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Welcome – Thanks for joining this ITRC Training Class

ITRC Internet-based training and
Technical and Regulatory Guidance

Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites (CS-1, 2011)

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

The U.S. Environmental Protection Agency estimates that approximately 10 percent (over a billion cubic yards) of the sediment underlying our nation's surface water is sufficiently contaminated with pollutants to pose potential risks to fish and to humans and wildlife that eat fish. Based on current average costs for managing contaminated sediments, this volume of material could cost several trillion dollars to dredge. Methods to assess the potential effect of sediment contamination on human or ecological health are historically based on total contaminant concentrations in the bulk sediment. However, research conducted over the past fifteen years has shown that the bioavailability of many of these contaminants to receptors is much less than the total amount of contaminant in the sediment. "Bioavailability processes," as defined by the National Research Council, are the "individual physical, chemical, and biological interactions that determine the exposure of plants and animals to chemicals associated with soils and sediments." Only the bioavailable fraction of an environmental contaminant may be taken up and subsequently result in an effect on an organism. Incorporating bioavailability considerations in the calculation of risk can optimize the extent of cleanup required to be protective, improve site decision-making, and can be an important factor in balancing the risks caused by remedial action with the risks addressed by remedial action.

ITRC's web-based Technical and Regulatory Guidance, Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites (CS-1, 2011) and associated Internet-based training are intended to assist state regulators and practitioners with understanding and incorporating fundamental concepts of bioavailability in contaminated sediment management practices. This guidance and training describe how bioavailability considerations can be used to evaluate exposure at contaminated sediment sites, the mechanisms affecting contaminant bioavailability, available tools used to assess bioavailability, the proper application of those tools, and how bioavailability information can be incorporated into risk-management decisions. This guidance and training also contain summaries of case studies where bioavailability has been assessed and considered in the contaminated sediment remedial decision making process. This guidance and training provide insight on how bioavailability assessments can be used to understand, mitigate, and manage risk at a contaminated sediment site, often at a reduced overall project cost.

The intended users of this guidance and training participants are individuals who have a working knowledge of contaminated sediment management but seek additional information about bioavailability. Prior to the training class, participants are encouraged to review the following documents:

ITRC's web-based Technical and Regulatory Guidance, Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites (CS-1, 2011)
http://www.itrcweb.org/contseds-bioavailability/

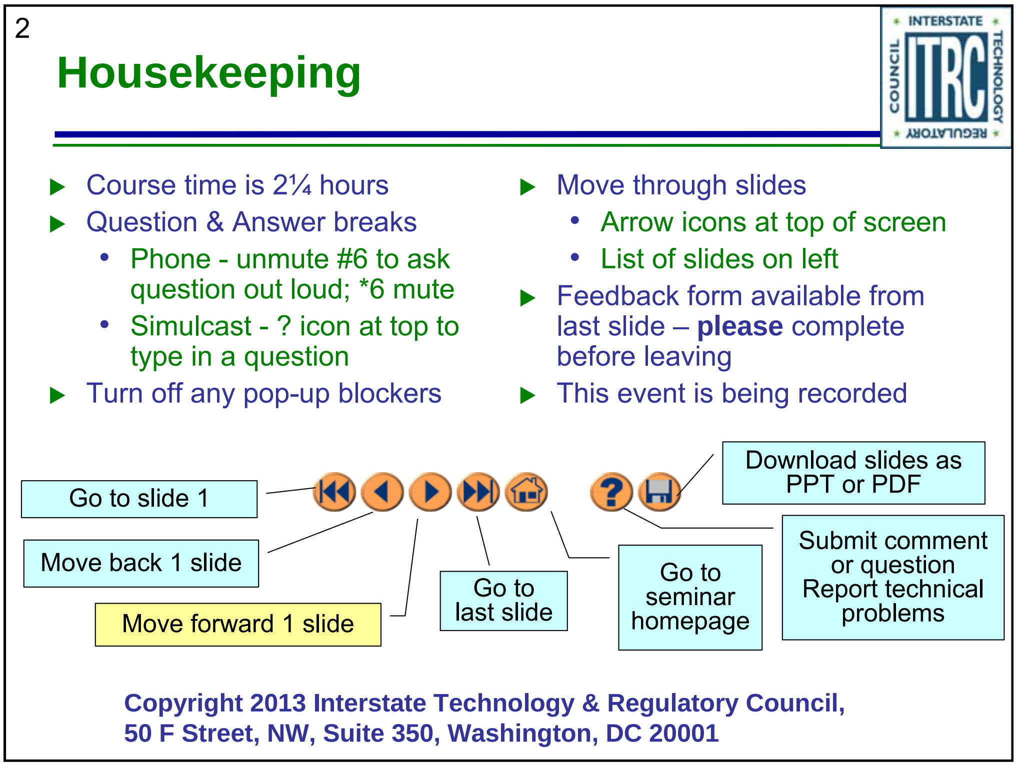
U.S. Environmental Protection Agency, "Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment"- Interim Final, June 1997 http://www.epa.gov/oswer/riskassessment/ecorisk/ecorisk.htm

U.S. Environmental Protection Agency, "Risk Assessment Guidance for Superfund (RAGS)" Volume 1 -- Human Health Evaluation Manual, Supplement to Part A: Community Involvement in Superfund Risk Assessments, 1989 http://www.epa.gov/oswer/riskassessment/ragsa/ci-ra.htm

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)

ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419



Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press *6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

You should note that throughout the seminar, we will ask for your feedback. You do not need to wait for Q&A breaks to ask questions or provide comments using the ? icon. To submit comments/questions and report technical problems, please use the ? icon at the top of your screen. You can move forward/backward in the slides by using the single arrow buttons (left moves back 1 slide, right moves advances 1 slide). The double arrowed buttons will take you to 1st and last slides respectively. You may also advance to any slide using the numbered links that appear on the left side of your screen. The button with a house icon will take you back to main seminar page which displays our presentation overview, instructor bios, links to the slides and additional resources. Lastly, the button with a computer disc can be used to download and save today's presentation slides.

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ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
  ECOS
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners
    DOE DOD EPA
  - ITRC Industry Affiliates Program
    IAP
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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ITRC Course Topics Planned for 2013 – More information at www.itrcweb.org

Popular courses from 2012

- Decision Framework for Applying Attenuation Processes to Metals and Radionuclides
- Development of Performance Specifications for Solidification/Stabilization
- Green and Sustainable Remediation
- Integrated DNAPL Site Strategy
- LNAPL 1: An Improved Understanding of LNAPL Behavior in the Subsurface
- LNAPL 2: LNAPL Characterization and Recoverability - Improved Analysis
- LNAPL 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
- Mine Waste Treatment Technology Selection
- Project Risk Management for Site Remediation
- Use and Measurement of Mass Flux and Mass Discharge
- Use of Risk Assessment in Management of Contaminated Sites
- Soil Sampling and Decision Making Using Incremental Sampling Methodology (2 parts)
- Bioavailability Considerations for Contaminated Sediment Sites
- Biofuels: Release Prevention, Environmental Behavior, and Remediation

New in 2013

- Environmental Molecular Diagnostics
- Biochemical Reactors for Mining-Influenced Water
- Groundwater Statistics and Monitoring Compliance

2-Day Classroom Training on Light Nonaqueous-Phase Liquids (LNAPLs)

- April 9-10 in King of Prussia, PA
- June 4-5 in Springfield, IL
- October 1-2 in Garden Grove, CA

More details and schedules are available from www.itrcweb.org.

Meet the ITRC Trainers

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John G. Cargill is a Hydrologist IV with the Delaware Department of Natural Resources and Environmental Control (DNREC) located in New Castle, Delaware. Before joining DNREC in 2005, John worked as a geologist in the private consulting industry, where he became familiar with environmental regulations and guidelines associated with contamination assessment and remediation of various media. In 2005, John relocated to Delaware and was hired as a regulator within the DNREC Site Investigation and Restoration Branch. He oversees contamination assessment and cleanup projects conducted by responsible parties and developers in the State, and also designs and implements State lead assessment and remediation projects, including contaminated sediment projects. John's has been a member of the Contaminated Sediments Team since its inception in 2008, and he became a co-leader of the Team in 2009. His involvement as co-Team Leader has helped him communicate the intricacies of contaminated sediment assessment, and specifically bioavailability assessment concepts, to audiences within the State of Delaware as well as at meetings around the country. His overall goal for the team's product is to help demystify some of the complexities of contaminated sediment and bioavailability assessment and to provide a "tool box" for regulators, consultants and practitioners to help manage the risks associated with contaminated sediments. John earned a bachelor's degree in geology from the University of North Carolina at Chapel Hill in 1994 and a master's degree in coastal geology from the University of South Florida in Tampa in 1996. John is a licensed Professional Geologist and licensed Geotechnical Well Driller in the State of Delaware, and has worked as a licensed geologist in the states of North Carolina, South Carolina, Georgia and Virginia.

Dr. Steve Clough is a Senior Environmental Toxicologist at Haley & Aldrich in Manchester, NH. Since 1988, Steve has performed ecological risk assessments under CERCLA/RCRA, which require detailed exposure assessments that incorporate bioavailability factors and an in-depth knowledge of the physicochemical parameters that affect them. Steve specializes in assessing the impact of point and non-point sources to benthic communities in estuaries, rivers, and streams and has a wide range of experience using both active and passive pore water sampling techniques. In 1996, Steve worked for NCASI, a pulp and paper trade group, where he conducted field studies to evaluate the uptake of extremely persistent hydrophobic compounds into both aquatic and terrestrial food chains (including the calculation of site-specific bioavailability factors). Steve then joined environmental consulting and has conducted numerous multipathway ecological risk assessments that require formulating a Conceptual Site Models, which are subsequently validated in the field by sampling of sediment and biota to determine the actual exposure and risk that environmental chemicals/stressors may pose to key receptors. Steve specializes in the toxicology of metals, routinely presents at scientific conferences, and has been active in ITRC since 2007. Steve earned a bachelor's degree in pathobiology from the University of Connecticut in Storrs, Connecticut in 1976. After managing both mammalian and aquatic toxicology laboratories addressing product development under TSCA, he attended the University of Michigan in Ann Arbor, Michigan where he earned a master's in water quality in 1983 and a Ph.D. in toxicology in 1988. Steve is also certified as a Diplomate of the American Board of Toxicology.

Diana Marquez is an Associate Toxicologist with Burns & McDonnell Engineering Company, Inc. in Kansas City, MO and has worked for the company since June 1995. She has experience in human health risk assessment, vapor intrusion, RCRA corrective action, CERCLA project management, environmental site assessment, and hazardous waste management. Diana has experience in: conceptualizing, peer-reviewing, and conducting human health risk assessments, and managing ecological risk assessments, encompassing varied contaminants, media, migration routes, potentially exposed populations, and exposure pathways. Her previous experience involved two years working at a DOE nuclear weapons manufacturing facility in the hazardous waste management and environmental remediation fields. Diana is a member of the ITRC Contaminated Sediments team. She earned a bachelor's degree in biology from Villanova University in Villanova, PA in 1991 and master's degree in toxicology from University of New Mexico in Albuquerque, NM in 1992.

Greg Neumann is a Research Scientist in the Bureau of Environmental Evaluation and Risk Assessment at the New Jersey Department of Environmental Protection (NJDEP) in Trenton, NJ. Since 1992, Greg's primary responsibilities at the NJDEP are the review of Baseline Ecological Evaluations and Ecological Risk Assessments associated with both State and Federal Superfund Sites; as well as the review of remedial investigations and remedial actions for soils for the most complex sites in NJ. Greg serves as a member of the US Environmental Protection Agency Biological Technical Assistance Group that provides ecological guidance to EPA Remedial Project Managers. He was one of the primary authors of the NJDEP's *Guidance For Sediment Quality Evaluations* and is presently a member of the Licensed Site Remediation Professional Ecological Committee that is developing guidance on evaluating ecological risk for this new program. Greg, along with other DEP Staff, is an instructor for a short course on conducting Ecological Risk Assessments at Rutgers University. Greg has been a Team Member of the ITRC Contaminated Sediment Team since its inception in 2008 and will be Co-Leading the Teams next Contaminated Sediment project that will focus on Remediation. Greg earned a bachelor's degree in Biology (Ecological Science concentration) from the State University of NY College of Oneonta in 1989, and a master's degree in Environmental Science from Ohio University in Athens, Ohio in 1991.

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ITRC Sediments Team

- **States**
  - Alabama
  - California
  - Delaware
  - Florida
  - Kentucky
  - Michigan
  - New Jersey
  - New York
  - Oklahoma
  - Oregon
  - Pennsylvania
  - Texas
  - Washington
- **Universities**
  - Purdue
  - U. of Florida
  - U of Texas
- **Federal Agencies**
  - Navy
  - Army
  - AFCEE
  - EPA Including Region 2 & 5
  - USACE
  - DOE
- **Community Stakeholders**
  - Mtn Area Land Trust
  - AAEJC
- **Industry**
  - AMEC
  - Alta Environmental
  - AECOM
  - AFMC
  - Alcoa
  - Arcadis
  - Battelle
  - Beacon
  - Brown and Caldwell
  - Bootheel LEPC
  - Burns & McDonnell
  - BP
  - CDM
  - CH2MHill
  - CETCO
  - Columbia Analytical
  - DuPont
  - Geosyntec
  - EMCBC
  - Environ
  - ExxonMobil
  - Haley & Aldrich, Inc
  - Kleinfelder
  - Langan Engineering
  - LATA-Kemron
  - Malcolm Pirnie
  - M.W. Global
  - MWH
  - RegTech
  - Neptune and Co.
  - SAIC W.L.
  - Gore
  - SRNL
  - Test America labs
  - Tetra Tech
  - URS
  - WRI
  - SPAWAR
  - SSC
  - Shell

Welcome.

Team initially formed in 2007 and kicked off in 2008 - comprised of a mix of State, Federal and Private entities, as well as academic and community interests.

Great mix of professionals that look at contaminant issues from differing points of view and for different client interests.

Purpose of Team: to evaluate how and to what degree bioavailability is being addressed at contaminated sediment sites across the country, and to understand the usefulness and problems associated with the incorporation of bioavailability into exposure assessments.

