Sustainability Considerations for 1,4-Dioxane Treatment Technologies

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Delivering Sustainable Solutions to Complex Local Challenges, Worldwide

Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies

Topics Covered

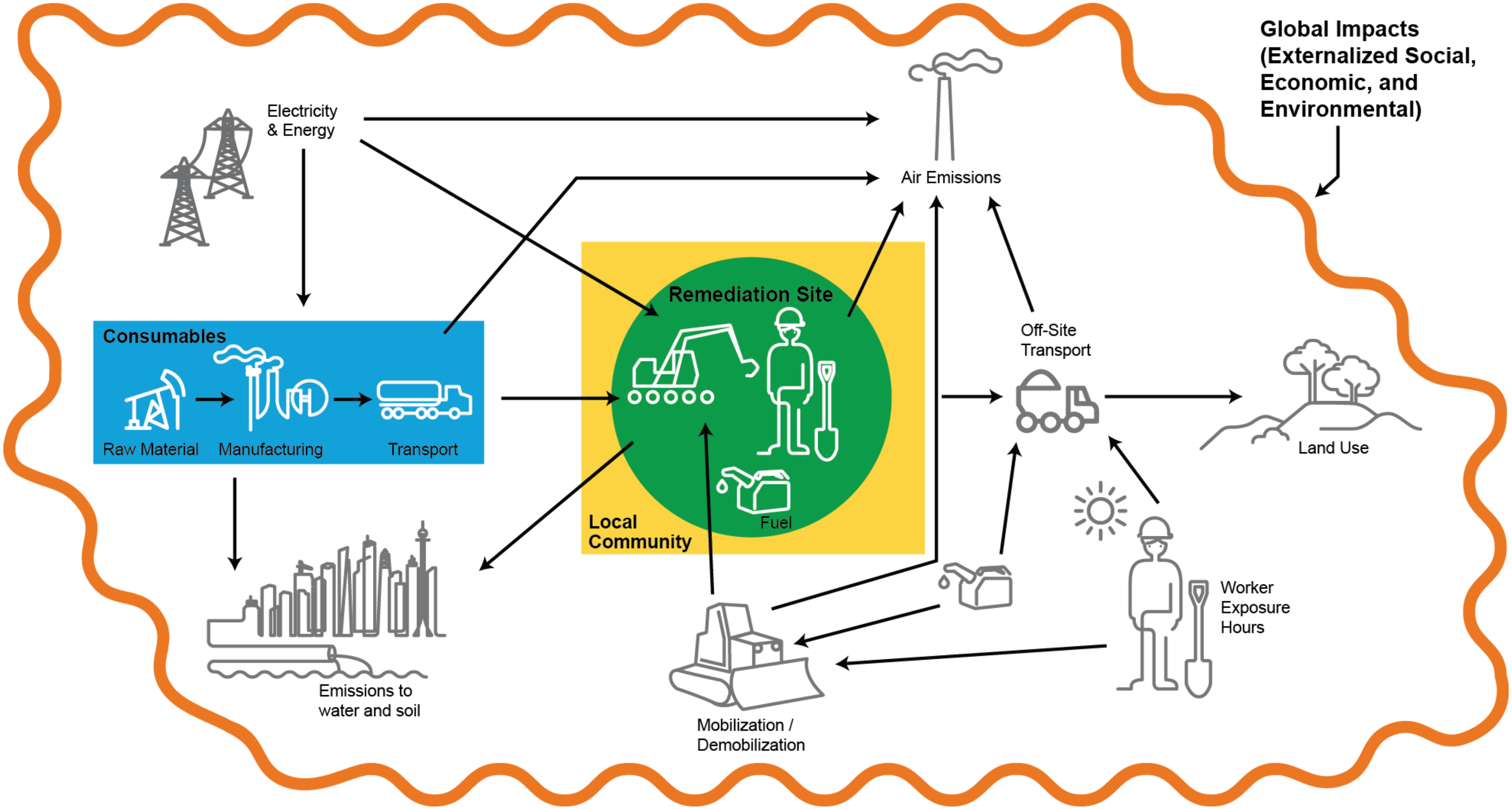
- Sustainability/Green Remediation Definitions
- Dioxane background
- Remedial Technologies
- Assessment of Remedial Options
  - – Soil – Not explicitly covered
  - – Groundwater
    - Ex situ
    - In situ

