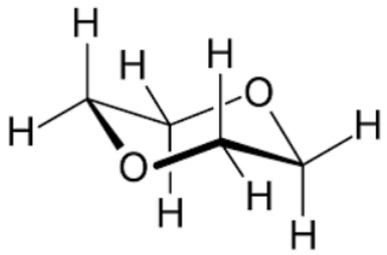
1,4-Dioxane Remediation Services



AECOM has a unique grasp on 1,4-dioxane treatments due to our multiple research and technology demonstration projects, which identified biomarkers for tracking metabolic biodegradation.

Areas of Expertise

- Field investigation
- Use of advanced characterization tools
  - Microbiological and enzymatic activity evaluation
  - Isotopic characterization
- Developed innovative forensics tools - 1,4-dioxane biomarkers
- Toxicity/risk assessment
- Innovations in 1,4-dioxane bioremediation and natural attenuation
- Innovations in amendment delivery
- Feasibility studies
- Remedial design/ remedy implementation,
- Operations & Maintenance
- Process optimization
- Regulatory navigation/negotiation
- Off-Site transport mitigation

Remediation of 1,4-dioxane is challenging, due to its miscibility in water, low sorption, and low volatilization potential. Because of its use as a solvent stabilizer (specifically for 1,1,1-trichloroethane [TCA]), 1,4-dioxane has been found to be frequently commingled with chlorinated solvents. In some cases, it was generated as byproduct of manufacturing process and detected in leachate of landfills commingled with petroleum compounds and other contaminants. We understand the complexities of 1,4-dioxane remediation — not just as a result of its chemical characteristics but also because it is typically discovered later in the project cycle and often after remedial actions are undertaken for treatment of other contaminants (especially chlorinated solvents), without considering 1,4-dioxane. AECOM has more than 90 1,4-dioxane projects of which 75% have 1,4-dioxane commingled with chlorinated solvents. Approximately 40 sites are currently under full-scale remediation. The conventional treatment technologies for 1,4-dioxane include advanced chemical oxidation and *in situ* chemical oxidation.

However, bioremediation is a green and sustainable approach for 1,4-dioxane which has been proven in the laboratory and in recent (primarily pilot-scale) field applications. The understanding of biodegradation potential at field scales has remained limited. AECOM has been collaborating with UCLA since 2009 to develop tools for validating 1,4-dioxane biodegradation and demonstrate biostimulation as well as bioaugmentation at field scales.

Our Approach

AECOM's diverse remediation portfolio includes experience at over 90 1,4-dioxane projects. Of these, 42% are under full-scale operation of pump and treat systems and the rest are undergoing a variety of *in situ* and sustainable approaches, including *in situ* chemical oxidation (ISCO), bioremediation, phytoremediation, Monitored Natural Attenuation (MNA), and long-term monitoring (see pie chart).

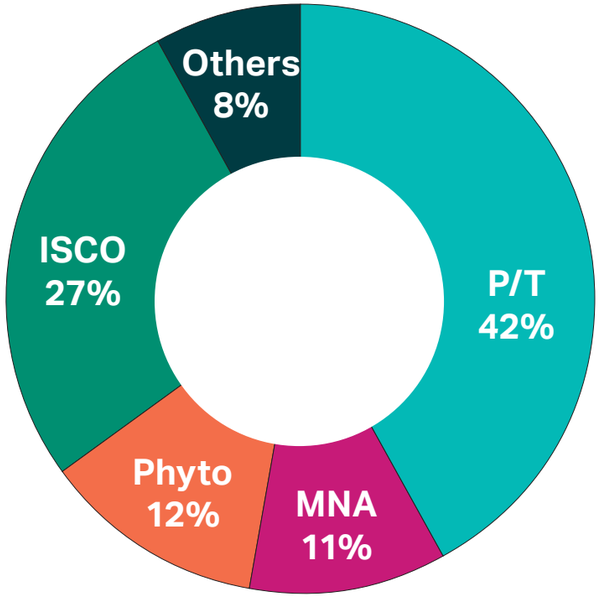
Our teams began managing 1,4-dioxane sites in the 1990s, many years before it was discovered as an environmental issue related to its use as a solvent stabilizer for TCA.

Our cumulative 1,4-dioxane project experiences include:

- Evaluation and implementation of treatment technologies since 1990s, including different pump and treat techniques, *ex situ* biological treatment for wastewater treatment facilities. Phytoremediation for transpiring 1,4-dioxane impacted seepage water, aerobic cometabolic bioremediation, *in situ* chemical oxidation, and monitored natural attenuation (MNA);
- Evaluation of laboratory analytical method development.
- Collaboration with UCLA's Dr. Shaily Mahendra to characterize the intrinsic bioremediation potential of 1,4-dioxane and trichloroethene using innovative environmental diagnostic tools, including development of biomarker genes.
- Regulatory criteria review and negotiation.
- Fate and transport modeling, including the development of site-specific degradation rates to document plume stability and build MNA argument.