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ITRC Web-based Guidance Outline

- Introduction and background on bioavailability
- Overview of bioavailability processes
- Bioavailability pathway exposure assessment
    - Screening
    - Background
    - Pathway exposure assessment
        - Benthic invertebrates
        - Fish and water column invertebrates
        - Wildlife
        - Plants
        - Human health
- Risk management decision-making

http://www.itrcweb.org/contseds-bioavailability/

•This document is web-based

•Easy navigation between chapters and sections

•Option to print a paper document will be there

•Easy maneuverability to topics that interest the user most

•Easy to link the user to important supporting documents

•Already plans to review all of the links to keep them current.

•Will likely be more web-based formats from ITRC in the future, so we appreciate any feedback we can get

Slide shows basic outline of what is covered in the document.

•Describes mechanisms affecting contaminant bioavailability

•Tools used to assess bioavailability within the most common exposure pathways

•Proper application of the tools

•How bioavailability information can be incorporated into risk-management decisions

•Also includes numerous case studies illustrating the application to tools and how the information gathered was utilized.

Assumptions:

•reasonable understanding of risk assessment processes

•reasonable understanding of contaminated sediments

•an appreciation for the value of using bioavailability assessment information

•a basic knowledge of human health and ecological risk assessment terminology, methods, and approaches.

We recommend that, at a minimum, the users should familiarize themselves with EPA ERAGs before reading this document.

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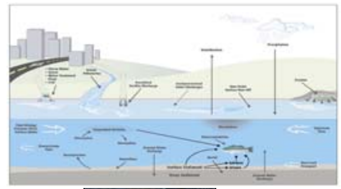
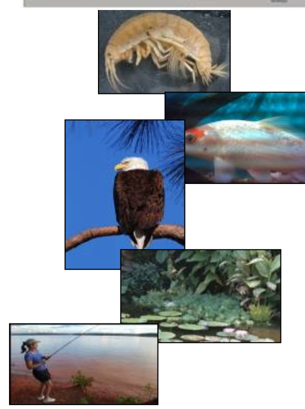
What You Will Learn…

The intended users of this guidance are individuals who have a working knowledge of contaminated sediment management but seek additional information about bioavailability.

- What is bioavailability?
- When do we apply bioavailability adjustments?
- What are the available tools and how do we use them?
- How do we use the information to make risk management decisions?
- You will **NOT** learn how to conduct a Risk Assessment that incorporates bioavailability.





The intent of today's presentation is to give you a brief glimpse of what the web-based *Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites* document has to offer, and hope you will find that it's a good tool or reference when investigating a contaminated sediment site.

Topics covered in presentation:

• the concept of bioavailability

• what bioavailability means when looking at contaminated sediments

• when you should apply bioavailability adjustments to assess risk

• some of the tools available for use to assess bioavailability within the most common exposure pathways

• how the information gathered might be incorporated into your risk management decisions

Reminder: the level of detail in this document is a result of the assumption that the users have a working knowledge of sediment sites, and a basic level of understanding when it comes to risk assessment.

* **We intentionally focus on bioavailability concepts, and have omitted information that pertains directly to performing eco and human health risk assessments**.

Recommended ITRC document and training: *Examination of Risk-Based Screening Values and Approaches of Selected States* (Risk-1, December 2005). Available from http://www.itrcweb.org/guidancedocument.asp?TID=44

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The Problem!

- US EPA reports – **10% (1.2 billion yds^3)** of U.S. sediment underlying surface water pose a potential ecological or human health risk
- Cost of clean-up is in the trillions
- Contaminant concentration in sediment and actual exposure is not a direct relationship
- Bioavailability will give a more accurate characterization of exposure

Conventional Clamshell

Excavator

USACE 2008. Technical Guidelines for Environmental Dredging of Contaminated Sediments

Contaminant concentrations in sediment have an indirect relationship with exposure to those same contaminants

- Big opportunity to use bioavailability concepts to re-evaluate levels of cleanup required to be protective of receptors
- Assure unnecessary cleanup costs aren't incurred, or more sites cleaned up with fewer monetary resources

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What is Bioavailability?

"…individual physical, chemical, and biological interactions that determine the exposure of plants and animals to chemicals associated with soils and sediment (National Research Council, 2003)."

Specifically, bioavailability addresses the fact that only a fraction of the contaminant concentration present in the environment may be taken up or result in an effect on an organism!

Definition of bioavailability as it relates to our document:

Our web-based contaminated sediment document is focused on the second definition, along with

- how to communicate and assess the concept
- how to benefit from its use while remaining protective of human health and the environment

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How can Bioavailability Make a Difference?

- If contaminants are not physically accessible, or chemically or biologically available, they should not be included in the calculation of risk
- Can optimize the extent of cleanup required to be protective
- Can provide optimization of remedial approach and cost
- Can be an important factor in balancing the risks caused by remedial action

How can bioavailability make a difference?

•if contaminants aren’t physically accessible, or chemically or biologically available, then they shouldn’t be included in the calculation of risk.

•Particularly important for sites where capping and dredging can alter the physical, chemical and biological conditions, and disrupt existing habitat

•By using the tools described in today’s training, one might minimize or avoid this disruption

•Possibly at a reduced cost to States or Potentially Responsible Parties (PRPs).

Put another way, bioavailability can be an important factor in *balancing the risks caused by remedial action with the risks addressed by remedial action*.

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How is Bioavailability Being Used?

- 2008 – ITRC Team distributed questionnaire to assess extent bioavailability was used for the development of site cleanup levels
- 35 case studies collected (Table 9-1 and Appendix D)
  - Summarized exposure pathways addressed
  - Summarized contaminants evaluated/addressed
  - Summarized tools used at each site
  - Includes contacts for more information about each site

Case Study Questionnaire sent out in 2008

- •To help focus scope of the document
- •Document how bioavailability was being used in the industry and if it contributed to the risk management decisions at the site
- •Submitted to: ITRC Contaminated Sediment team, Federal agencies, State agencies, and industry professionals.

A total of 35 case studies were received and reviewed. The results of the questionnaire were used to summarize case studies by the primary pathway where bioavailability was assessed, the contaminants of concern at the site and the tools that were used during the assessment (Table 9-1 in Chapter 9 and Appendix D).

More information can be obtained from individual sites by using information provided in Appendix D (i.e. websites, or project manager contact information)

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Questionnaire Results

- Most common exposure pathways evaluated
  - Benthic exposure
  - Human health
  - Pelagic exposure
- Most common tools used to assess bioavailability
  - Bulk sediment chemistry
  - Tissue sampling (fish, bivalves, other water column receptors)
  - Porewater chemistry
  - Bioassays of benthic invertebrates

Most common exposure pathways:

•Benthic

•Human health

•Pelagic (organisms living in the water column)

•Most common tools used:

•Bulk sediment chemistry

•Tissue sampling

•Porewater chemistry

•Bioassays

Important note: Of the case studies where bioavailability was used, about half only assessed one pathway (benthic), but every case study used more than one tool to assess each pathway. **This multiple line of evidence approach is important to remember.**

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Risk Management Role in Decision-Making

- Risk management integrates the results of the risk assessment with
  - Technical
  - Political
  - Legal
  - Social
  - Economic objectives

- Bioavailability is used to make risk management decisions within the
  - Risk assessment - Section 9.1
  - Remedy selection – Section 9.2, Table 9-2
  - Remedial design/Implementation – Section 9.2

Talk about the usefulness of what we are presenting today in making risk management decisions, prior to going into the tools used to gather the information.

The USEPA recognizes the need to improve the scientific foundation for contaminated sediment remedy selection by improving site and risk characterization, by understanding how different remedial options can effectively reduce risks to humans and the environment, and optimize the cost-effectiveness of remedial actions (USEPA 2005a).

Understanding and characterizing bioavailability can:

• increase the understanding of the cause and sources of toxicity and the potential long-term effects to receptors

• help identify the most effective remedy to target critical exposure pathways

• lay the foundation for the most appropriate monitoring requirements at a site

In other words, assessing bioavailability can be a great tool in managing the overall risk posed by site contaminants.

This slide: risk management is an integration of chemical data and risk assessment information with technical, political, legal, social and economic objectives.

In the document, we refer to three areas where bioavailability data could be used to help make risk management decisions:

•Risk assessment

•Remedy selection

•Remedial design/implementation

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Risk Assessment

The assessment of risk to all receptors identified at a contaminated sediment site related to physical, chemical, and biological processes!

- Bioavailability should be used to actively refine conceptual site model (CSM)
- Risk assessment will likely involve a "weight of evidence" approach, or "multiple line of evidence" approach
  - Be aware of sources of variation in risk assessments
  - Collect data essential to risk assessment
  - Analyze to understand exposure and risk
  - Remember: bioavailability is highly site specific
- Be aware of your stakeholder interests, and communicate with them regularly
- View ITRC's Use of Risk Assessment in Management of Contaminated Sites (Risk-2, 2008) – available from www.itrcweb.org

•Risk assessment refers to the cumulative assessment of risk to ALL receptors identified at a site, long term risks, and evaluation of stakeholder interests.

•Bioavailability information should be used as a tool to augment traditional site characterization and human/ecological risk assessments to actively inform/refine the CSM for a contaminated sediment site.

•Weight of evidence or multiple line of evidence approaches are common (i.e. Sediment Quality Triad, or SQT): three tiered approach using:

- •Sediment chemistry
- •Toxicity testing
- •Macroinvertebrate surveys

Some (i.e. responsible parties or uninformed regulators) may see the collection of bioavailability data as extravagant, unnecessary or costly. But good communication with stakeholders can help to justify the fact that additional costs incurred during the assessment phase may result in a reduction in overall risk and/or cost of remediation. The critical factor is to ensure that the collection of additional bioavailability data can be directly translated into a reduction of risk and subsequent remedial cost.

Recommend: ITRC's Use of Risk Assessment in the Management of Contaminated Sites (Risk-2, December 2005). http://www.itrcweb.org/guidancedocument.asp?TID=44

- •details the usage of risk assessment information to aid in risk management

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Risk Assessment & Bioavailability

- Advantages
  - If contaminants aren't bioavailable, then they aren't included in the evaluation of risk (no exposure)
  - Optimization of cleanup goals, with a possible cost reduction
  - More effective use of available resources
  - Can achieve more accurate defensible cleanup goals while ensuring protection of receptors
- Challenges
  - Uncertain acceptance by regulators, stakeholders, and the public
  - Bioavailability may vary across a site (or operational units)
  - Potentially higher site characterization costs
  - May take longer to gain full understanding of site conditions

Go over advantages and challenges of using bioavailability to assess overall risk.

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Remedy Selection

- Bioavailability evaluation within risk assessment process will result in selection of remedy that will better address concerns at site
- Example: Mocks Pond Case Study
  - Site history and bulk sediment testing identified contaminants of potential concern (COPCs)
  - Further evaluated using bioavailability tools
    - In-situ pore water metal concentrations
    - Chemical analyses of whole body and fillets of pelagic fish species

Bioavailability can be used to make a more informed decision as to whether further action is required, and help form the basis for evaluating the extent of sediment requiring further action.

Example:

At Mocks Pond (a case study that will be fully reviewed for you later), contaminants identified by bulk sediment testing were further evaluated using *in situ* pore water measurements, surface water measurements, tissue testing, and solubility testing . **Remember earlier when I mentioned using multiple lines of evidence to assess the risk . . . this is an example.**

Although bulk sediment testing identified elevated concentrations of heavy metals in the sediment, the bioavailability testing performed showed that some site contaminants were tightly sequestered and not biologically available to water column organisms.

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Remedial Design and Implementation

- Risk mitigation, reduction, or removal is ultimate goal of every remedial action
- If bioavailability indicates adverse impact to receptors, then design the remedy accordingly
- Bioavailability measurement tools can be used to monitor effectiveness of remedy
- Reduction in uncertainty will enhance ability to evaluate monitored natural recovery

Assessing bioavailability will:

•Help to understand what chemicals are available for uptake by receptors (with the potential to cause adverse effects)

•Help characterize toxicity in order to effectively design or implement a remedy to mitigate any negative effects

•Incorporating bioavailability in the early stages will likely reduce overall cost

Bioavailability measurement tools can also be useful in monitoring the effectiveness of a remedy

•Example: pore water monitoring within or above a cap might indicate whether groundwater discharge or upwelling is mobilizing contaminants into a clean cap, or whether bioturbation is mixing clean sediment with the underlying contaminated sediment to a degree that receptors are being exposed again at harmful levels.

20

Limitations and Uncertainty

- There are uncertainties with data assessment methods and models
- Aquatic environments are dynamic, which may alter physical, chemical and biological properties, and therefore bioavailability factors, through time
- Stakeholder interests and land usage at or surrounding a site can change over time, thus shifting remedial priorities
- Regulatory acceptance cannot be assumed

Just remember . . .

- Collect data that answers a question about the site
- Knowing your site and good communication is the key

Highlight of a few limitations and uncertainty.

The take home messages here are:

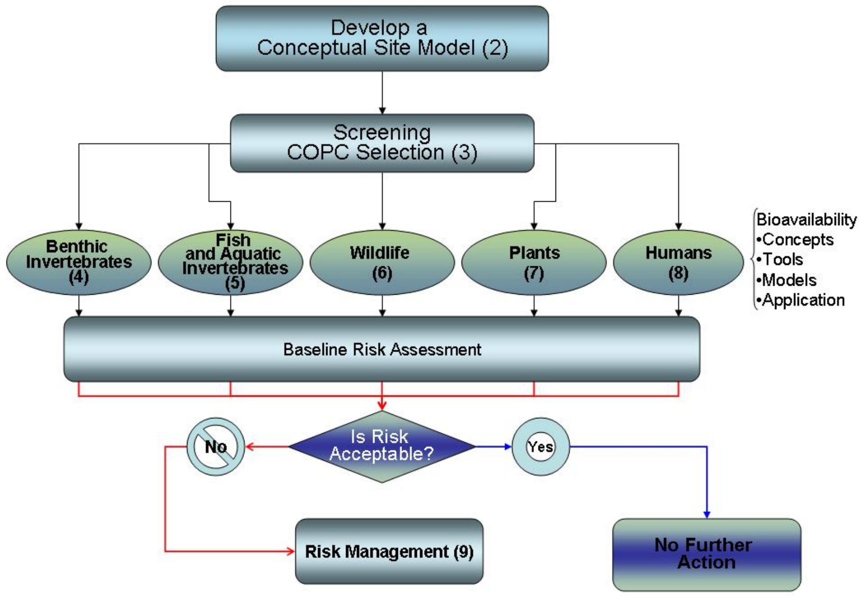
•Collect data that answers a question about the site

•Know your site

•Communicate with regulators and stakeholders

21

Contaminated Sediment Assessment Approach

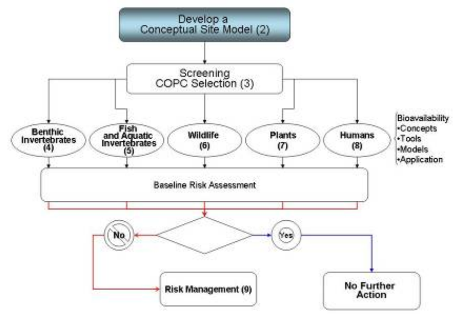


This is a general flow diagram of the layout of the Web-based document. Chapter 2 and 3 cover Scoping and Screening, while chapters 4 through 8 address bioavailability considerations in the evaluation of ecological and human health. Note over on the right that, within each chapter, we address the various concepts, tools, models and applications of bioavailability. All of this information is fed into the risk assessment. As risk is directly proportional to exposure, the risks and costs of the site will be decrease if the bioavailability decreases (e.g. if a bioavailability factor goes from 100% to 50%, the risks are cut in half).