ITRC, 2014

Green Remediation Nomenclature

- Sustainable Remediation Forum (SURF):
  - The use of sustainable practices during the investigation, construction, remediation, redevelopment, and monitoring of environmental cleanup sites, with the objective of balancing economic viability, conservation of natural resources and biodiversity, and the enhancement of the quality of life in surrounding communities.
- U.S. Environmental Protection Agency (EPA):
  - "…the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup" (EPA, 2011).
- Interstate Technology and Regulatory Council (ITRC) uses a term called "green and sustainable remediation [GSR]," which is defined as:
  - The site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and environmental effects.

Life Cycle Assessment in Remediation

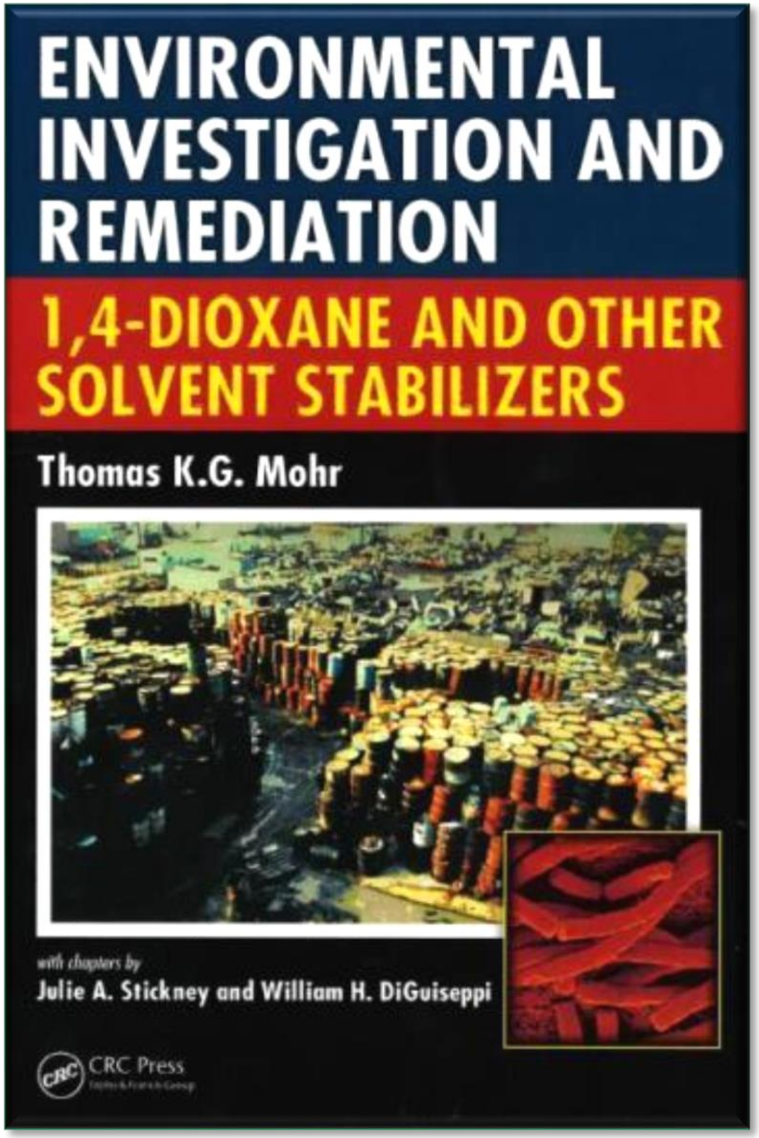


Towards "Greener" Remediation

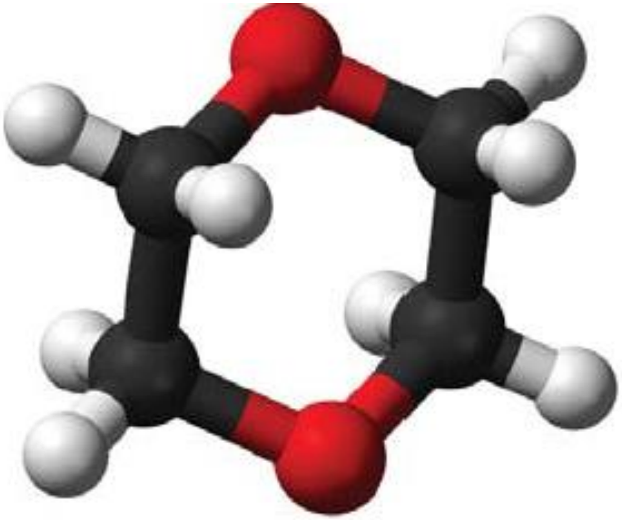
- Best Management Practices that are favorable to GSR concepts
- Use of renewable energy
- Use of locally available materials and labor
- Sourcing materials from sustainable suppliers
