

Arsenic Complicates Groundwater Bioremediation

A common groundwater contaminant, trichloroethene (TCE), can be reduced by certain bacteria, a process known as bioremediation. But, according to a new NIEHS Superfund Research Program (SRP) study, this process may stall when arsenic is present. TCE, a widely used industrial solvent, pollutes groundwater from improper handling practices.

Arsenic has been detected at 63% of current TCE-contaminated Superfund sites in the U.S. Degradation of TCE by *Dehalococcoides mccartyi* (*D. mccartyi*) bacteria in culture has been well characterized, but less is known about how these bacteria degrade TCE under various environmental conditions, including in the presence of other contaminants such as arsenic.

In a study led by Lisa Alvarez-Cohen, Ph.D., researchers at the University of California, Berkeley, assessed whether arsenic affected the TCE-degrading activities of *D. mccartyi* strain 195 (Dhc195), which is known to convert TCE into nontoxic products.

They focused on two common types of arsenic, arsenate [As(V)] and arsenite [As(III)]. Generally, aerated surface waters with higher oxygen levels contain more As(V). In lower oxygen conditions, including in well water, As(III) is more prevalent. Although both types have been shown to disrupt cell processes, As(III) is generally considered more toxic

Dhc195 Changes in Response to Arsenic

Using laboratory microcosms of TCE-contaminated groundwater, the researchers measured growth and physiology of Dhc195 amended with As(V) or As(III) and identified changes in genes and metabolites in the bacterial community.

Addition of As(III) led to a 50% decrease in Dhc195 cell growth and significant decrease in TCE degradation. When As(V) was added, Dhc195 converted As(V) to As(III) over time. While As(V) exposure did not initially impact TCE degradation, they observed inhibition of TCE degradation after exposure for more than 12 days, corresponding to the conversion of As(V) to As(III) and its subsequent accumulation.

The researchers identified significant genetic changes in the Dhc195 bacterial community in response to As(III) and As(V). In As(III)-amended cultures, 52 protein-coding genes, or transcripts, were downregulated and 278 transcripts were upregulated. In cultures amended with As(V), 33 transcripts were downregulated and 332 transcripts were upregulated.

Some of the gene regulation changes were shared between As(III) and As(V) but others were specific to the different types of arsenic. With exposure to both types of arsenic, genes involved in DNA repair, replication, and translation were found at higher levels, which is consistent with promoting DNA mutations in bacteria.