22

Scoping Your Site….Chapter 2

- Site history - Due Diligence
- Site boundaries (extent of contamination)
- Contaminants of potential concern (COPC)
- Conceptual site model (CSM) – source, exposure pathway/route, receptors, space, time, fate & transport



Steps to Scoping Bioavailability in Site Characterization

- Know your Site History (study old aerial photos and site maps, historical processes, blueprints and schematics)
- Realize that “sediments know no boundaries”. For example, dioxins/furand from pulp & paper mills may still be detected 20 mi. downstream .
- Develop a X-tab matrix of COPCs, i.e. chemical class vs. exposure media. Contact State to apply all applicable standards and criteria.
- Develop a conceptual site model (CSMs) that clearly illustrates the source(s), ecological and/or human receptors , exposure pathways linking them, as well as known fate and transfer pathways of the chemicals of concern in sediments.

Identify the tools (biological, chemical, and physical) and models available to measure and test whether those chemicals may be bioavailable to the site receptors.

Explicitly consider the potential site actions and end use, and how bioavailability may be applied in management decisions.

23

Processes to Consider During Scoping

Physical

- Bed Transport
- Deposition/ Resuspension
- Bioturbation
- Advection/diffusion
- Grain size COPC distribution
- Burial
- Temperature

Chemical

- Sorption/desorption
- Transformation/ degradation
- Geochemical (TOC, salinity, pH, Redox)

Biological

- Uptake
- Biotransformation
- Bioaccumulation
- Mode of action
- Critical body burden

Caution – Sediment are mixtures

•It is important to recognize that individual physicochemical and biological processes will INTERACT to affect contaminant bioavailability and therefore exposure of receptors. It is important to address one or more of the factors within each category when developing a Conceptual Site Model (in the next slide) for sediment sites.

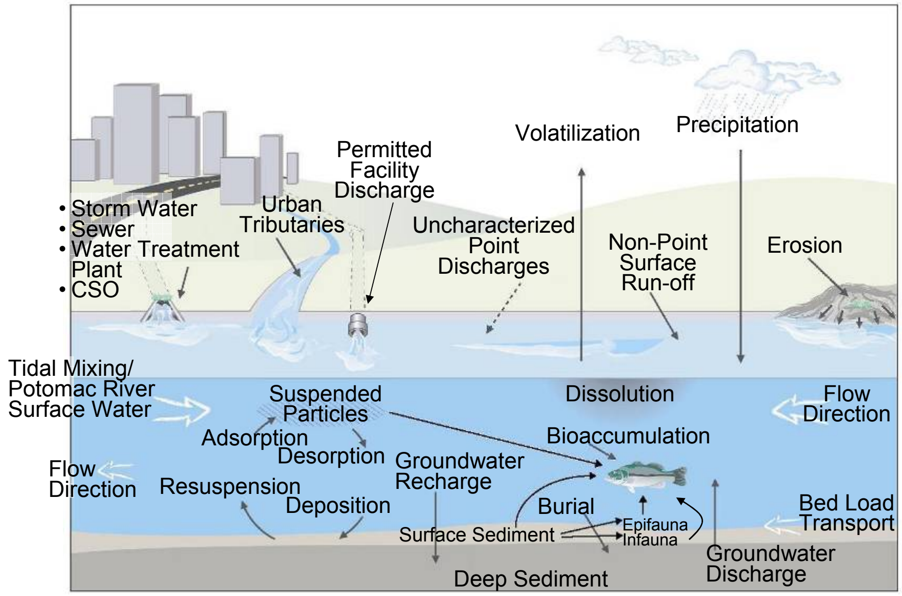
•When designing a field study, the most important physicochemical parameters to measure are TOC (e.g. they bind both organics and metals) and grain size (increased fines increases surface area). AVS, SEM and pore water contaminants may also be included if applicable.

-A good chemical example would be the bioavailability of chromium in sediment. If reducing conditions are observed in all sediment samples due to a high content of organic carbon and/or sulfide (e.g. in estuaries), Cr(III) will be the species that predominates. Cr(III) is virtually insoluble and therefore unlikely to affect benthic invertebrates and will not bioaccumulate in higher trophic levels.

-A good physical example would be the dilution and capping action of sediments due to the tidal deposition of suspended sediment, followed by rapid mixing by fiddler crabs.

24

Example Conceptual Site Model
Anacostia River



•Slide 30 presents an example of how a CSM can be depicted graphically, showing how sediments and receptors within the Anacostia River are affected by non-Site sources and natural processes. This graphic also illustrates the various physicochemical mechanisms that affect contaminant release, fate and transport. A CSM can also be depicted narratively as a flow chart but, however it is presented, it should include the primary and secondary sources, release mechanisms and transport pathways, environmental fate and key receptors.

This is an example of a graphic CSM for the Anacostia River, showing how contaminants are dispersed over time and space by tidal movement, river flow, circulation, deposition. Because many constituents are hydrophobic, sediment dynamics are a key element to understanding contaminant distribution.

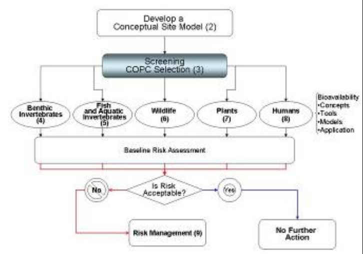
25

Screening Your Site…Chapter 3

- Screening values (e.g. SQVs) are not site specific
- Conservative values
  - Levels below which there is a good probability there is low risk
  - Values above screening levels do not imply unacceptable level of risk
- Determine if there is a need for further investigation
- Do not use as clean up levels/PRGs

Many SQVs have been established

- Beware – know how your screening levels were derived! (e.g. McDonald 2000 "consensus" values)



The US Environmental Protection Agency, 2001, states "Since these [Screening Values] numbers are based on conservative endpoints and sensitive ecological effects data, they represent a preliminary screening of site contaminant levels to determine if there is a need to conduct further investigations at the site. Ecological screening values should not be used as remediation levels."

There are essentially 2 types of sediment quality values:

Benchmarks are essentially established screening levels from the literature. Most benchmarks are based on a sediment quality triad data from co-located samples, i.e. a combination of bulk sediment concentrations, benthic invertebrate metrics and the results of laboratory sediment bioassays. Benchmark values typically include thresholds below which there is a low probability of toxicity and above which the probability of a toxic effect occurring is fairly certain.

The other type of sediment quality benchmarks are site-specific values, which generally capture critical variables related to bioavailability, and rely on the derivation of ecological-, human health-, or water quality-based endpoints to determine the need for further evaluation.

Beware of the validity of the screening values – it is important that you know how the benchmarks were derived.

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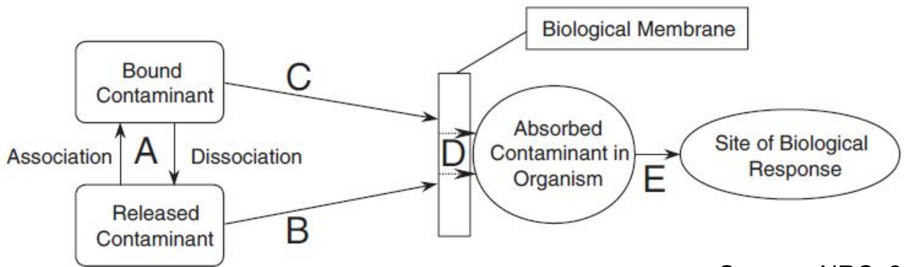
Screening and Bioavailability

- Normalization of bulk sediments (section 3.1.2.2) can be applied within the screening process under some state regulatory programs (e.g. TOC for PAHs/EqP; iron, aluminum for metals)
- However the assessment of site impacts is improved by incorporating bioavailability in later stages of the site investigation using site specific considerations



Source: NRC, 2003

Most states will allow the normalization of bulk sediments, which is simply the reported concentration divided by the fraction (not percent) of TOC.

Example: Wisconsin Dept. of Natural Resources Sediment Guidance

"In the case of nonpolar organic compounds such as PAHs, PCBs, dioxins/furans, and chlorinated pesticides, the bulk sediment concentrations can be normalized to the TOC content for site-to-site comparison purposes by dividing the dry weight sediment concentration by the percent TOC in the sediment expressed as a decimal fraction."

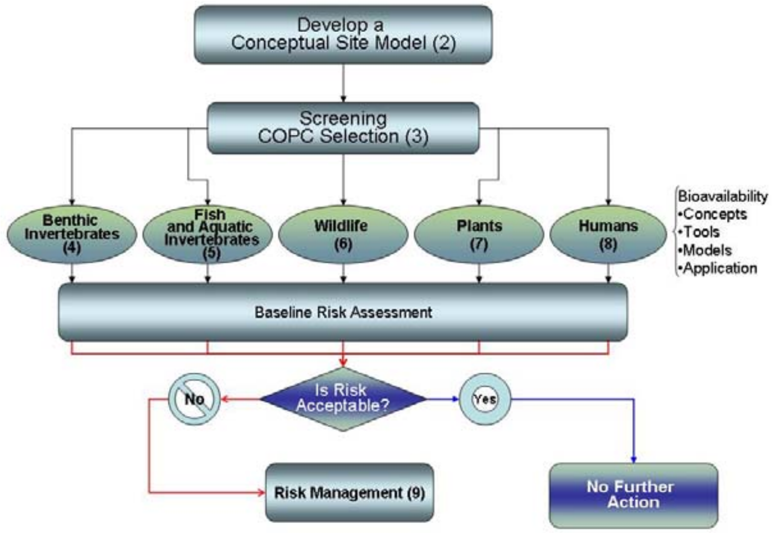
Others states will allow for normalization, such as NJDEP, Washington and Delaware, which allow the use of Equilibrium Partitioning.

THEN

Identify if specific toxicity is made later on in the pathway IF the SQG's are exceeded. You will then need to look into that exposure pathway in more detail.

27

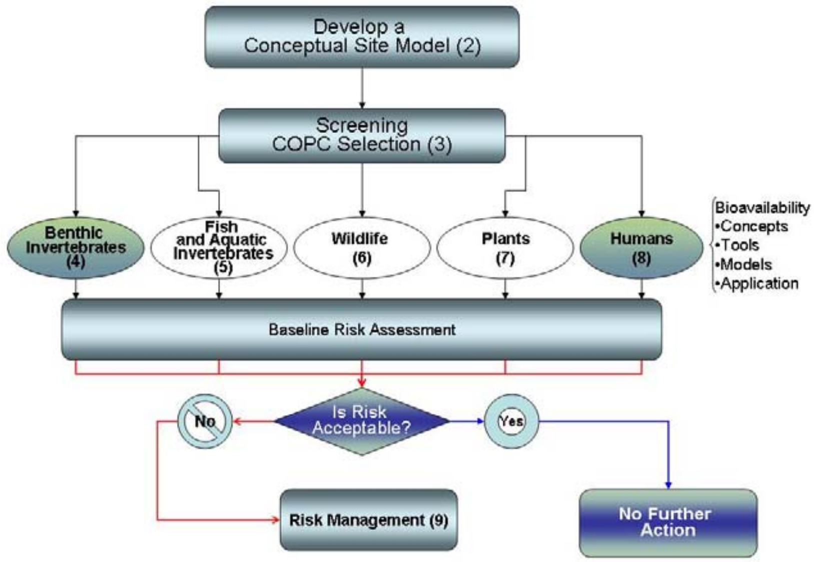
Specific Exposure Pathways



- This slide shows a reiteration of the general structure and flow of the ITRC Contaminated Sediments Bioavailability document. The remainder of this webinar will address Chapters 4 – 9, which examine the role of bioavailability in the direct and indirect exposure of human and ecological receptors at contaminated sediment sites.

28

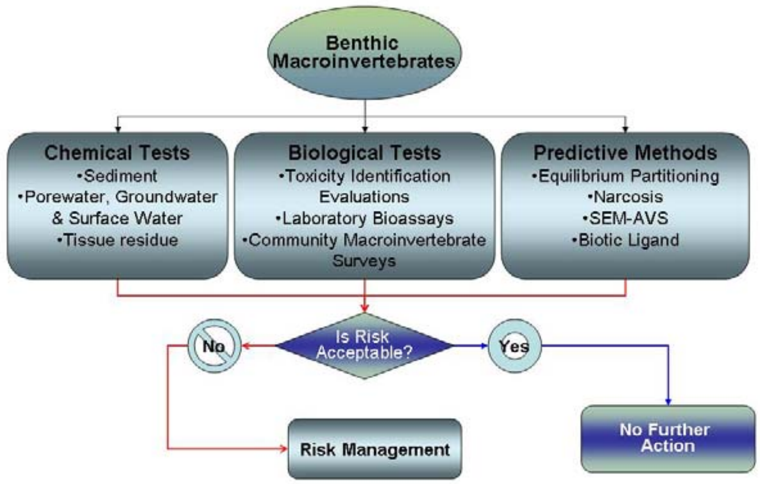
Most Common Exposure Pathways



- Benthic invertebrates and human receptors are the most important in terms of driving a sediment risk assessment. Invertebrates are predominantly sessile and in intimate contact with contaminated sediments and therefore the most susceptible trophic level. They also partially support higher trophic levels and, because humans consume fish, indirectly affect the degree of risk to the local population. Humans may also consume macroinvertebrates (e.g. shellfish) or inadvertently ingest sediment at beaches and recreational areas.