- Considering impacts of off-site waste management
- Considering the resource benefit of water that has been pumped and treated
- Considering reuse (but taking into account possible liability for emerging contaminants)

1,4-Dioxane Background

- Primarily used as a 1,1,1-trichloroethane stabilizer (>95% of 1970's production)
- Commonly co-mingled with chlorinated volatile organic compounds and metals
- Hepatotoxic, neurotoxic, "Likely to be carcinogenic in humans"
- Low remediation goals:
  - US EPA tapwater Regional Screening Level 0.46 ug/L



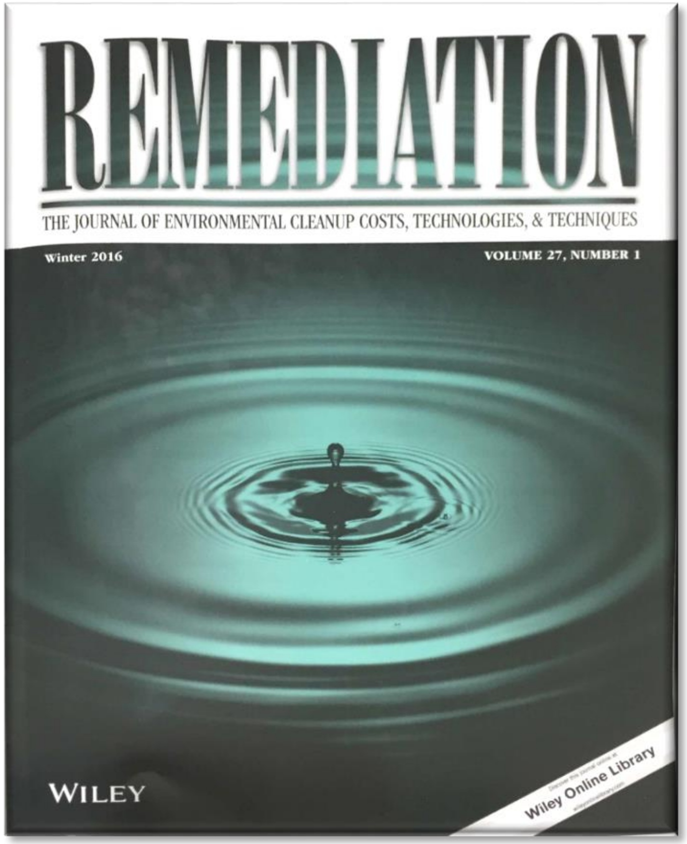
More 1,4-Dioxane Background



- Formula: $C_4H_8O_2$
- Synthetic cyclic ether
- Colorless, highly flammable liquid
- Miscible in water (infinite solubility)
- Migrates rapidly, sorbs minimally
- Potential for larger plumes than associated source 1,1,1-TCA
- Diffuses into/through low permeability soils
- Results in large dilute plumes (<20 µg/L); few "source areas"
- Many CVOC remedies (e.g., air sparge, GAC, ERD, KMnO4) are only marginally effective on 1,4-dioxane