More Information: AskEnvironment@aecom.com

1,4-Dioxane Remediation Services *(continued)*



- Characterization of large 1,4-dioxane plumes with decades of 1,4-dioxane datasets to build plume stability arguments and use site experience to better select site-specific treatment approach.
- The first large scale *in situ* chemical oxidation treatment using persulfate activated chemistry at a superfund landfill site.
- Using AECOM's treatability study laboratory to advance new approaches for 1,4-dioxane remediation and to model the biodegradation kinetics of this emerging chemical.

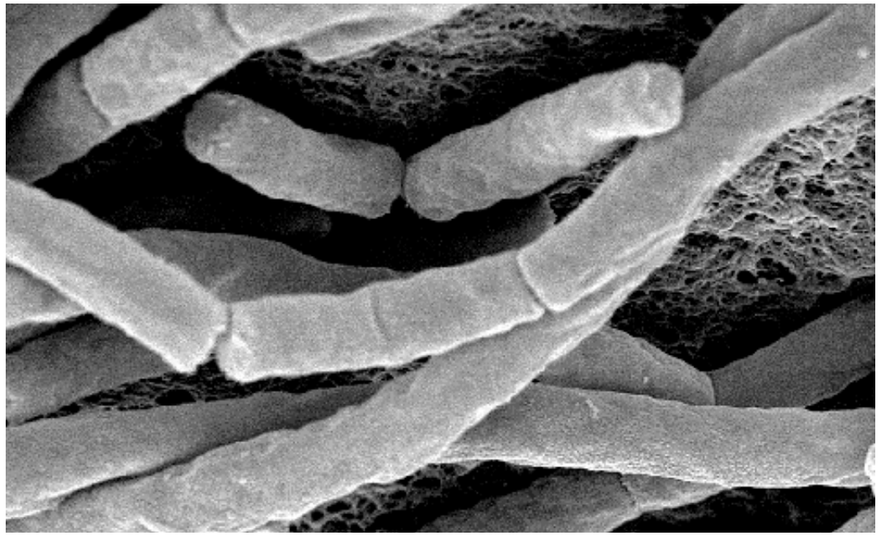
Key AECOM Attributes

- **EXPERIENCE** - Almost 3 decades of 1,4-dioxane site management experience to apply to our clients' most challenging sites.
- **SCALE** - Experience at over 90 1,4-dioxane sites world-wide covering all aspects of site management in different regulatory environments.
- **RANGE** - 1,4-Dioxane remediation experience includes pump and treat, *in situ* chemical oxidation, bioremediation, phytoremediation, and natural attenuation.
- **INNOVATION** - Committed to innovation and industry leadership in 1,4-dioxane biodegradation, as illustrated by our collaboration with academic and commercial laboratory partners.
- **SUPPORT** - AECOM's "Innovation Fund" supports development of innovative ideas and tools for 1,4-dioxane remediation, on a stand-alone basis, or in collaboration with our clients and academic and commercial partners .
- **DEMONSTRATION** - Our Treatability Study Laboratory provides proof-of-concept evidence and data in support of 1,4-dioxane remediation design and understanding of degradation mechanisms and kinetics.
- **TECHNICAL PRACTICE NETWORK (TPN)** - A virtual community of professionals working together to drive continuous improvement. Comprised of 157 Technical Practice Groups, they disseminate technical knowledge and practice-specific experience through an library of technical resources, company-wide technical webinars, participation at industry-leading seminars, and supporting technical vendor presentations.
- **COMMITMENT TO SAFETY** - AECOM's safety culture is inherent in every project. With accolades ranging from BP to the U.S. National Safety Council, our professionals around the globe understand the importance and value of safety.
- **GREEN AND SUSTAINABLE REMEDIATION** - We incorporate green remediation into our projects to reduce the impact of our cleanup techniques on the environment, and to reduce costs.

DIFFERENTIATORS

AECOM and UCLA worked together to identify and demonstrate a novel treatment scheme to address cleanup of 1,4-dioxane. This work involved multiple research and technology demonstration projects funded by the U.S. Department of Defense (DoD). The team completed the development of a set of two biomarkers (DXMO and ALDH) for tracking metabolic biodegradation and confirmed the incorporation of 1,4-dioxane into microbial communities using stable isotope probing under natural environmental conditions. The biomarker evaluation is now available from Microbial Insights, representing a successful collaboration between the DoD, UCLA, AECOM and Microbial Insights to commercialize the 1,4-dioxane biomarkers and make them available to the environmental industry. The biomarkers will serve as a valuable tool for practitioners to monitor the performance of *in situ* bioremediation and enhanced natural attenuation of 1,4-dioxane.

The team also collaborated on characterizing the effects of co-contaminants, such as chlorinated solvents and chromium on 1,4-dioxane bioremediation, has published multiple peer-reviewed journal articles since 2008 and has presented at multiple conferences annually to assist with technology transfer.



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