29

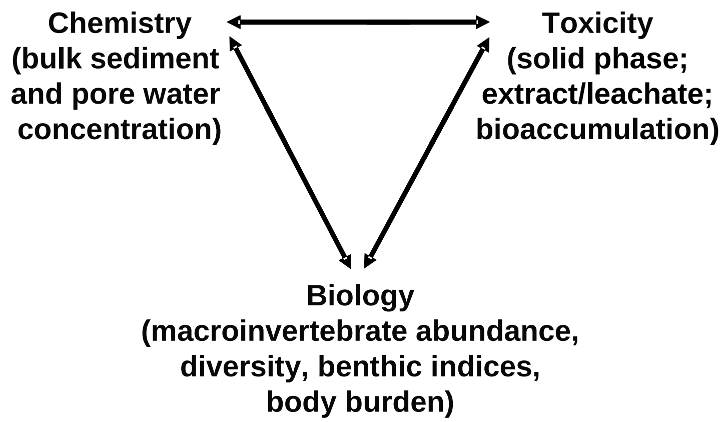
Benthic Pathway…Chapter 4



➢ General schematic for Chapter 4, which addresses bioavailability to benthic invertebrates via chemical tests, biological tests and predictive models and methods. Laboratory analysis of bulk sediment and surface water is a given at a site, but measures in porewater, groundwater and sometimes tissues are critical metrics in the assessment of bioavailability. The second and third leg of a sediment quality “triad” are toxicity bioassays and benthic community surveys, both significant lines of evidence in the assessment of bioavailability and risk. Finally, predictive methods that are based on sound physicochemical and toxicological science can be used to model or directly measure the availability of COC’s to ecological receptors.

Procedures for Assessing Bioavailability to Benthic Invertebrates

- Sediment Quality Triad (SQT):

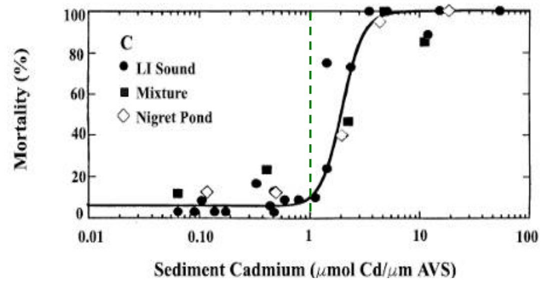


This slide presents the concept of a Sediment Quality Triad, which is a WOE (weight of evidence) approach where measurements on sediment chemistry, toxicity and metrics on native macroinvertebrates are all taken into account to determine whether SS contaminants are responsible for any adverse impacts.

- A Sediment Quality Triad is a three-pronged approach whereby measurements on sediment chemistry, toxicity and metrics on native invertebrates serve as individual lines-of-evidence to inform whether site-specific contaminants are responsible for any adverse impacts.
- SQTs can be modified to address particular concerns, e.g. extraction of in situ pore water and testing it on aquatic organisms (e.g. Daphnia spp.). Another example would be, for sites where divalent metals may be a concern, to include a chelating agent in a separate set of replicates (a TIE approach). Some States have also allowed exposure of caged organisms in situ. Be careful with bioaccumulation testing, as you may need to know a predefined critical body burden if the endpoint is going to be ug contaminant/gram tissue.

Tools to Assess the Benthic Pathway; Chemical - Sediment

- SEM/AVS
  - Simultaneously Extracted Metals/ Acid Volatile Sulfides

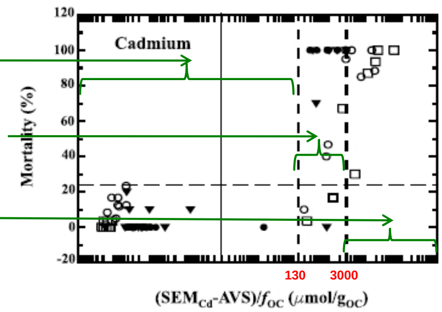


- SEM-AVS/f_{OC}

No Toxicity

Toxicity Uncertain

Toxicity Probable



From EPA-600-R-02-011, 2005

It is commonly accepted that bulk sediment chemistry (mg/kg or ug/kg) is a poor predictor of sediment toxicity.

One tool that is gaining widespread acceptance is the measurement of the amount of divalent metals and sulfide released following treatment with 1N HCl. Simply put, if the amount of sulfide exceeds the amount of extracted metal, then no toxicity will result; but if the amount of SEM exceeds the AVS, then toxicity may occur. The top graphic shows that if the ratio of Cd to AVS is below one, no toxicity will occur; but if the Cd/AVS ratio is above 1, excess metal is available and toxicity will result. The ratio method could only predict when toxicity would not occur, but could not predict toxicity outright.

This methodology has been further refined by observing that organic material binds metals, and both toxicity and the lack thereof can be predicted. The SEM-AVS difference is divided by the fraction of TOC in the sediment sample. Spiking experiments have shown that if the result is <130 umole/gOC, then no toxicity is observed. If the SEM-AVS/foc is between 130 – 3000 umole/gOC, toxicity is uncertain. And if the normalized SEM-AVS >3000 umole/gOC, toxicity is typically seen. It is important to remember this test may be subject to both spatial and temporal variability, and that it does not appear to account for changes in bioavailability that may occur after sediment ingestion by an invertebrate.

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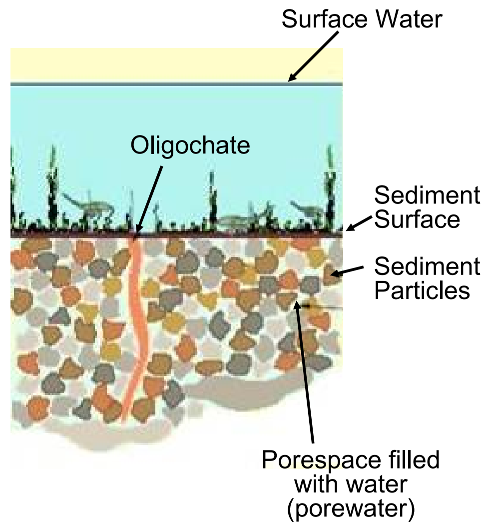
Tools to Assess the Benthic Pathway; Chemical - Porewater

- Porewater (Direct)
  - Centrifugation (lab)
  - Syringes/suction devices
  - Piezometers
  - Ultraseep/Trident probe
  - SPME (solid phase microextraction; EPA SW-846 8272; ASTM D73-63-07)
- Porewater (Indirect)
  - Peeper
  - SPMD (semi-permeable membrane device) / dialysis bags
  - Diffusion in thin films (DGT)
  - SPME, POM (Polyoxymethylene) film, PE (Polyethylene) strips
  - GORE® Module
  - Diffusive flux



- This slide presents some commonly used tools to assess bioavailability, which can be estimated either "Directly" (e.g. centrifugation of sed core sample) or, using "surrogate" devices, "Indirectly" e.g. partitioning to a fat-soluble media over time (e.g. semipermeable membrane devices). Direct examples can be as simple as sampling of porewater using syringes attached to a filtering device (such as an airstone) or complex, using advanced technologies such as an Ultraseep (which we will discuss later).

- Examples of indirect sampling of porewater include all passive sampling technologies, such as "peepers", Semipermeable Membrane Devices (SPMDs), and GORE(tex) Modules. Polyoxymethylene (POM) or polyethylene (PE) strips are polymer strips that will directly sorb hydrophobic organic compounds over time.

33 **Tools to Assess the Benthic Pathway; Chemical - Porewater (Direct) – Suction Devices**

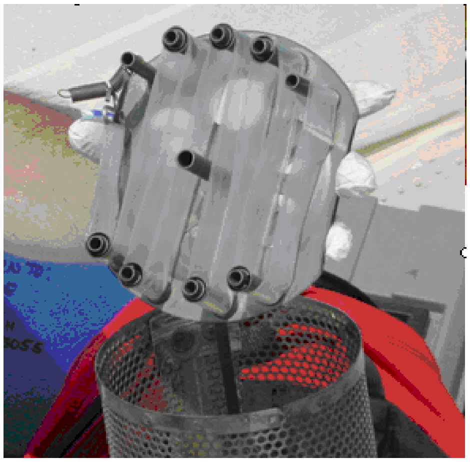
Airstone "Before"

Airstone "After"

- This slide presents an example of a direct porewater study conducted at Farm Pond in Framingham, MA. The source was a TCE groundwater plume moving into adjacent sediments, which exceeded a calculated Equilibrium Partitioning guideline. The problem here is that you cannot conduct a sediment bioassay on VOCs, so the State agreed to allow the comparison of pore water VOCs to Ambient Water Quality Criteria (AWQC).

- The left hand photograph shows a clear PVC "air column" that was introduced from the boat's moon pool into the sediment. A 2.5" white PVC well point was then driven about 8" into the sediment. An "airstone" connected to silicone tubing was then introduced into the well point and suction was applied via a peristaltic pump. The pore water was then collected, analyzed and compared to AWQC. The photograph on the right shows the air stone after it was removed from the pore water. Note that a fine layer of silt that the airstone prevented from entering the porewater sample (which may have biased the results high). This technique is even simpler if the technician is able to wade in and insert the sampler by hand.

34 **Tools to Assess the Benthic Pathway; Chemical - Porewater (Indirect) – SPMD/Dialysis Bags**



SPMD “Before”

SPMD “After”

- This slide presents a study in a large river in Maine, where SPMDs were used to determine the bioavailability of dioxins and furans below a pulp & paper mill. The SPMD is “loaded” with 1 milliliter of triolein, which is a pure oil that mimics the lipid in an aquatic organism. The left hand photograph shows the SPMD wound around a “spider”, and four of these are then loaded into a perforated stainless steel cylinder shown at the bottom of the picture. These stainless steel deployment devices are then left in the waterbody for about a month.
- The right hand photograph shows the SPMD after retrieval from the deployment device, with a moderate degree of biofouling. The debris on the SPMD is gently wiped off and then it undergoes reverse dialysis in hexane to quantitate the dioxin/furan congeners. The amount in the downstream SPMDs is then compared to the amount in the SPMDs that were deployed upstream of the mill.

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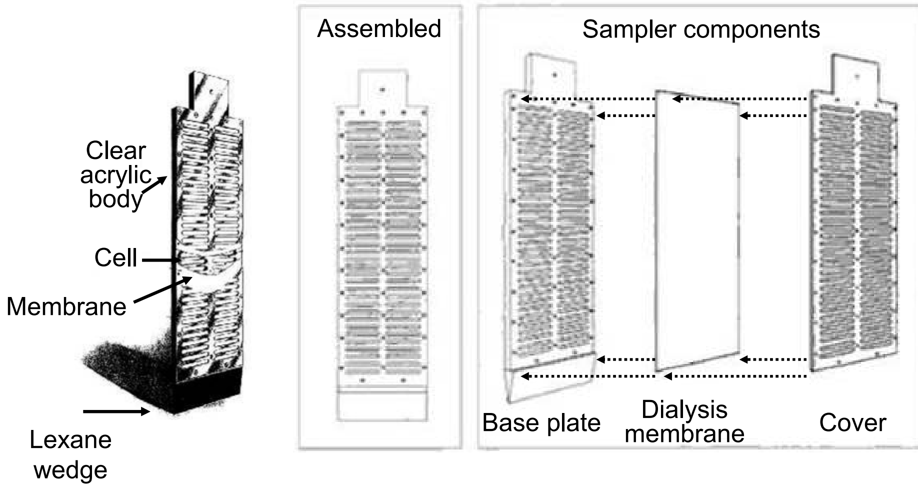
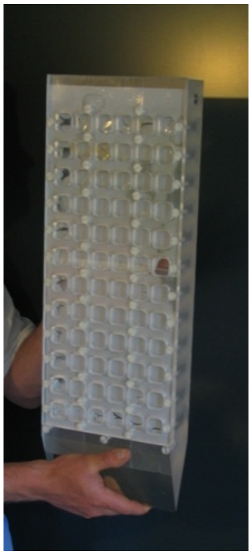
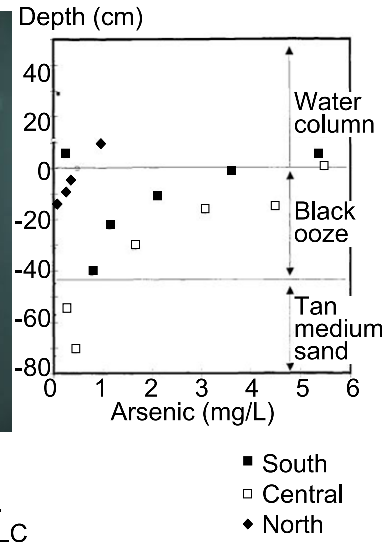
Tools to Assess the Benthic Pathway; Chemical - Porewater (Indirect) – "Peepers"



- This slide presents another indirect passive method known as "sediment peepers". Porewater can be measured indirectly using these "peepers", which are Lexan sampling devices containing rows of empty cells that are milled into the unit. The cells are filled with distilled water, a dialysis membrane sheet is placed over all the cells, and a protective cover is then screwed down over the sheet. The Peeper is then inserted into the sediment, leaving 3 or more cells projecting up into the water column. They are typically deployed for about a month, retrieved, and each cell is the sampled and analyzed. The analysis provides a vertical snapshot, typically every 2 cm or so.

Tools to Assess the Benthic Pathway; Chemical - Porewater (Indirect) – "Peepers"



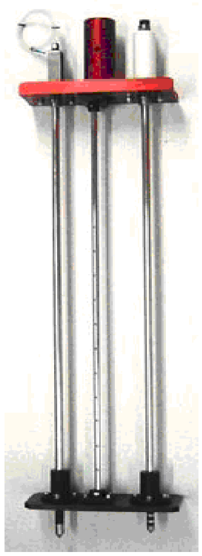


Photographs courtesy of A. Lee Gustafson, Net Zero LLC

- The photos (left) shows a large Lexan peeper, with six individual cells in each row. The wedge at the bottom allows for easier penetration of the peeper into the sediment.
- The photo in the middle shows a smaller peeper that is designed for harder substrates (e.g. a flowing stream containing a coarse sand or gravel substrate).