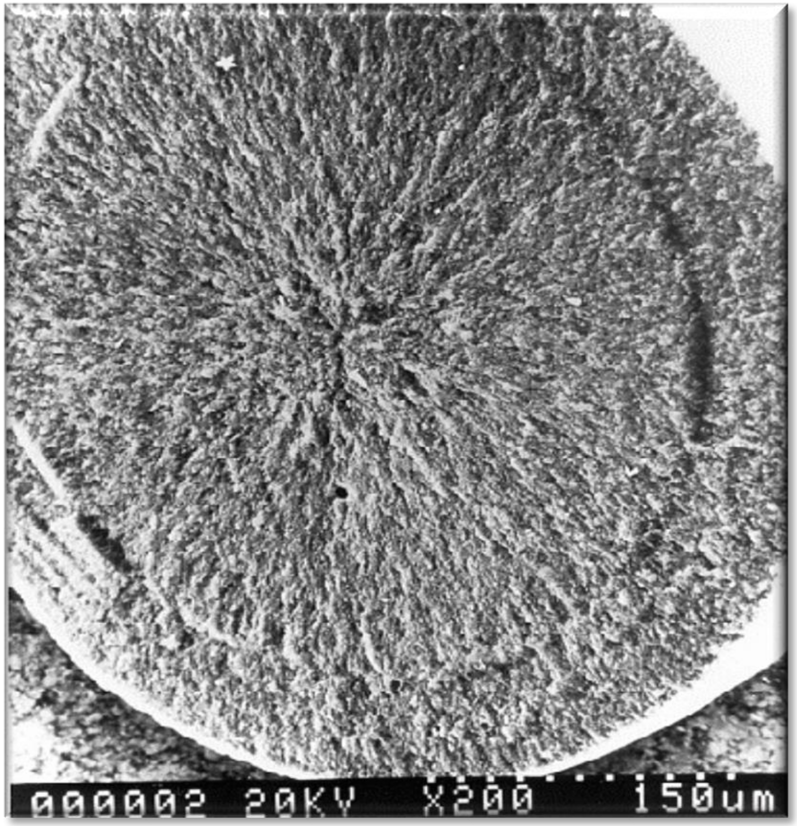
Water Treatment Technologies

- Assessment is excerpted from Remediation Journal Article (Favara, Tunks, Hatton & DiGuiseppi, 2016)
- Ex Situ Technologies
  - Sorption
  - Advanced Oxidation
  - Biological Treatment
- In situ Technologies
  - Phytoremediation
  - Thermal
  - Chemical Oxidation
  - Biodegradation
  - Natural Attenuation



Ex Situ - Sorption

- Synthetic sorbants have been demonstrated effective (e.g. Dow Ambersorb 563)
- Negative Drivers:
  - Pump & treat and regeneration are energy intensive
  - Liquid waste generated
  - Transfers, does not destroy
- Positive Aspects:
  - Sorption media is reused
  - Low waste volume, with possible on site destruction
  - Could use renewable energy



