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When arsenic enters soils - biogeochemical adaptation under future climatic conditions

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Arsenic contamination of soils is a critical environmental issue, affecting ecosystem health, agricultural productivity, and food safety. Climate change influences soil biogeochemical cycles, including the fate of contaminants like arsenic. While arsenic is a known toxin, it also serves as an electron acceptor or donor for certain microorganisms, supporting a subset of the microbiome. Despite extensive research, the integration of arsenic into soil structures and microbial adaptation remains poorly understood. This study hypothesizes that arsenic partially integrates into mineral structures rather than solely binding to mineral surfaces and that soil prokaryotes adapt more rapidly under future climatic conditions.

To test this hypothesis, arsenic was spiked into oxic soils, and its biogeochemical fate was monitored over six weeks under different climate scenarios. Sequential metal extractions tracked arsenic binding, while prokaryote qPCR and amplicon sequencing assessed microbial community shifts.

Following a 38-day acclimatization period, spiked arsenic remained primarily associated with short-range ordered minerals, showing limited integration into mineral interiors, unlike naturally occurring arsenic. While weak adsorption onto mineral surfaces reached equilibrium quickly, deeper incorporation into mineral structures was much slower. Future climatic conditions accelerated the movement of exogenous arsenic into mineral interiors. Arsenic initially stimulated prokaryotic absolute abundance, with beta diversity analysis revealing that communities responded to spiked arsenic for approximately 21 days before stabilizing. Climate increased prokaryotic adaptation rates, with both climate conditions almost reaching a stable prokaryotic composition after six weeks.

These findings suggest that while the microbiome may adapt within weeks, achieving a natural distribution of arsenic in soils after contamination may take years, highlighting the long-term persistence of mobile arsenic. The interplay between climate change and metal(loid) contamination underscores the need to consider their combined effects when assessing soil adaptation. This study enhances the understanding of arsenic behaviour in soils and informs contamination mitigation strategies under changing environmental conditions.