37 **Tools to Assess the Benthic Pathway; Chemical - Porewater (Direct) – Trident Probe and Ultraseep**

Trident Probe*

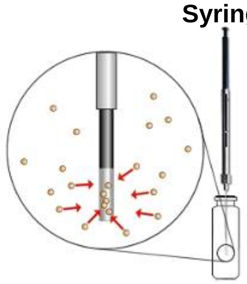


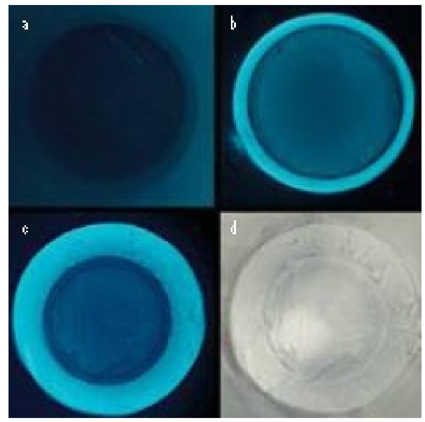
Ultraseep*

*http://www.oceanscience.com/pdf/ultraseep_trident.pdf

- This slide presents a much fancier technology for directly sampling and monitoring of porewater. The Trident probe is typically used to identify where a groundwater plume may be moving into a water body. It is equipped with a two sensors, one for temperature and one for conductivity, as well as a probe for sampling pore water. The Trident probe is pushed into the sediment bed from a small boat with a 12-m push rod. The use of these probes will allow the identification of the colder groundwater plume.
- Using the resulting map of conductivity and temperature, the UltraSeep monitor is then deployed at the most appropriate location. The seepage through the instrument is measured with a specially developed flow meter. Seep fluid is conditionally sampled when threshold levels of T,C or flow are exceeded. Data is recorded with an onboard logger.

38 **Tools to Assess the Benthic Pathway; Chemical - Porewater (Direct/Indirect) – SPME (Solid Phase Micro Extraction)**





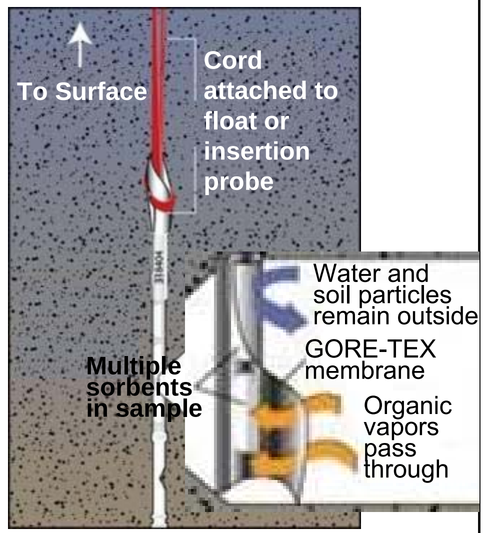
- This slide presents a method known as Solid Phase Microextraction, or SPME for short. SPME's are coated with a hydrophobic polymer that binds hydrophobic organic contaminants (HOCs). They can be thought of as a very short gas chromatography column turned inside out. The quantity of analyte extracted by the fiber is proportional to its concentration in the sample as long as equilibrium is reached. The beauty of SPME is that extraction is fast, simple and performed on small volumes of samples w/o solvents. Detection limits can reach parts per trillion (ppt) levels for certain compounds.

- The photograph on the left shows a SMPE device, and the middle graphic shows how it can be inserted into a sampling vial in the laboratory, where it will bind hydrophobic organic compounds. The photographs on the right show 4 magnified cross-sections of a SPME. The upper left and lower right hand photographs are unexposed SPMEs under fluorescent and light microscopy, respectively. The lower left and upper right hand photographs show respective thick and thin coated SPMEs after exposure to PAHs, which will fluoresce under UV light.

- SPME has great potential for field applications; on-site sampling can be done by nonscientists without need to have gas chromatography-mass spectroscopy equipment on location. When properly stored, samples can be analyzed days later in the laboratory without a significant loss of analytes.

39 **Tools to Assess the Benthic Pathway; Chemical - Porewater (Indirect) – GORE® Module**

- Screening tool that can be used to sample porewater
- Measure concentrations in GORE lab only
- Verified use in groundwater
- Mainly effective for VOCs



- This slide presents another methodology that can be used in either the field or the laboratory. The GORE® Module is a hydrophobic gas-permeable GORE-TEX Membrane that acts as a partitioning surface, allowing dissolved compounds with sufficient volatility to partition out of solution and adsorb to the membrane. Liquid water and particulates do not come in contact with the adsorbent. A wide range of volatile and semi-volatile compounds can be detected.

- The Module is inserted directly into sediment with no additional modification. Installation generally requires minimal equipment and allows sampling in areas that may not be accessible for more invasive sampling methods. Impact to eco-sensitive areas is minimal. Divers may be needed for deeper water installations.

- Exposed samplers can be held on the shelf for several days to weeks prior to analysis with virtually no compound loss. Analysis is by thermal desorption (no solvents), gas chromatography, mass selective detection. Porewater concentrations are calculated based on the measured mass adsorbed (ug), measured compound-specific sampler uptake rates (L/hr), and measured exposure time (hr).

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Tools to Assess the Benthic Pathway; Biological - Sediment Toxicity Tests

Hyalella azteca

FRESHWATER

Chironomus dilutus

Neanthes arenaceodentata

BRACKISH OR SALTWATER

Eohaustorius estuarius

- Now we move on from chemical tools to biological tools in Slide 44. Sediment toxicity tests measure whether organisms exposed in the laboratory will exhibit adverse effects following acute or chronic testing. Because sediments are mixtures of chemicals, toxicity tests will measure the combined effects of all of the physicochemical parameters of bulk sediment such as bioavailable contaminants, grain size, nutrients, ammonia, and sulfide.
- The photographs on the left of Hyalella and Chironomus species are representative of typical test organisms for freshwater sediments. The photographs of Neanthes and Eohaustorious species are typically used for testing sediment sampled from brackish or marine environments. The photograph in the middle shows a typical laboratory set up, where sediment is placed in jars with overlying water, allowed to equilibrate for 24 hours, and then organisms are added, typically in replicates of 5 – 7 jars per station.
- At the end of the test (typically 10 days for acute and >28 days for chronic), the organisms are sieved out of the sediment and a wide range of biological endpoints are measured, most commonly survival and growth. There are also bioaccumulation tests that will measure indirectly measure bioavailability (i.e. concentration in sediment vs. concentration in test organisms).
- If correctly performed, the results can be ecologically meaningful and relevant. For example, if you graph sediment concentration vs. mortality but there is no increase in effect with an increase in concentration, then site-related constituents were not bioavailable.

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Tools to Assess the Benthic Pathway; Biological - Macroinvertebrate Surveys

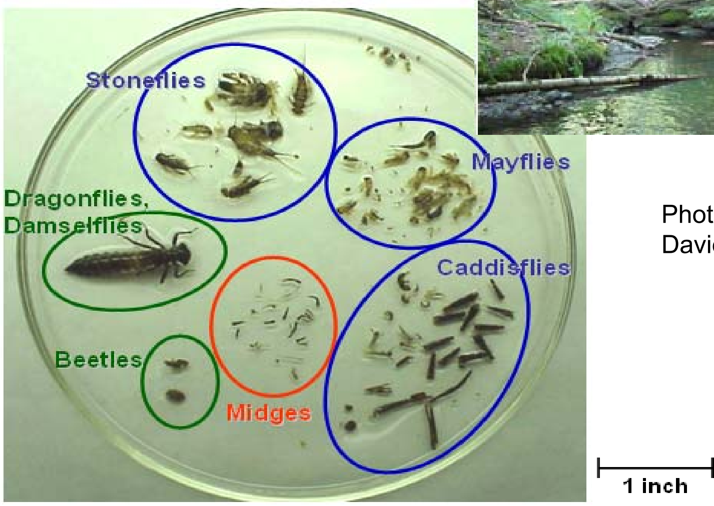
“Pollution Sensitive” “Pollution Tolerant”

Benthic Metrics: Abundance, Richness, %EPT, %Dominance, %Chironomids, Hilsenhoff’s or Shannon-Weiner Diversity Indices

- This slide moves on to macroinvertebrate surveys, which are useful in that the types and numbers of organisms directly reflects the combined influences of physicochemical stressors. It should be evident from this slide that pollution sensitive organisms, in the left hand group of photographs, are delicate in appearance and typically have external gills (represented here by larvae of mayfly, caddisfly and stoneflies), whereas pollution tolerant organisms (in the right hand set of photographs) generally include worms, leeches and dipterans (such as black flies).

- USEPA’s Rapid Bioassessment Protocol’s, which provide a tiered approach tailored to your time and budget, have been used or adapted by many States for over two decades. They include habitat analysis and benthic macroinvertebrate field scoring sheets, as well as a complete “cook book” approach to how to use biological endpoints to assess the various functions of stream ecosystem health. Metrics include measures of abundance and diversity, and pollution tolerance scores are published in the Appendix for estimating impacts such as the Hilsenhoff Biotic Index..

Tools to Assess the Benthic Pathway; Biological - Minimally Disturbed Stream



Photos courtesy of Susan Davies, Maine DEP

- This slide presents a community in a stream that sees very little, if any, disturbance by human development. All the major insect families are well represented and evenly distributed.
- The USEPA likes to see three major families represented: the mayflies, the stoneflies and the caddisflies. The acronym “EPT” is used to represents the first letter for each of the three families. The percent EPT is often used as an indicator of clean water and, if all three families are present and evenly distributed, then the macroinvertebrate community is considered to be robust and the waterbody relatively unimpacted.

43 **Tools to Assess the Benthic Pathway; Biological - Stream Adjacent to Shopping Mall**

Photos courtesy of Susan Davies, Maine DEP

1 inch

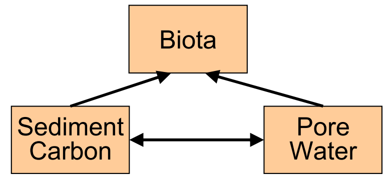
- On the other hand, this slide presents a sample from a community that is below a stormwater outfall in a suburban area. This graphic shows that the community is dominated by pollution tolerant organisms such as leeches, snails, midges and amphipods. The organisms represented here are fairly resistant to poor water quality (e.g. low Dissolved oxygen, high conductivity and temperature).

44

Tools to Assess the Benthic Pathway
Predictive

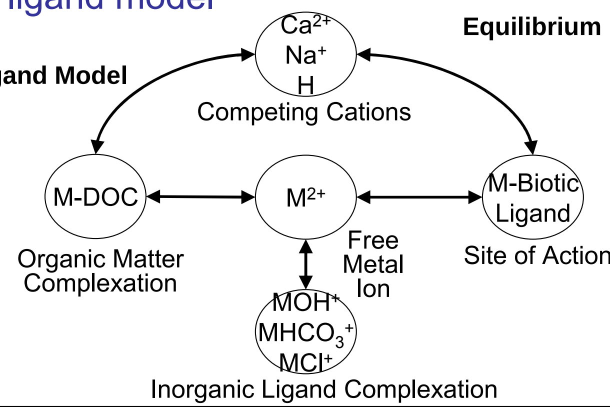
- Equilibrium partitioning
- Narcosis model
- SEM-AVS/f_{OC}
- Biotic ligand model

Sediment – Pore Water Exposure



Equilibrium partitioning

Biotic Ligand Model



Tipping, 1994

Finally, we list some of the predictive tools that can be used to determine whether a site-related chemical may be bioavailable or exceed a toxic threshold. We have already discussed how sulfides and organic carbon in sediment can bind metals and thus reduce or eliminate bioavailability.

Equilibrium partitioning theory assumes that the dissolved porewater concentration of an organic compound is in equilibrium with the concentration bound to organic carbon in sediment. A nontoxic sediment concentration is then back-calculated by setting the porewater concentration equivalent to an Ambient Water Quality criterion and, using the chemical-specific organic carbon partition coefficient, calculating an organic carbon-normalized sediment value. This value can then easily be converted to a bulk concentration based on the site-specific total organic carbon in sediment.

Additional information on both Narcosis Theory, which addresses Critical Body Residues at which a toxic effect will occur, and the Biotic Ligand Model, which addresses the toxicity of metals to aquatic organisms, are explained in more detail in Chapter 4 of the Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites document.

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Case Study Using the Benthic Pathway
Tectronix Wetlands Beaverton, OR

- Historic operations → sediment metals exceeding Oregon Department of Environmental Quality (DEQ) Level II screening level values
  - Assessed chemistry, toxicity, SEM/AVS,TOC
    - Maximum (SEM-AVS)/f_{oc} was ~10 less than EPA's adverse effect level
  - Toxicity tests
    - Hyalella azteca mortality
    - Chironomus dilutus growth
    - No adverse effect on amphipods or midges
- Assessment concluded concentrations did not pose potential risks to benthic community
- NFA for stretch of Beaverton Creek based on
  - Results from bulk sediment chemistry
  - Toxicity testing
  - Comparison to (∑SEM-AVS)/f_{OC} toxicity threshold

Photo courtesy
Kathleen Hurley

Historic operations → sediment metals exceeding Oregon DEQ Level II screening level values

Assessed chemistry, toxicity, SEM/AVS,TOC

maximum (SEM-AVS)/foc in any sediment sample was a factor of approximately 10 less than the EPA's adverse effect level

Toxicity tests with *Hyalella azteca* and *Chironomus dilutus* performed on subset of upstream and on-site sediment samples

None of sediment samples had adverse effect on amphipods or midges based on the *H. azteca* mortality endpoint and *C. dilutus* growth endpoint

Assessment concluded that surface sediment metals concentrations exceeding Oregon DEQ Level II SLVs did not pose potential risks to the benthic community

An NFA was determined for a stretch of Beaverton Creek in Oregon based on results from bulk sediment chemistry, toxicity testing, and comparison to (∑SEM-AVS)/f_{OC} toxicity threshold.