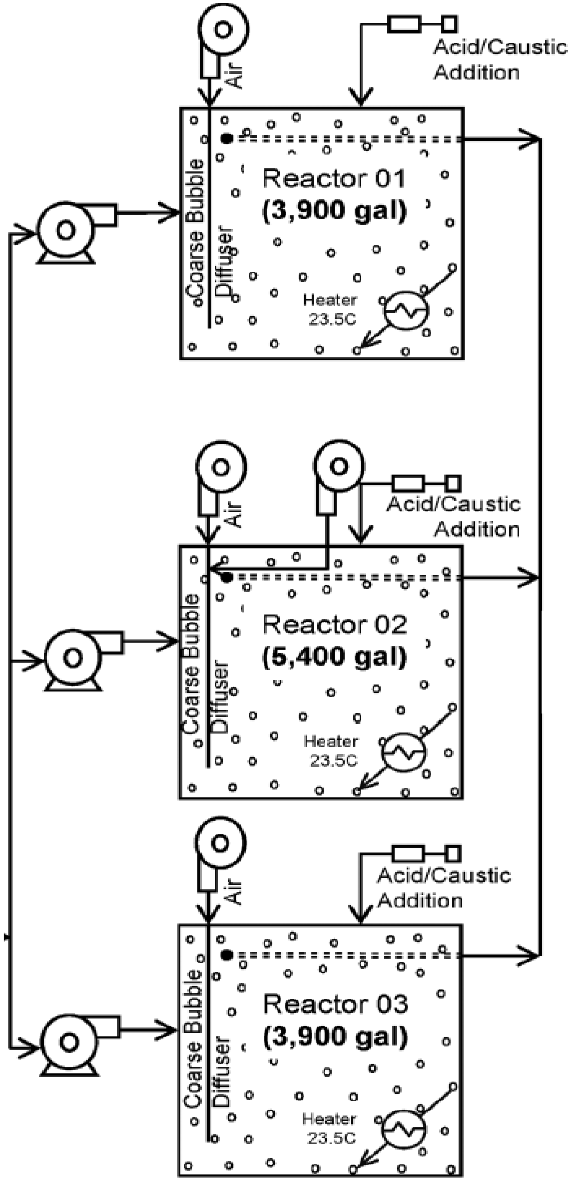
Woodard, 2016

Ex Situ – Advanced Oxidation

- Many demonstrated technologies (e.g., Ozone + H2O2, UV + H2O2)
- Negative Drivers :
  - Pump & treat and UV light/O_3 generation are energy intensive
  - Hazardous chemicals
  - Labor-intensive operations
- Positive Aspects:
  - Destructive technology
  - Consider renewable energy
  - Can handle organic co-contaminants

