Remediation Futures

A Collective Effort By Taiwan 2022
Technical Exchange Presenters

Gazing Into The Crystal Ball/Looking Over the Horizon

- Posed as a series of questions

- Trying to think what remediation may look like in the next 10-20 years

- Personal reflections, not an expression of EPA policy

- 'Audience Participation' Encouraged – Feel free to send in thoughts regarding future developments

Will Site Characterization Efforts Continue To Improve?

- It's (Still) Dark Down There
  - - Paul johnson, President, Colorado School of Mines

- "We Run Around In Circles and Suppose, While the Secret Sits in the Middle and Know"
  - Robert Frost, poet

Some Current Limitations on High Resolution Site Characterization

- Still Making Too Many Simplifying Assumptions
  - Average Hydraulic Conductivity
  - Assumptions regarding homogeneous and isotropic conditions

- Large Error Bars on Estimates of Contaminant Mass in the Subsurface

- Many site characterization tools are qualitative/semi-quantitative

Will <u>Digitization</u> Continue To Improve Data Management/Interpretation/Communication?

▶ Cheap sensors

▶ Increasingly cheap computing power

▶ Telemetry

▶ 3D Visualization software

▶ Allow high data density development/updating of CSMs and facilitates communication among team members

    ▶ BUT NOTE: Some analysis like ESS takes time and expertise – Take the time!!

    ▶ INTERESTING NOTE: **Narrative Boring logs** are a challenge for digitization, but photos and videos can be linked!

Will the Uniform Soil Classification System (USCS) Used to Interpret Boring Logs Be <u>Replaced</u>?

▶ The USCS was originally developed for <u>Geotechnical</u> Applications – NOT to support Remedial Engineering decisions

▶ "Graphical Shading Logs: An Improved Approach for Collecting High Resolution Sedimentological Data at Contaminated Sites"

- J. Meyer et al, Groundwater Monitoring

and Remediation, pp 59-74 Summer 2022

'Connecting the Dots' - Trifecta

Geophysical Tools

3D
Tools
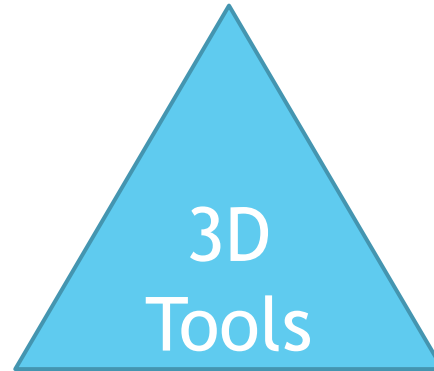
Environmental Sequence Stratigraphy

Artificial Intelligence/ Machine Learning

Will Understanding of Contaminant Mass Distribution in Plumes Improve?

▶ Operationalize the '80/20' Rule – 80% of contaminant mass in the plume is in 20% of the plume cross-section area

   ▶ *Might be 95/5%*

▶ Use of Mass Flux tools can assist in discerning mass distribution/movement

   ▶ 2D/3D observation tools instead of point temporal data

Will Understanding of Typical Plume Geometry Improve?

- Dissolved phase plumes are generally NOT 'Blobs'

- Lateral dispersity coefficients used on models are often incorrect
  - Payne, et al '*Remediation Hydraulics*'

- Plumes are usually more elongated/'cigar'-shaped

- Better Understanding of Plumes has Implications for 'Matrix Diffusion'

# Plumes Are Generally NOT 'Blobs'

Will the "Outward Progression' Model of Subsurface Redox Zonation Be Replaced?

- *Biodegradation: Updating the Concepts of Control for Microbial Cleanup in Contaminated Aquifers*

- Rainer U. Meckenstock,*,† Martin Elsner,○ Christian Griebler,○ Tillmann Lueders,○ Christine Stumpp,○Jens Aamand,‡ Spiros N. Agathos,§ Hans-Jørgen Albrechtsen,‖ Leen Bastiaens,⊥ Poul L. Bjerg,‖ Nico Boon,∇ Winnie Dejonghe,⊥ Wei E. Huang,◆ Susanne I.