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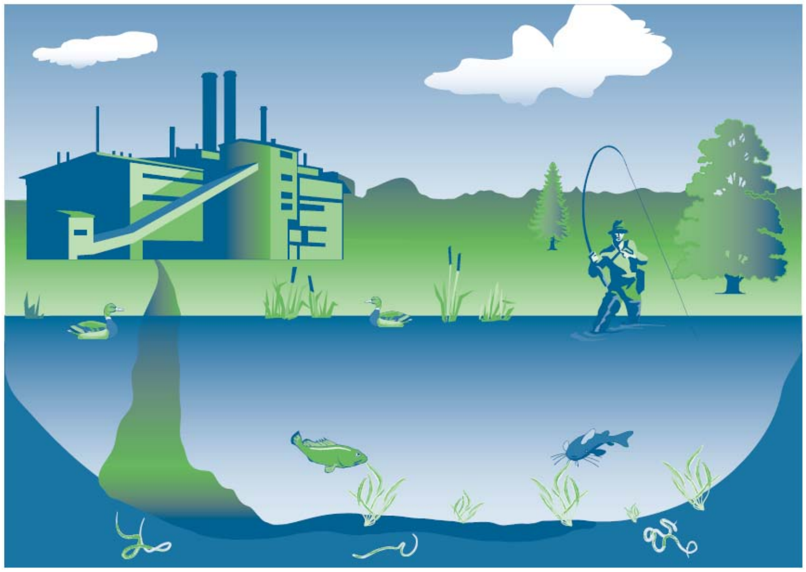
Questions & Answers



No associated notes.

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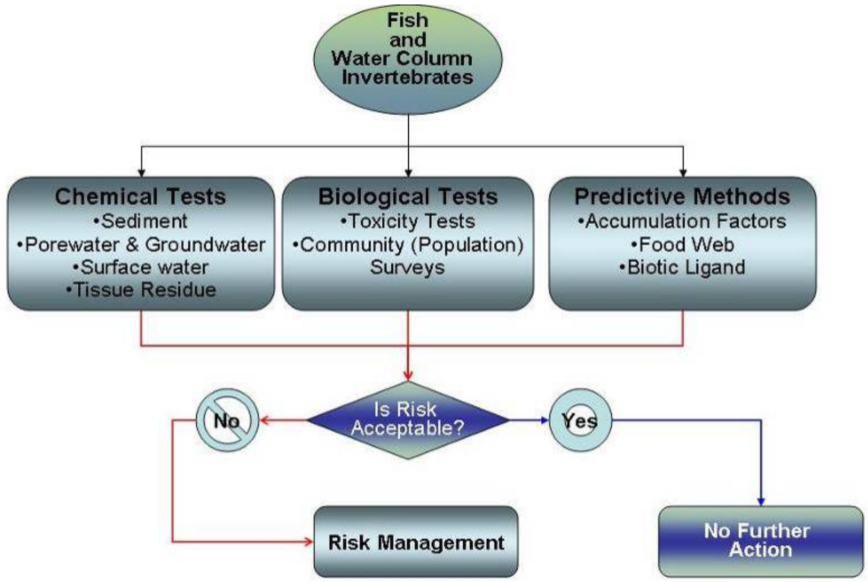
Fish and Water Column Invertebrates Pathway…Chapter 5



A schematic for Chapter 5 which addresses bioavailability to fish and water column invertebrates. This flow chart is similar to Chapter 4 in that the chapter has segregated assessment into Chemical, Biological and Predictive Methods.

You have to first identify that there is a problem that may impact ecological or human receptors before needing to assess bioavailability. The primary pathway that becomes the basis of the response action is typically based on a benthic impact or on the results of risk from consumption of fish by humans. Incorporating bioavailability tools into the sampling plan can significantly affect the type and costs of the response action.

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Tools to Assess the Fish and Water Column Invertebrates Pathway Chemical

- Measure water quality above sediment bed → compare to
  - National recommended water quality concentration
  - State water quality standards
- Measure water and tissue residues → compare to
  - Bioaccumulation Factors (BAF)
  - Critical Body Burden (CBB): ~2.5 umol/g wet weight
  - Toxicity Reference Values (TRV)
- Measure Biota-sediment accumulation factors (BSAFs) = $[COPC_{tissue}/f_{lipid}] / [COPC_{sed}/f_{OC}]$
  - <1 or >1?

- This slide addresses chemical measurements which always include comparing surface water data to National Recommended Ambient Water Quality Criteria
- COPCs measured in water and fish tissue will allow the calculation of site-specific Bioaccumulation Factors (BAFs). These data will also allow the estimation of Critical Body Burdens and, for food chain models, comparison to Toxicity Reference Values (in mg/kg/day).
- Measuring site-specific Biota Sediment Accumulation Factors (BSAFs) is one of the most common screening tools. If the ratio of lipid-adjusted tissue residues are generally less than two, then the COPC will not bioaccumulate. Ratios typically greater than 2 may have a potential to accumulate within the food chain.

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Tools to Assess the Fish and Water Column Invertebrates Pathway Biological

- Conduct sediment toxicity tests using appropriate organisms and conditions
- Measure in situ bioavailability from field-collected organisms
- Conduct population surveys → compare to "reference" conditions

- This slide addresses the incorporation of biological tools, such as performing sediment toxicity tests using appropriate organisms and conditions. An example would be exposing fathead minnows above sediment in aquaria followed by measurements of biological endpoints (survival, growth) and/or the estimation of BSAFs.
- In situ bioavailability can also be measured in the field by collecting fish and sediment from the site. Once collected, residues can be measured in the fish and sediment and, once normalized to % lipid and TOC, respectively, site-specific BSAFs can be calculated.
- Finally, fish can be quantitatively sampled from both the site and off-site reference areas and fish meristics, such as growth rate and biological condition factors, can be compared to see if the site has impacted the fish community.

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Tools to Assess the Fish and Water Column Invertebrates Pathway Predictive

- Accumulation factors
  - Bioconcentration factors
    - USEPA EPISuite
  - Bioaccumulation factors
    - Public domain
    - Peer-reviewed literature
  - Biota-sediment accumulation factors
    - e.g. U.S. Army Corp of Eng or ORD BSAF Dbase
  - Biomagnification factors
- Biotic ligand model (metals)
- Food web models

- This slide presents predictive methodologies that can be used to evaluate impacts to fish or water column invertebrates, such as the use of BSAFs (which can be researched using databases in the public domain, such as the Army Corp Environmental Effects Residue Database).
- The Biotic Ligand Model has been shown to be an accurate method for addressing the toxicity of metals dissolved in the water column. For example, it is currently being used to develop a National Recommended Water Quality Criterion for copper. Although this model contains very complicated algorithms, it has a very user friendly "front end" and only requires conventional water chemistry parameters, including pH, hardness and electrolyte concentration.
- Finally, there are many different types of food web models in the public domain, some of which can predict fish tissue concentrations with a fair degree of accuracy (assuming the model is adequately calibrated to the waterbody at hand). Many of these models, however, have a steep learning curve and are "data hungry", so to speak.

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Case Study Using the Fish and Water Column Invertebrates Pathway

McCormick and Baxter Superfund Site, OR

- Residual creosote-derived contaminants including PAHs and dioxins
- Assessments
  - Sediment chemistry
  - Bioassays
  - Tissue residues in fish and crayfish
  - Fish histopathology
- Results
  - Sediment chemistry and toxicity testing
    - Indicated area of the Willamette River - likely to be toxic
  - Tissue residues for PAHs were low in
    - Crayfish (Pacifastacus leniusculus)
    - Large scale sucker (Catastomus macrocheilus)
    - Examination of 249 fish livers found no statistical differences between the site and upstream locations
- ROD required placement of an impermeable cap, based on
  - Sediment chemistry and bioassay data
  - Continuing NAPL discharges from sediments to Willamette River

McCormick and Baxter Superfund Site, OR

Assessed effects of residual creosote-derived contaminants including PAHs and dioxins

Assessment included sediment chemistry, bioassays, tissue residues in fish and crayfish, and fish histopathology

Sediment chemistry and toxicity testing indicated a substantial area of the Willamette River (adjacent to the site) are likely to be toxic

By contrast, tissue residues for PAHs in crayfish (*Pacifastacus leniusculus*) and Largescale sucker (*Catastomus macrocheilus*) were low

An examination of 249 fish livers found no statistical differences between the site and upstream locations

Based principally on sediment chemistry and bioassay data, as well as continuing NAPL discharges from sediments to Willamette River, the ROD (Record of Decision) required placement of an impermeable cap

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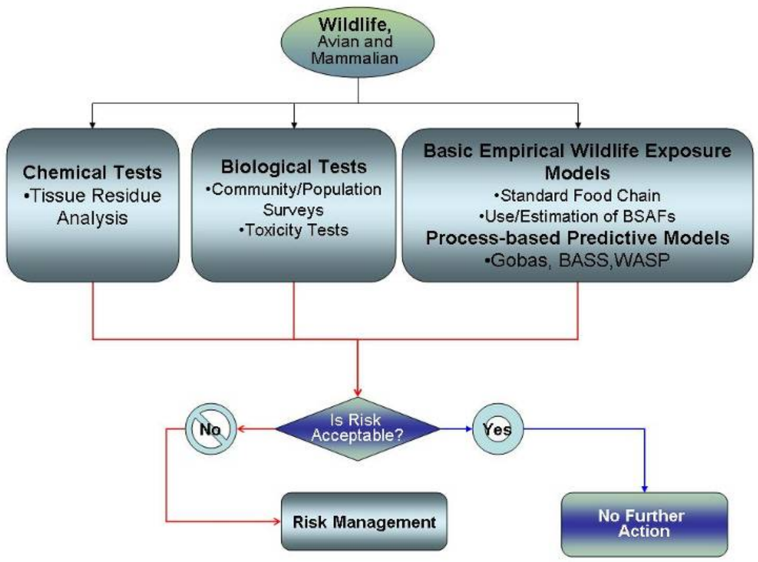
Wildlife Pathway…Chapter 6



Similar to the past chapters, the wildlife pathway is also categorized into chemical and biological tests, as well as the use of predictive methods that can be found in the public domain.

Have to identify that there is a problem first that may impact ecological or human receptors. (EPA ERAGS) The primary pathway that becomes the basis of the response action usually based on benthic, fish or human health consumption data. Incorporating bioavailability tools into the sampling plan can potentially impact that response action.

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Tools to Assess the Wildlife Pathway: Indirect Measures

- Wildlife effects (already known)
  - Bulk sediment (mg/kg)
  - Literature BAFs
  - Percent of diet
- Calculate: dose (mg/kg/day)
- Compare: to threshold reference value (TRV)
- Pass?
  - Yes → NFA
  - No → SLERA/BERA
- Exposure/effect: bioaccessibility in sediment

Freshwater (Mallard)

Saltwater (Sandpiper)

$$\text{Dose}_{(mg/kg/day)} = \%\ \text{Sediment (in diet)}$$

$$C_{SED}\ (mg/kg) \times \%_{diet}\ (kg/day) = mg/kg/day$$

- These slides present some of the indirect measures to assess the bioavailability of COPCs to wildlife. Screening is the first step and can be carried out with just the bulk sediment concentrations and 1) assuming that wetland-dependent birds inadvertently ingest a known percentage of sediment (adjusted for the % of the “home range”) 2) that the “dose” can be easily calculated based on literature-derived BAFs (e.g. 50% for arsenic) and 3) this dose can be compared to published TRVs. If the dose is less than the TRV, then no further action is required. If the dose is greater than the TRV, then the risk evaluation would proceed to a SLERA (screening level environmental risk assessment) or a BERA (baseline environmental risk assessment).

BAFs = bioaccumulation factors

TRV = threshold reference value

SLERA = screening level ecological risk assessment

Tools to Assess the Wildlife Pathway; Indirect Measures

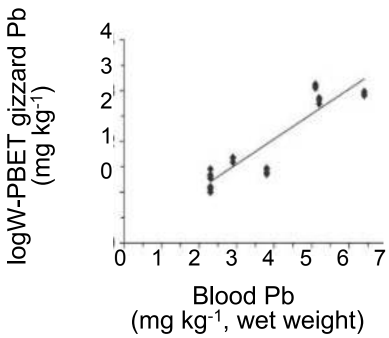

Photo courtesy of Nick Basta, Soil & Envir. Chemistry, Ohio State Univ.

Furman et al., J. Environ. Qual. 35: p. 450 https://www.soils.org/publications/jeq/articles/36/3/899

- Another method to indirectly assess the fraction of COPC available to a wildlife receptor would be to perform an in vitro gastric simulation test, which is a sediment extraction test that mimics the gastric juices of a bird. The amount of COPC that is extracted off the sediment would be the maximum amount that would be available for uptake by the GI tract of the receptor. The photograph is an actual laboratory set up for this type of extraction test. The graph shows the strong correlation between the results of an in vitro test and the blood lead measured in mallards dosed with the same material.

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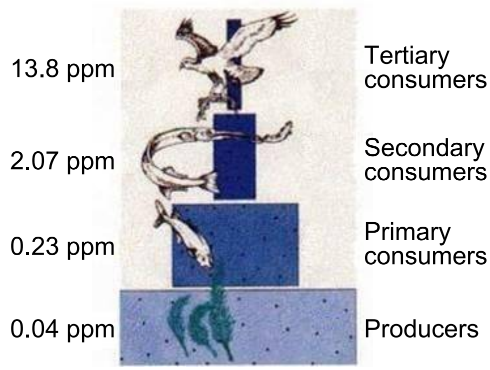
Tools to Assess the Wildlife Pathway; Direct Measures

- ▶ Tissue residue analysis
  - Need clear endpoints
- ▶ Toxicity testing
  - Expensive but site-specific
- ▶ Food web modeling
  - Simple vs. complex
- ▶ Population surveys
  - Consider scale vs. home range



- This slide addresses more direct, but costlier, methods for determining bioavailability of sediment residues to wildlife. Tissue residue analysis is commonly used by wildlife or fish & game managers, but it is important to first know the specific endpoint you are researching. For example, will a particular mercury level in the eggs, feathers or blood of loons indicate an adverse effect to the local population? Or is this measurement being used to try to determine if there is a trend over time for a particular water body that has elevated levels of mercury in the sediment?
- Toxicity testing is available for a number of wildlife species, but this route is generally used for very large hazardous waste sites where millions of clean-up dollars are at stake. Wildlife testing by private animal laboratories is time consuming and expensive, but the results are generally dependable in that a dose-response function can be generated for a particular COPC and/or species of interest.
- Food web modeling can be as simple as an Excel spreadsheet (e.g. using USEPA's equations and parameters in their Exposure Factors Handbook) and can be as complex as public domain legacy models that have more than 3 decades of research and programming experience behind them. Although somewhat data intensive, fugacity models appear to be the best trade off, in that they accurately predict receptor exposure concentrations at the local, regional and even global levels.
- Finally, population surveys can be done for various wildlife receptors but, as with environmental monitoring of residues, one needs to carefully balance not only the cost/benefit ratio of initiating an expensive survey but also whether the answer will be environmentally relevant in terms of the animals exposure range vs. its "home" foraging range.