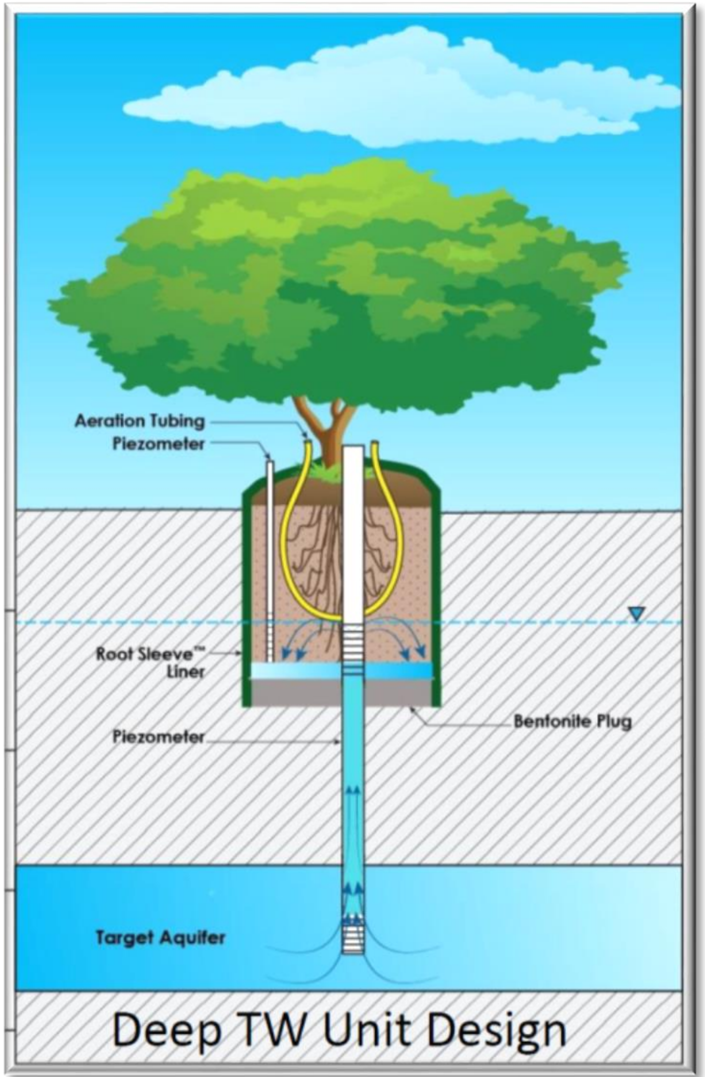
Ex Situ – Biological/Bioreactors

- Bioreactors proven effective in limited applications
- Negative Drivers:
  - Pump and treat is energy intensive
  - Waste products management
  - Needs cometabolite/amendments
  - Sensitive to chemistry/flow changes
- Positive Aspects:
  - Non-chemical remedy
  - Destructive technology



After Cordone, et al, 2016

Phytoremediation

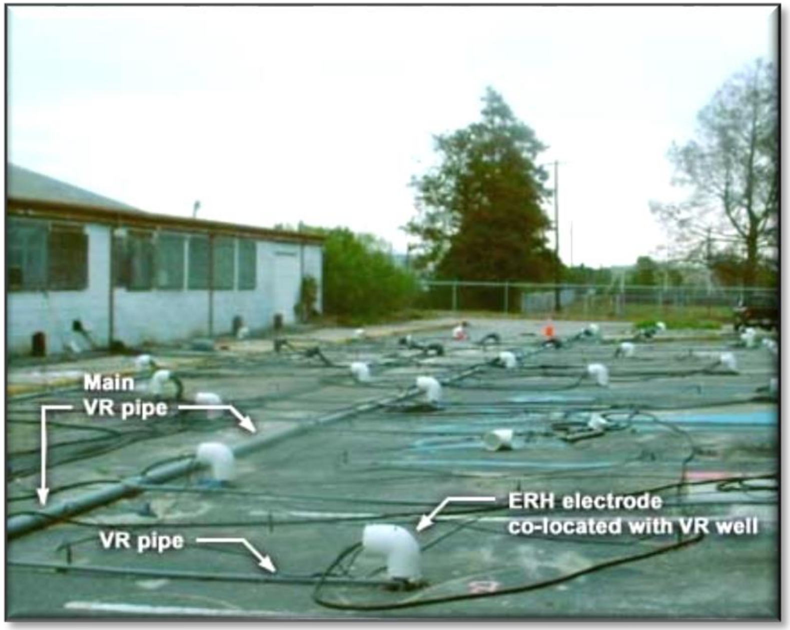


Gatliff, et al, 2013

- Proven effective in limited applications
- Negative Drivers:
  - Slow, seasonal process
  - Containment not clean up
  - Large footprint not available for other beneficial uses
- Positive Aspects:
  - Relatively low construction and O&M efforts
  - Potential habitat creation
  - Perception/aesthetic of Trees!