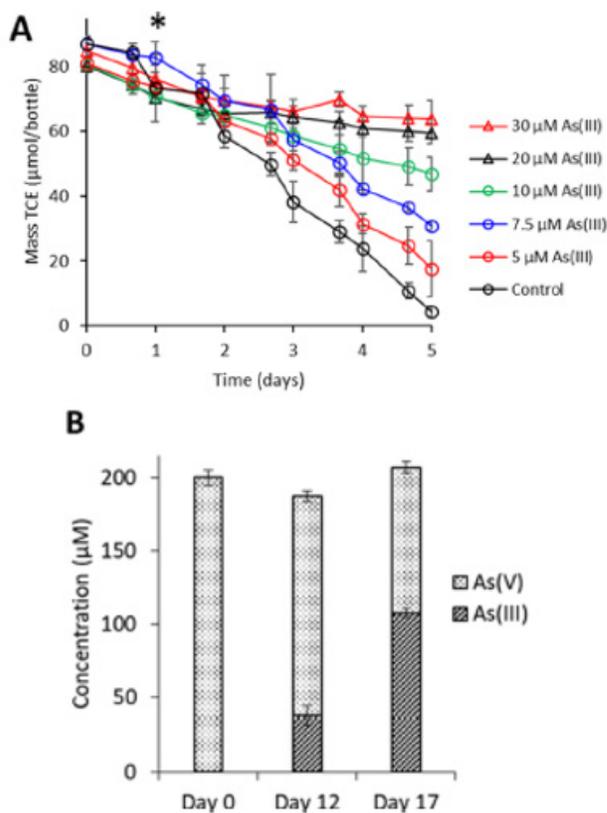
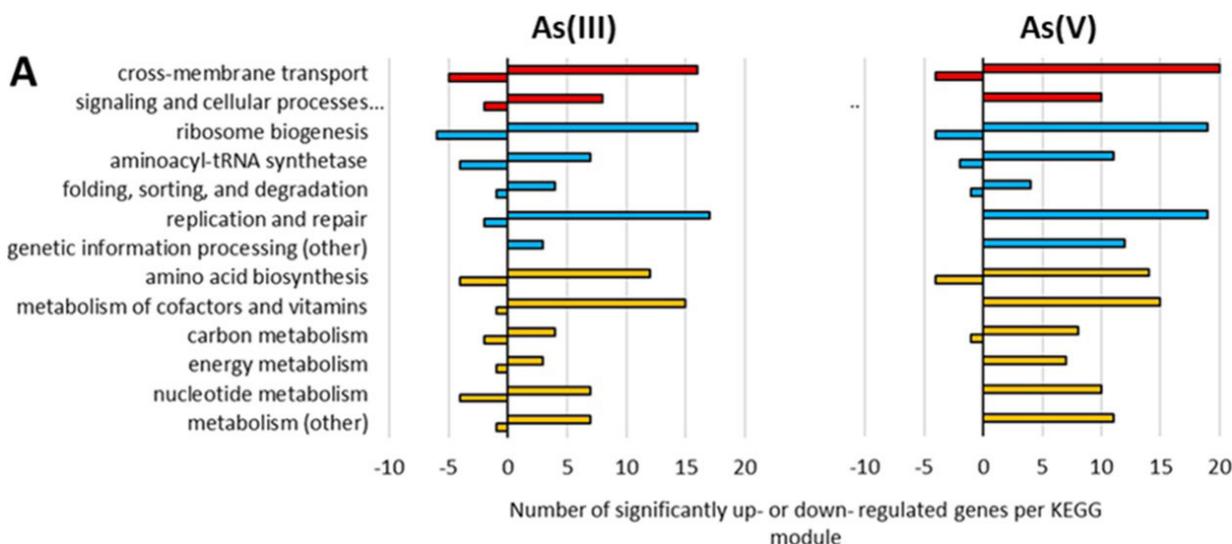


Figure A shows that the amount of TCE degraded by Dhc195 decreased over time with higher As(III) concentrations. Figure B shows the conversion of As(V) to As(III) over time, after addition of As(V) at Day 0. (Images from Gushgari-Doyle et al. 2020)



The study identified significantly up and downregulated genes in Dhc195 amended with As(III) and As(V). Positive numbers denote genes upregulated, negative numbers denote genes downregulated. (Image from Gushgari-Doyle et al. 2020)

Altering the Bacterial Community to Enhance Degradation

The researchers also observed significant changes in metabolite abundances within the Dhc195 community in response to both types of arsenic. Based on the analysis of metabolites, they identified specific amino acids, or building blocks of proteins, that could increase arsenic tolerance of Dhc195. Addition of a 20-amino-acid solution increased the growth rate of Dhc195 in arsenic-contaminated cultures, indicating that adding amino acids enhances Dhc195 tolerance to arsenic and may improve TCE degradation.

According to the authors, the study improves understanding of potential inhibitors of Dhc195 metabolism caused by arsenic and can inform the design of bioremediation strategies at co-contaminated sites. Based on these results, engineered bioremediation strategies, such as developing ways to inhibit conversion of As(V) to As(III) or providing the TCE-dechlorinating bacterial community with additional nutrients, could promote TCE degradation at arsenic-contaminated sites.

For more information, contact:

Lisa Alvarez-Cohen, Ph.D.

University of California-Berkeley
 Civil and Environmental Engineering
 760 Davis Hall
 Berkeley, California 94720-1710
 Phone: 510-643-5969
 Email: alvarez@ce.berkeley.edu

To learn more about this research, please refer to the following sources:

Gushgari-Doyle S, Alvarez-Cohen L. 2020. Effects of arsenic on trichloroethene-dechlorination activities of *Dehalococcoides mccartyi* 195. *Environ Sci Technol* 54(2):1276-1285 doi: [10.1021/acs.est.9b06527](https://doi.org/10.1021/acs.est.9b06527) PMID: [31913608](https://pubmed.ncbi.nlm.nih.gov/31913608/)