'Better' Concept of Redox Zonation?
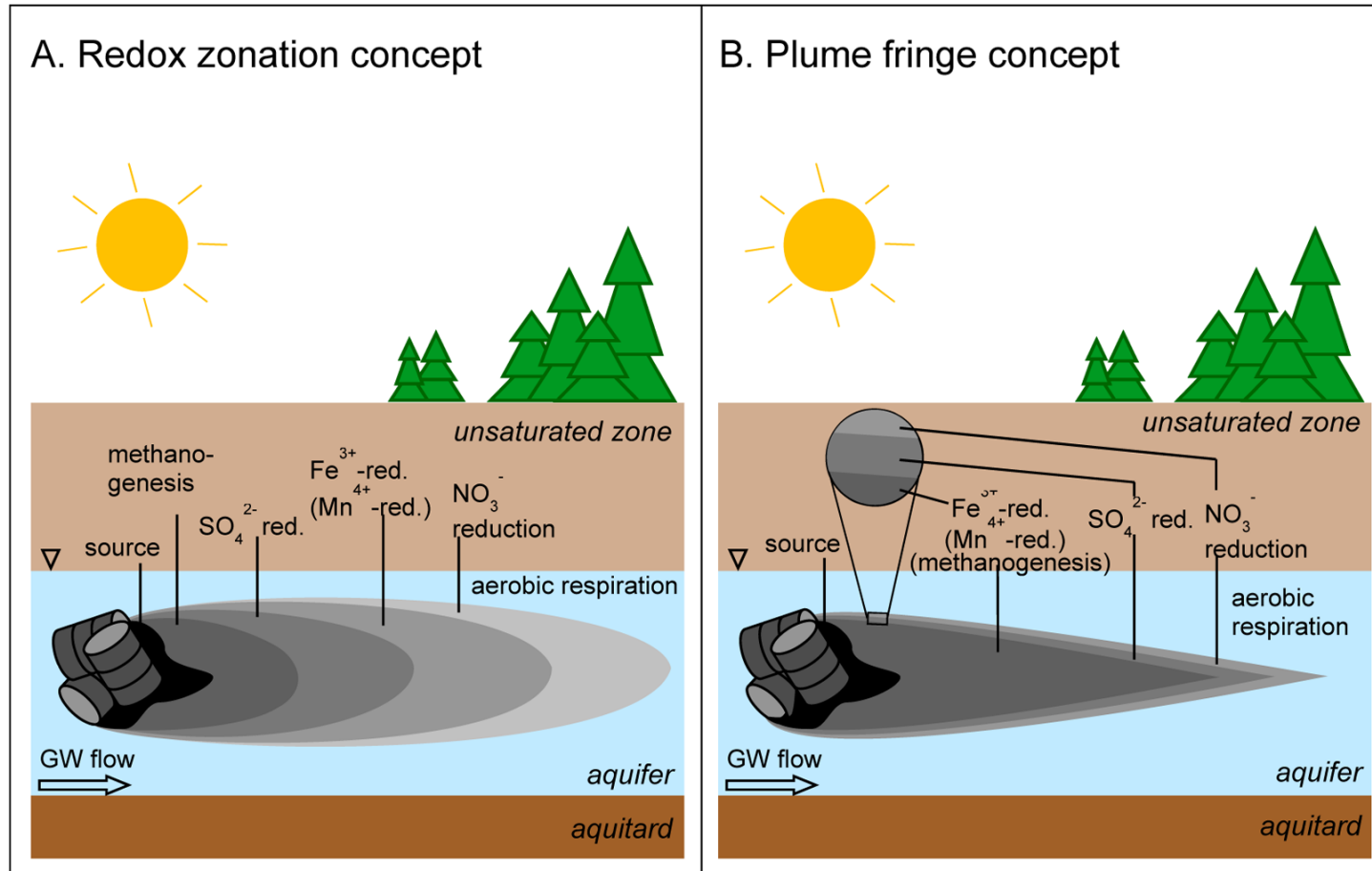
Can the Practice of Bioremediation Be Significantly Improved – 'Bio 2.0'?