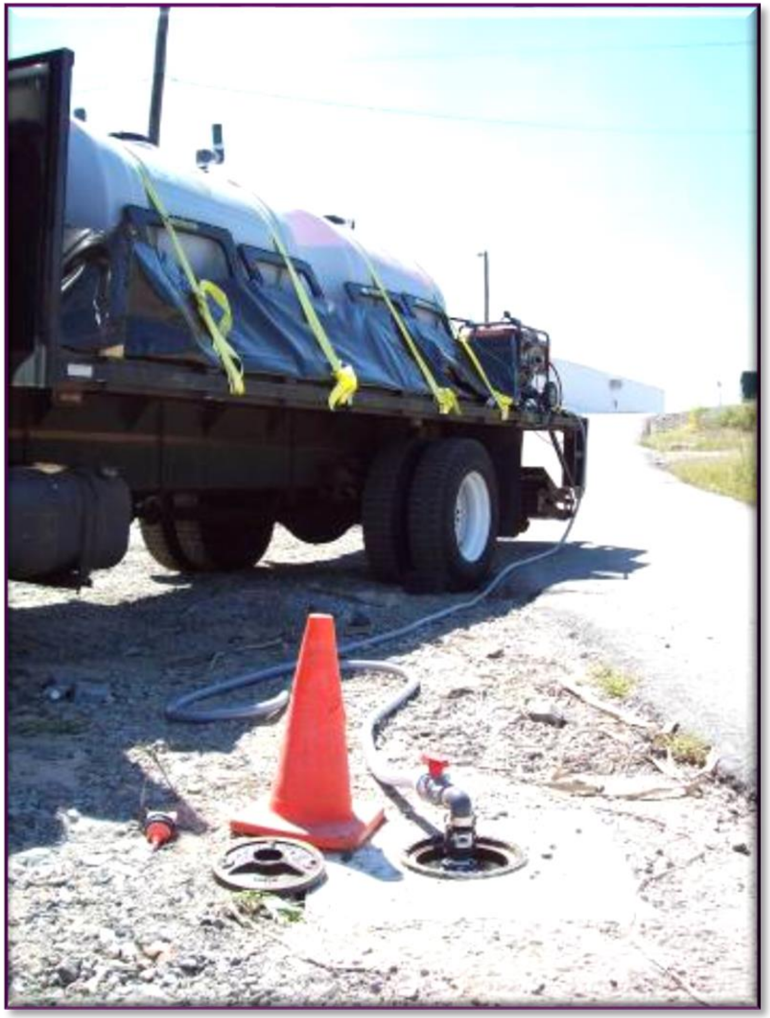
In Situ Thermal Treatment (ISTT)

- Effective source area soil/groundwater treatment
- Negative Drivers:
  - Very high energy consumption
  - Can be logistically difficult
  - Transfers DX to vapor GAC
- Positive Aspects:
  - GAC regeneration is destructive
  - Likely fastest solution, returning groundwater and land to productive use
  - Can handle organic co-contaminants



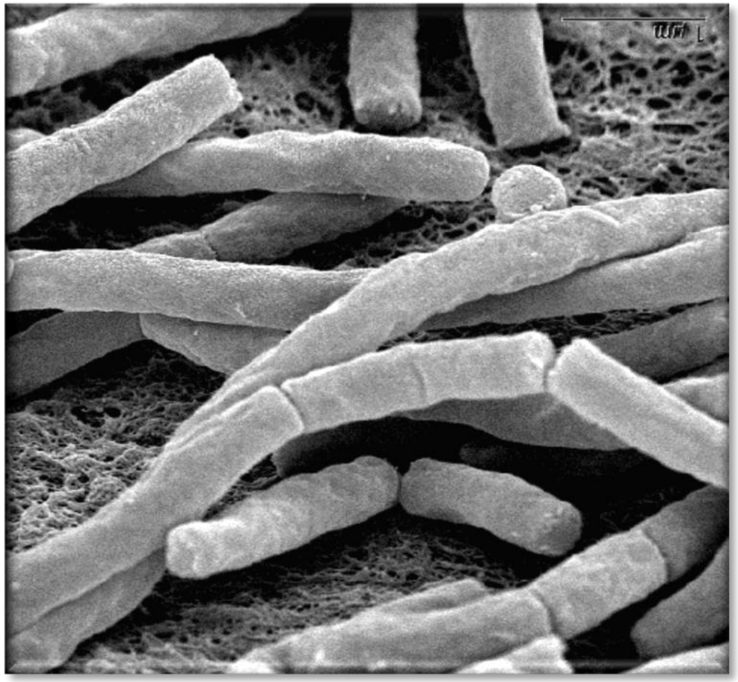
In Situ Chemical Oxidation

- Demonstrated in situ technology
- Negative Drivers:
  - Hazardous chemicals
  - Delivery uncertainty
- Positive Aspects:
  - Fast
  - Destructive
  - Minimal infrastructure