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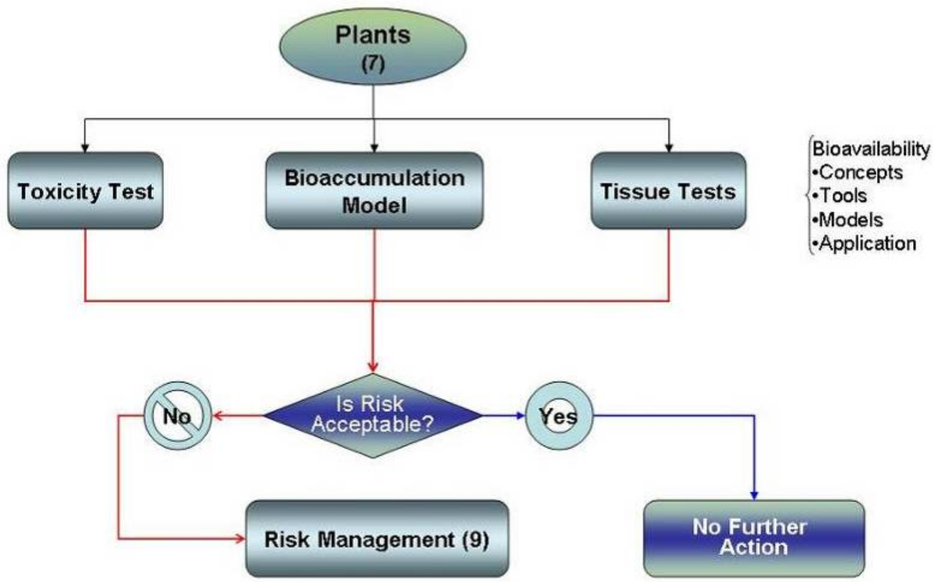
Plants Pathway…Chapter 7



- The flow chart used for Chapter 7, which evaluates the typical assessment/sampling protocol for aquatic plants. Plants can be assessed using toxicity tests, bioaccumulation models or through the direct sampling of vegetation.
- It must be kept in mind that toxicity to plants are often assessed in terrestrial environments but rarely addressed in the evaluation of sediment sites. When they are assessed, it is usually the measurement of plant residues to be used as input for foraging wildlife, such as the consumption of seed by birds or lily pad root nodules by swans.

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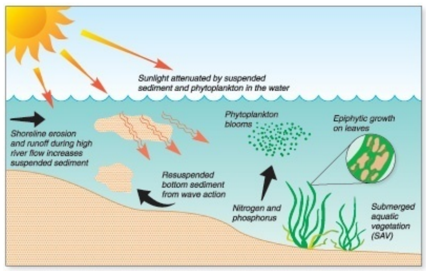
Tools to Assess the Plants Pathway

- Bioassay (e.g. seedlings)
- Bioaccumulation (vegetative)
- Plant toxicity (e.g. boron)



- This slide briefly addresses the 3 areas of assessment in terms of sediment exposure adversely affecting plants. Plants are typically viewed as a dietary component of certain wildlife and therefore are usually sampled for residues, which in turn are used as input into a food web model.
- Bioassays using various types of aquatic plants or marsh plant seeds are available, which will examine whether a particular sediment at a site is phytotoxic (e.g. dredge spoil), conducive for the growth of a native plant species or may bioaccumulate COPCs (e.g. cadmium).
- Plant toxicity would be considered an important component of a site that needed to recover through plantings or by natural revegetation (e.g. marsh grasses). This is important because growth of rooted aquatic vegetation serves to encourage sediment deposition which, in turn, will provide more substrate for additional plant growth. Rooted aquatic vegetation serves as critical habitat for the breeding and survival of fish eggs and small fish fry.

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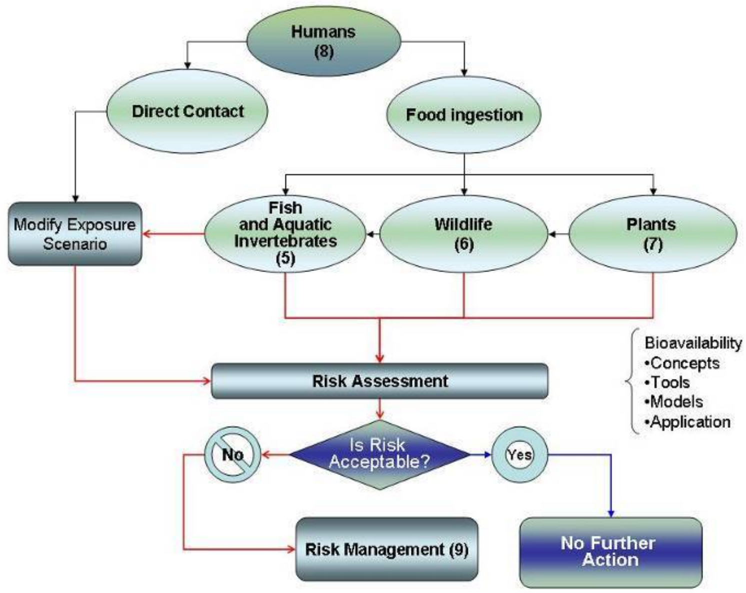
Human Health Pathway…Chapter 8



Typical assessment/sampling protocol follows this simplified pathway

Have to identify that there is a problem first that may impact ecological or human receptors. (EPA ERAGS) The primary pathway that becomes the basis of the response action usually based on benthic, fish or human health consumption data. Incorporating bioavailability tools into the sampling plan can potentially impact that response action.

Exposure in Human Health Pathway

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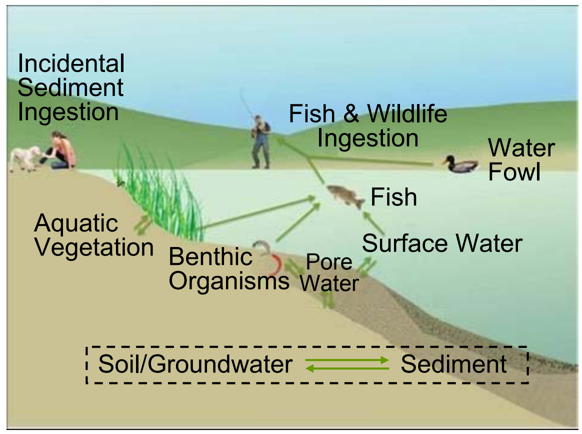
- Direct contact with sediment
  - Ingestion
  - Dermal contact
- Consumption
  - Fish
  - Wildlife
  - Plant



Human exposures risks may arise from dermal contact with sediment or incidental ingestion of sediment during activities such as swimming, beach use, dockyard work, boat and marine equipment operation/repair, diving, etc.

In evaluating whether dietary exposure to human is an important pathway, consideration should be given to the type of contaminant. The USEPA has identified 12 constituents as persistent, bioaccumulative and toxic (PBT; http://www.epa.gov/pbt/pubs/aboutpbt.htm). Some states and regions, such as Texas and the Sediment Evaluation Framework for the Pacific Northwest, have established lists of contaminants for which the bioaccumulative pathway must be considered. In general, however, bioaccumulation concerns should be limited to selected classes of organics (pesticides, PCBs, dioxins) and mercury.

Direct Contact

- Preliminary screening
  - Compare bulk sediment concentrations to human health-based soil screening levels (SSLs)
- Refine screening levels
  - Modify exposure variables
  - Modify bioavailability assumptions
    - Adherence of sediments to skin
    - Dermal absorption efficiency
    - Gastrointestinal absorption efficiency

EPA's Risk Assessment Guidance (RAGS) provides information on bioavailability factors for various COPCs in soil.

The Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles also provide contaminant-specific absorption information (http://www.atsdr.cdc.gov/toxprofiles/index.asp).

Dermal Contact

Factors that decrease bioavailability include:

water content, complexation in the water column, and degree of sediment presence above water

Skin adherence (e.g. wet soil) could also be applied to sediment

Uptake

Gastrointestinal tract comparable to soil

EPA Regions may provide how to develop site-specific bioavailability factors

For Example: Region 8 recommends a "conservative" relative bioavailability factor of 0.5 for arsenic from contaminated soil (i.e. 50% of the soil arsenic, relative to sodium arsenate, will be absorbed from the gastrointestinal tract).

In vitro gastric simulation test can generate site-specific bioavailability factors

Human Consumption of Fish and Shellfish

- Contaminants of concern
  - Primarily concerned with bioaccumulative constituents
  - *In general* bioaccumulation concerns should be limited to select classes of organics (pesticides, PCBs, dioxins) and mercury
- Adjust screening levels
  - Contaminant concentration available in sediment pore water (Section 4)
  - Site specific conditions such as TOC or fish lipid fraction
- Direct tissue analysis

In evaluating whether dietary exposure to human is an important pathway, consideration should be given to the type of contaminant

- Primarily concerned with bioaccumulative constituents.
- *In general* bioaccumulation concerns should be limited to select classes of organics (pesticides, PCBs, dioxins) and mercury.
- USEPA has identified 12 constituents as persistent, bioaccumulative and toxic
- Texas & Sediment Evaluation Framework for the Pacific Northwest has lists of contaminants that are bioaccumulative

Evaluation of sediment-associated contaminant accumulation by fish and shellfish has been described in Sections 4 through 6. This section considers the specific dietary bioavailability to humans.

Direct Tissue Analysis

- **Field measurements provide more accurate estimates of bioaccumulation than published BSAFs**
  - **BSAFs are generic and overly conservative**
  - Can be difficult to correlate with sediment concentrations

Factors that impact representativeness

- **Site fidelity**
- **Species**
- **Tissue**

Human Consumption of Fish and Shellfish

- Adjust screening levels
  – example (Text Box 8-1)
  - Recreational human fisherman screening level = 0.019 mg/kg for hexachlorobenzene (HCB)
    - Default values for fish lipid fraction = 0.03
    - Sediment fraction organic carbon (foc) = 0.01
  - Site-specific screening level = 0.28 mg/kg
    - Used site-specific fish lipid fraction of 0.02 and foc of 0.10
  - Applying site-specific information raises screening value 15x

No associated notes.

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Human Consumption of Wildlife and Plants

- Wildlife
  - Incidental ingestion of sediment, aquatic vegetation and benthic and/or pelagic organisms
  - Obtain information on dietary habits of species of concern
  - Addressed in Chapter 6
- Plants
  - Grown in contaminated area (e.g. seaweed, wild rice) or crops in dredge spoils
  - Tissue sampling to determine COPCs
  - Addressed in Chapter 7

In evaluating whether dietary exposure to human is an important pathway, consideration should be given to the type of contaminant

Typically, Fish are the primary species of concern in assessing human health risks for bioaccumulative contaminants in sediment.

Wildlife

Obtain information on dietary habits of species of concern

Estimate concentrations that may accumulate

Population Surveys, Toxicity Testing, Tissue Residue Analysis

Model using dietary components to estimate human exposures

Plants

Grown in contaminated area (e.g. seaweed, wild rice) or crops in dredge spoils

Tissue sampling to determine COPCs

Model using ingestion rates to estimate human exposure

Case Study – Industri-plex Superfund Site

- Once nation's leading producer of lead arsenate
- 2-step study of arsenic in river sediments
  - Step 1 – Narrow focus for live tests
    - In vitro test on river sediments from four areas
    - Sediments in reactor that simulates the stomach fluid of humans
  - Step 2 – Test relative bioavailability to humans
    - Tested two sets of river sediment materials
    - Immature swine fed dough balls with sediment test materials
    - RBA of the site sediments were 37% and 51%, respectively

- Study reduced the estimated human health risk in half

Industri-plex Superfund Site, Woburn, MA. The Industri-plex site was once occupied by the former Merrimac Chemical Co., which was once the nation's leading producer of lead arsenate, the main insecticide used in apple orchards in the 19th century. Prior to completion of the human risk assessment, an arsenic bioavailability study was performed to assist in the quantification of sediment risks.

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Case Study Using Bioavailability

Indiana Steel and Wire Site - Mocks Pond

Now that you have a rather good understanding of how bioavailability can be used to assess risk from exposure to contaminated sediments,   we'd like to share a case study with you that illustrates the application of a few of the measurement tools described earlier.

For the purposes of this training, we have selected the Indiana Steel and Wire Site

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Site Description and Background

- Galvanizing plant, Muncie, Indiana
- 2.8 acre former limestone quarry
  - Received plant production wastewater from 1962-1973
  - Lime was added to neutralize wastewater before discharge to pond
  - Pond contained 51,000 cubic yards of stabilized spent pickling sludge
  - Sediment samples contained high concentrations
    - Heavy metals (Sb, As, Cd, Cr, Cu, Pb, and Zn)
    - Cyanide

Indiana Steel and Wire was a galvanizing plant located in Muncie, Indiana. Manufacturing operations began in the early 60's and consisted of the production of steel wire products. Operations at the plant were ceased in 2002.

From 1962 through 1972, plant waste water and treatment sludge was discharged to a 2.8 acre limestone quarry. As part of the wastewater treatment process, lime was added in the influent pipeline to neutralize the wastewater before discharging to Mocks Pond. Mocks Pond ultimately discharges to the to the nearby White River.

In 1973 a new wastewater treatment system was installed and treated effluent from the system was directly discharged to Mocks Pond. The discharge from the pond to the White River was managed under a NPDES permit.

As a result of its past use, Mocks Pond contained an estimated 51,000 cubic yards of sediment. This material was primarily lime-stabilized spent pickle liquor sludge, comprised of iron and other metal hydroxides, calcium sulfate and calcium carbonate. The specific COC associated with the sediment were: antimony, arsenic, cadmium, chromium, copper, lead and zinc.