▶ Awareness that Biological remedies are particularly dynamic - and temporally

▶ Better Understanding/Exploitation of Biological Phenomenon and Processes

  ▶ Biofilms – keep (good) things in/keep (bad)things out

  ▶ Biologically Enhanced Mass Transfer

  ▶ Importance of <u>Consortia</u> rather than just 'superbugs' – practitioners cite consortia but then focus on plate counts of DHC

  ▶ Microbial 'agriculture'

Excerpts from ES&T Redox Zonation Paper

- *"…despite decades of biodegradation research, the true drivers governing contaminant degradation are still poorly understood."*

- *"We argue that groundwater ecosystems are much more h**eterogeneous** and **dynamic** than currently perceived."* **(emphasis added)**

How Much Better Can We Do in Incorporating Geology in Our CSMs and Remedial Decisions?

- ► It's the 'Plumbing'

- ► 'Layer-cake' depictions of the subsurface border on remedial malpractice

- ► 3D visualization vendors are working to better incorporate Geology

- ► See EPA paper on 'Environmental Sequence Stratigraphy'

Where to invest to lower risk to humans and environment?

1. Overinvesting in remediation without understanding likelihood/consequences for failure

2. Overreliance on well data (especially long-screened interval wells)

3. Underinvesting in characterization (Return On Investigation)

4. Underinvesting on data analysis and visualization

5. Underinvesting in K-12 pipeline for new environmental scientists

6. Machine learning/AI can help only if data is spatially and temporally correct and undergone QA/QC//Can't solve the 'GIGO' problem

A Bright Future?

1. Site remediation will become more reliable - like modern surgery (Although experienced surgeons expect to be surprised despite tools like CT scans)

2. Microbial communities will become better remediation partners

3. Digital tools will allow better data management, support dynamic CSMs and facilitate communication among team members and with stakeholders
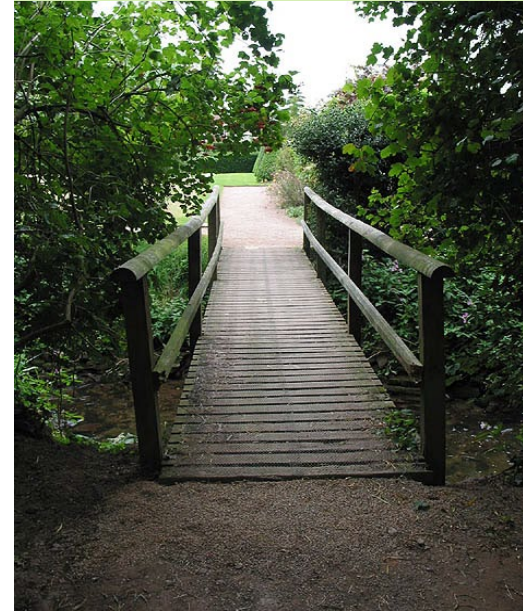
State of the Art vs. State of the Practice

State of the
Practice

Short-Term
Cost Pressures

State of the
Art

- Initial low cost
- Limited or "rule of thumb" design
- Lower certainty of success
- Ultimately higher cost

- Potentially initial higher cost
- Appropriate testing and design
- Higher certainty of success
- Ultimately lower cost

Courtesy Mike Marley

What Will Be The Next High Notoriety/High Anxiety-Inducing Contaminant After PFAS?

- Who Knows? Micro-plastics?

Other Thoughts/Ideas?

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