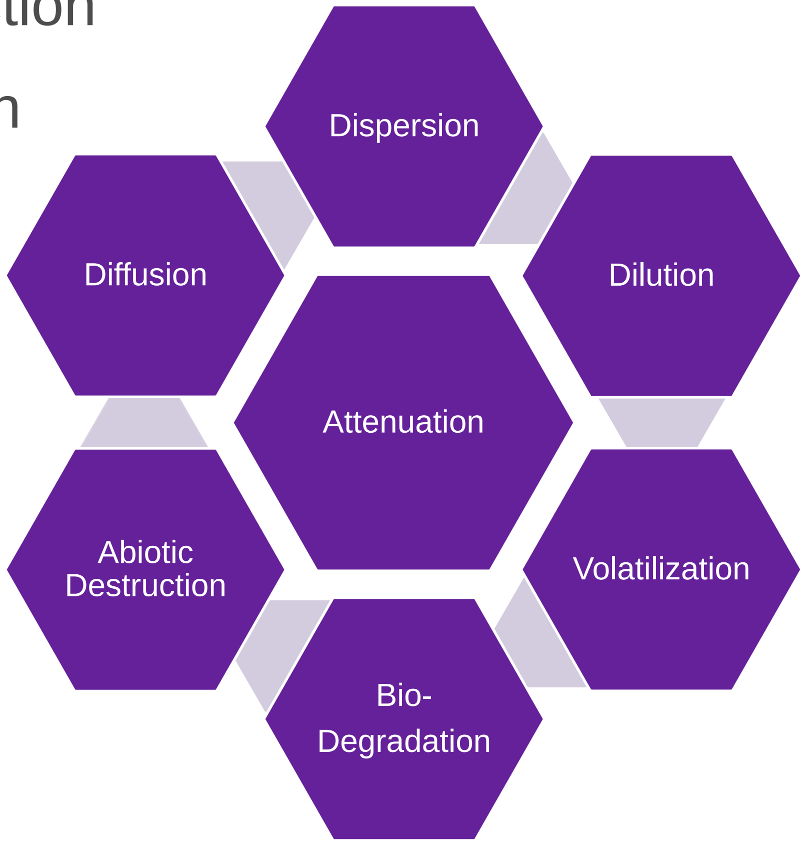
Biodegradation

- Demonstrated at field pilot scale
- Negative Drivers:
  - Slow
  - Amendment safety (e.g., propane)
  - Technical immaturity
- Positive Aspects:
  - Low implementation footprint
  - Low maintenance
  - Non-chemical solution



Monitored Natural Attenuation

- Minimally demonstrated but effective
- Negative Drivers:
  - Uncertainty of complete destruction
  - Stakeholder approval/perception
  - Slow
- Positive Aspects:
  - Minimal infrastructure
  - Low cost/labor/materials
  - GREENEST!



1,4-Dioxane GSR Evaluation Takeaways

- Assessment of impacts can/should be done at several stages during the cleanup process
- Factors of importance vary depending on remedial objectives
- Always a site-specific process
- Many options to consider for 1,4-dioxane treatment
- Several options minimize chemical and energy usage
- Recent developments are dominantly in the biodegradation arena, which is often the greenest path
- Natural attenuation may be demonstrable

Thank you!

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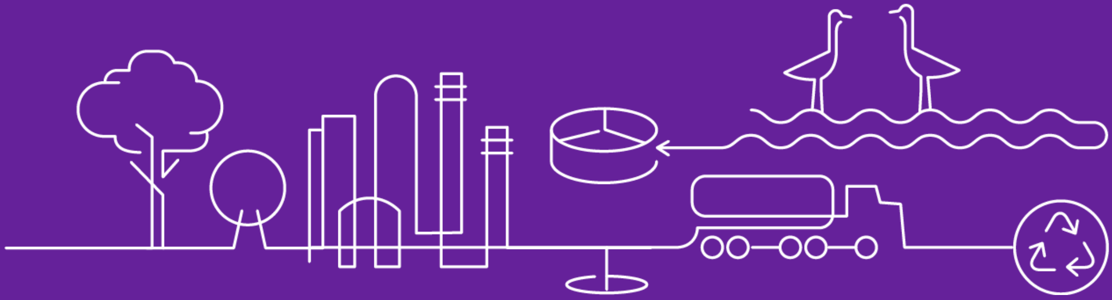

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