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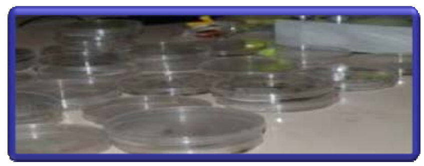
Site Characterization Efforts

- Sediment and surface water investigations
  - Sediment toxicity and leachability studies (1980’s)
  - Waste characterization study (1993)
  - Standard bulk chemistry sediment and surface water sampling for metals and cyanide (1999)
- Biological assessment
  - Water column properties assessment including plankton type
  - Macroinvertebrate and fish surveys
  - Fish tissue sampling for metals and cyanide
  - Wildlife surveys



Initial site characterization studies involved the evaluation of sediment, surface water, as well as an assessment of biological health.

The sediment medium was evaluated through bulk sediment chemistry analyses (Priority Pollutant Metals, cyanide), sediment toxicity tests, leachability studies, and waste classification sampling.

Surface water was evaluated with the collection of surface water samples analyzed for Priority Pollutant metals and cyanide.

The biological assessment was geared towards identifying the types of ecological receptors associated with the pond habitat. This was accomplished with a water column assessment to identify plankton type; as well as macroinvertebrate, fish, and wildlife surveys.

Additionally, to determine if the metal contamination was bioavailable, fish tissue samples were collected and analyzed for priority pollutant metals M and cyanide.

Site Characterization Results: Surface Water and Sediment

- Physical nature of the sludge not conducive to benthic organisms
  - Fine grained
  - No organic matter/nutrients
- Neutralization of the wastewater discharge with lime forming insoluble metal hydroxides suggested lack of metals bioavailability
- Preliminary surface water sampling results in compliance with water quality standards
- Sediment results exceed sediment screening criteria (SSC)

	Concentration	SSC
Cr	21 - 2,100 ppm	120 ppm
Cu	150 - 6,210 ppm	100 ppm
Pb	201 - 8,000 ppm	82 ppm

The results of the site characterization studies indicated that the physical nature of the sediment/sludge mixture was not conducive to supporting a benthic community. The sediment consisted of very fine grained material and was absent of organic matter. As noted earlier, it was visually apparent that lime was added to the waste stream prior to discharging to the pond. It was hypothesized that this step may have altered the bioavailability of the metals through the formation of insoluble metal hydroxides.

The surface water results were in compliance with the water quality standards.

However, as illustrated in the table, the sediment chemistry results were found to grossly exceed their respective sediment screening criteria; with Cr, Cu, and Pb contamination predominating.

Waste classification and leachability testing indicated that the metals were tightly bound and all leachate results were classified as non-hazardous

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Site Characterization Results: Biological Assessment

- Healthy populations
  - Present
    - Pelagic fish
    - Phytoplankton
    - Zooplankton species
  - Absent
    - Benthic fish
    - Macroinvertebrates

The biological assessment revealed the presence of both phytoplankton and zooplankton in the water column , as well as a healthy population of pelagic fish. Benthic fish, or fish associated with the pond bottom (catfish, suckers), and macroinvertebrates were not present.

The presence of plankton and fish in the water column provided preliminary evidence that the metals within the sediment may not be bioavailable to water column receptors.

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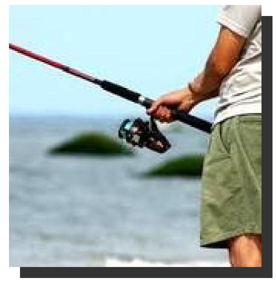
Bioavailability Investigation Activities: Human Health Risk Assessment

- Screened sediment and fish data
  - Indiana Tier II residential cleanup goals for soil
  - EPA Region III Residential RBCs for fish tissue
- COPECs in sediment: Sb, Cr, Pb and Zn
- Fish tissue: As
- Exposure routes
  - Incidental ingestion
  - Dermal contact
  - Ingestion of fish
- Receptors
  - Future construction workers
  - Park worker and recreational visitors
  - Anglers



Based on the initial investigations of the pond, it was assumed that the impacted sediment in the pond was biologically unavailable to upper trophic level organisms and not impacting the overlying surface water column. In consideration of future use, it was presumed that the pond the pond could potentially support recreational fishing.

However, the Indiana Department of Environmental Management required that a human health and ecological risk assessment be conducted to demonstrate/valid this assumption.

The human health risk assessment screening step involved the screening of sediment data and fish tissue concentrations to appropriate screening values. In this case, the sediment results were compared to Indiana's Tier II Residential cleanup goals, and this fish tissue concentrations to EPA Region III Residential RBCs.

The results of this comparison revealed that Sb, Cr, Pb & Zn were COCs in sediment, while As was identified as a COC in fish.

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Bioavailability Investigation Activities: Human Health Risk Assessment (continued)

- Used exposure modeling to determine risk
  - IEUBK model for Pb
  - Intake modeling for other metals

Conclusion: Remediation of pond sediment is necessary to address direct contact issues with Pb in sediment to the future construction worker and ingestion of arsenic in fish tissue for future recreational anglers.

The human health risk assessment involved exposure modeling to determine risk to future receptors. Specifically, exposure modeling was conducted for the construction worker and recreational angler. Pb was modeled using the USEPA IEUBK model while the remaining PP Metals were evaluated using an Intake Model.

The results of the modeling indicated an unacceptable risk to the construction worker for Pb based on direct contact, and recreational angler for As based on fish consumption

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Bioavailability Investigation Activities: Ecological Risk Assessment

- Screened sediment and fish tissue data
  - Sediment criteria
    - Assessment and Remediation of Contaminated Sediments (ARCS) Program for the Great Lakes Threshold Effects Levels (TELs)
    - Lowest Effects Levels (LELs) (Persuad, 1993)
    - Washington State Lowest Apparent Effects Thresholds (LAETs)
  - Fish tissue criteria
    - Compared to background concentrations from White River

Ecological risk was evaluated during the screening stage by comparing bulk sediment chemistry results to several sets of sediment screening criterion. The criteria utilized consisted of:

- Great Lakes ARCS Threshold Effect Levels
- Ontario (Persuad, 1993) Lowest Effect Levels
- Washing State Lowest Apparent Effect Thresholds

The fish tissue concentrations from Mocks Pond fish were compared to fish tissue concentrations from fish collected from a background area. For this comparison, the White River was selected to serve as the background area.

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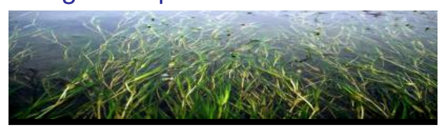
Bioavailability Investigation Activities: Ecological Risk Assessment (continued)

- Sediment COPCs
  - Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn and cyanide
- Fish tissue COPCs
  - None (concentrations less than background)
- Exposure routes
  - Incidental ingestion
  - Dermal contact
  - Ingestion of fish
- Receptors
  - Benthic invertebrate
  - Piscivorous birds
  - Piscivorous mammals
- Used dietary exposure modeling to determine risk to higher trophic level



Conclusion: Considerable level of risk exist to benthic organisms, benthic fish and submerged and emergent aquatic macrophytes from sediment exposures due to levels of metals in sediment and the absence of these feeding guilds in the pond

Based on the sediment screening conducted, Sb, As, Cd, Cr, Cu, Pb, Hg, Ni, Ag, Zn, and cyanide were detected at concentrations above their respective screening levels were retained as Contaminants of Potential Environmental Concern.

The comparison of Mocks Pond fish tissue concentrations to those of the White River revealed that concentrations were below background.

Based on sediment screening results, additional assessment of risk was warranted for sediment and associated receptors. Specifically, dietary exposure modeling was conducted to evaluate risk to fish eating birds and mammals.

The overall results of the ERA concluded that there is the potential for risk to benthic organisms, benthic fish, and submerged and emergent macrophytes from exposure to contaminated sediments. The lines of evidence that support this conclusion were the levels of metals measured in the sediment, as well as the absence of these guilds in the pond. The absence of these species suggests that a remedial action would be required to restore the pond bottom as a component of a healthy aquatic ecosystem. The risks appeared to be confined to bottom dwelling organisms, as a healthy pelagic community exists with little evidence of metals in fish tissue that could be transferred to piscivorous birds or mammals using the pond.

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Remedial Design: Sediment Excavation and Capping

- Dredging sediment to clear water depth of 10 feet
- Placement of a geotextile fabric liner followed by a subaqueous fine to medium grain sand cap atop the residual sediment
- Post-construction monitoring (borings/bathymetry)
- Five years of annual post-remedial monitoring to evaluate cap performance in restricting the migration of constituents into the biotic zone

In evaluating the results of the both the human health and ecological risk assessments, it was concluded that remediation of the pond sediment was needed to provide protections from the residual metal in the sediment for human use of the pond and ecological receptors that use the pond. The remediation undertaken included the removal of sediment as needed to provide an ultimate clear water depth of 10 feet, the installation of geotextile liner, and placement of a sand cap atop the residual sediments.

The remedial action plan required 2 Phases of post remediation monitoring.

1) Post-construction monitoring of the subaqueous cap (to be conducted within 6 months and 1 yr of cap placement). This monitoring assessed the physical integrity of the cap through sediment coring and bathymetry investigations.

2) Annual monitoring for a period of 5 years.

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5 Year Post-Remedial Monitoring and Bioavailability Testing

5 Year Annual Monitoring Plan

- Pore water sampling to evaluate cap performance
  - In situ sampling via large diameter peepers
  - Inserted 10 centimeters into the sediment
- Surface water sampling to assess functional effects on the water column community
- Sediment sampling to confirm isolation of metal contamination

The annual monitoring program was designed to determine the effectiveness of the cap at chemically isolating the sediment contamination. This was evaluated through the collection of pore water, surface water, and sediment samples.

The **bioavailability** of the metals in sediment was evaluated through the collection of sediment pore water samples. *In situ* pore water samples were collected via large-volume peepers. The peepers consisted of dialysis tubing filled with reagent grade water placed into a protective sheath. These were inserted into the pond sediment to a depth of 10 centimeters and left in place for 10 days to allow them to equilibrate with the surrounding interstitial water After 10 days, the samplers were retrieved and analyzed.

As discussed earlier, pore water concentrations provide a more accurate measure of bioavailability as compared to bulk chemistry sediment data. The pore water data, when combined with sediment and surface water data, provide a multiple lines of evidence approach to assess risk to the benthic community.

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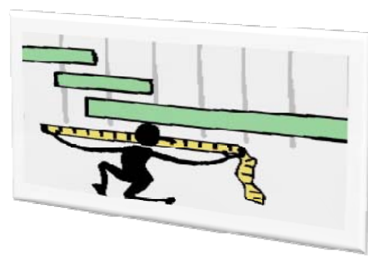
Post-Remedial Monitoring/ Bioavailability Investigation Findings

Post-Construction Monitoring Results

- Cap performed in accordance with design
  - Uniformly overlies pond bottom
  - Physically stable
  - Effectively isolating the residual underlying sediment

5 Yr Annual Monitoring Results

- Sediment, surface water and pore water quality met site-specific standards
  - Metals tightly sequestered
  - Metals not biologically available



This slide summarizes the results of the Post Construction Monitoring& 5 Yr Annual Monitoring.

Post-Construction:

The physical state of the cap was evaluated at 6 month and 1 year after cap installation and it was determined that the cap is stable and uniformly covers the pond bottom.

5 Year Annual:

The results of the post-remedial monitoring confirmed that metals were tightly sequestered and not biologically available as sediment, surface water, and pore water results were all below their respective screening

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Sediment Quality Improvements and Case Study Summary

Constituent	Initial Concentration Range (1999) (mg/kg)	Post-Remedial Concentrations (at 5th Year) (mg/kg)	Sediment Cleanup Standard (mg/kg)
Antimony	36 to 315	0.034 to 0.11B	64
Arsenic	8.9 to 18	2.2 to 6.7	48
Cadmium	1.3 to 12	0.13 to 0.39	3.2
Chromium	21 to 2,100	ND	120
Copper	150 to 6,210	5.9 to 80.4	100
Lead	201 to 8,000	4.6 to 63.8	82

This last slide concludes the Mock Pond Case Study.

As you can see from the table, the Year 5 post-remedial sediment data shows that the remedial action implemented has been effective – all metal concentrations in the sediment are well below their respective screening values. As stated previously, the pore water and surface water results at year 5 are also below their respective standards or background.

This case study highlights how bioavailability was assessed during the risk assessment through the use of sediment toxicity tests and fish tissue sampling; and in the post-remedial monitoring phase via pore water sampling.

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Overall Course Summary

- Bioavailability should be an integral part of characterization and remedial decision making
- Bioavailability can be assessed throughout the process but is more justifiable after the initial screening process
- Bioavailability will help you refine your exposure results and refine your risk management decisions

Current ITRC project:

- Remedial Decision-making at Contaminated Sediment Sites

This slide concludes our training on how bioavailability can be incorporated into the evaluation of contaminated sediments. In the past, sediment remedial actions were often based on conservative, literature based screening values that did not take into the account the concept of bioavailability. We hope this training has left you with a better understanding of bioavailability, and some of the innovative tools/ measures that can be used to more accurately define contaminant exposure concentrations, or that fraction of the contaminant that is truly available for receptor uptake.

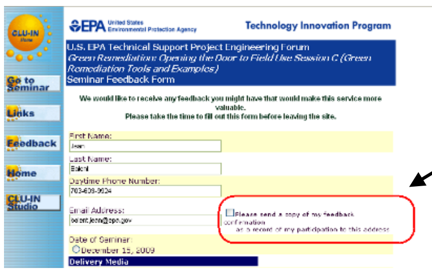
The incorporation of bioavailability into both the risk assessment and risk management process can result in the generation of technically sound, site specific remedial goals that are protective of the environment.

In closing, I'd like to let everyone know that the Contaminated Sediment Team is currently in the process of developing a follow-up document to this one that will address Sediment Remediation.

That wrap us the today presentation, at this time I'm going turn the presentation over to our moderator for some final comments.

Thank You for Participating

- Question and answer break
- Links to additional resources
  - http://www.clu-in.org/conf/itrc/ConSeds/resource.cfm
- Feedback form – *please* complete
  - http://www.clu-in.org/conf/itrc/ConSeds/feedback.cfm



Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.

Links to additional resources:
http://www.clu-in.org/conf/itrc/ConSeds/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/ConSeds/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects