
    - More detailed version of Step 1
    - Characterize exposures
    - Characterize ecological effects – exposure/response analysis
    - Evidence of causality
- Step 7
  - Risk estimation and risk description
  - Uncertainty
Step 8 – Risk Management

- Different process from risk assessment
- Variety of risk management issues established under the NCP
  - Ecological impact of remedial options
  - Monitoring

Vegetative Impact Considerations

- Direct loss of plants specimens and communities
- Change in vegetative classes
- Modification in structural diversity
- Change in successional stages
- Change diversity/frequency/abundance
- Loss of seed banks and litter layers
Potential Faunal Components

- Species list
- Wildlife habitats and niche requirements
- Feeding guilds
- Predator-prey relationships
- Reproductive success, dispersal rates, migration
- Population natality, mortality, longevity
- Population growth rates

Faunal Impact Considerations

- Direct loss of life
- Loss of habitat
- Migration/dispersal obstructions
- Changes in feeding behaviors
- Aerial deposition
- Chemical exposure
Faunal Characterization Techniques

- Paper studies (HEP)
- Cruise methods (tracks, signs, scat, calls)
- Populations studies (mark-recapture, spotlight surveys)
- Direct sampling – Permits may be required
  - Sweep nets
  - Drop-in traps
  - Drift lines
  - Mist nets
  - Live traps
  - Snap traps

Aquatic Resources

- Phytoplankton
- Zooplankton
- Macrophytes
  - Floating
  - Rooted
- Benthic Invertebrates
- Fish
Aquatic Habitat Characterization

- Lotic – running water
- Lentic – standing water
  - Littoral – well lit shallow water region
  - Limnetic – open water/region of light penetration
  - Profundal – open water/below point of light penetration
- Benthic – sediment
- Nekton – free swimmers in water column
- Periphyton – surface of rocks, aquatic vegetation
- Neuston – surface water film

Fish Community Assessment

- Electro-fishing
- Gill netting
- Seining
- Measured parameters
  - Number of species
  - Length/weight
  - Condition
  - Reproductive state
  - Presence of disease/parasites
  - Fish tissue
Description

- Located adjacent to the Mississippi River
- Includes approximately 14,000 feet of riverbank and over 250 acres of total area, including floodplains below a U.S. Army Corp of Engineers flood control dike
- The terrestrial portion includes five former disposal sites identified as Sites O, P, Q, R, and S
Description (Continued)

- Site O
  - Approximately 20 acres, sewage sludge dewatering, PCBs up to 1,900 ppm, dioxins at 170 ppb

- Site P
  - Approximately 20 acres, municipal/industrial waste disposal

- Site Q
  - Approximately 90 acres, municipal/industrial waste disposal, site of USEPA emergency removal, PCBs up to 16,000 ppm, contains two large ponds

- Site R
  - Approximately 36 acres, industrial waste disposal, closed landfill, covered with clean fill

- Site S
  - Chemical reprocessing waste disposal, very small
Aquatic Ecological Risk Assessment

- Sampling conducted in 6 locations, sampling plots established such that three samples set in a transect 50’ from shore, 3 samples 150’ from shore, and 1 sample 300’ from shore
- At each sampling location collect surface water and sediment samples
- Sediment samples
  - Surface grab
  - Chemical analysis (VOCs, SVOCs, metals, pesticides/herbicides dioxin), bioassay, sediment bioaccumulation
- Surface Water
  - Collected above sediment/surface water interface using pump/hose rig attached to sediment sampler frame
  - Chemical analysis (VOCs, SVOCs, dissolved metals, filtered metals, pesticides/herbicides dioxin), bioassays

Floodplain Ecological Risk Assessment

- Collected surface soil samples
- Ecological characterization of the Sites
- Collect plant tissue for chemical analysis (SVOCs, dioxin, PCBs, pesticides/herbicides, metals)
- Collect insects for chemical analysis (SVOCs, dioxin, PCBs, pesticides/herbicides, metals – some variation in analytes depending upon amount of tissue collected)
- Earthworm bioaccumulation tests