

Unlocking New Insights into Arsenic Contamination with XMaS

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Every day, millions of people unknowingly consume water contaminated with arsenic, which increases their risk of skin lesions, cardiovascular diseases, and developmental disorders. In Southeast and Central Asia alone, over 100 million people depend on groundwater sources that exceed safe arsenic limits. Arsenic mainly exists in two forms in natural environments: arsenite (As(III)) and arsenate (As(V)). As(III) is more toxic and mobile, making its presence in groundwater a significant concern. Traditionally, scientists believed that arsenic remained highly toxic and mobile in low-oxygen environments, like those found in Southeast Asia, making water treatment efforts challenging. It was widely assumed that As(III) could only be oxidized to As(V) in oxygen-rich environments. However, our research presents groundbreaking evidence that naturally occurring iron minerals along with organic compounds can transform the toxic arsenite into a less toxic form of arsenic, offering new hope for improving water safety.

Our team, which also included H. Forrester, and K. O'Neill, conducted high-resolution X-ray absorption spectroscopy (XAS) to investigate how arsenite (As(III)) interacts with green rust sulphate, a naturally occurring mixed-valent iron mineral. Using X-ray Absorption Near Edge Structure (XANES) spectroscopy, we made a surprising discovery: As(III) was partially oxidized even in the absence of oxygen. Furthermore, we found that it was fully converted to the less toxic arsenate form (As(V)) when citrate, a common organic compound found in soil, was present. XMaS' advanced X-ray techniques, including X-ray absorption near-edge structure (XANES) and extended X-ray absorption fine structure (EXAFS), provided unparalleled insights into arsenic and iron transformations at the molecular level⁵. Unlike conventional methods, which often rely on indirect measurements, XMaS enabled us to directly observe chemical/speciation changes. This capability was crucial in revealing how iron minerals act as natural arsenic detoxifiers, offering a new perspective on arsenic mobility in groundwater. Such findings are particularly relevant for flood-prone regions like Assam, where seasonal water fluctuations impact arsenic contamination levels.

Our findings challenge existing paradigms by showing that arsenic oxidation can occur without oxygen, driven by natural iron mineral transformations. If these processes are widespread in nature, they could help explain why arsenic behaves differently in certain groundwater systems, potentially reducing contamination risks. Furthermore, the study highlights the role of organic matter in enhancing arsenic transformation, paving the way for future nature-based, low-cost water treatment solutions.

This research effort has direct applications for communities reliant on groundwater, Figure CS6. Understanding the role of iron minerals in controlling arsenic mobility can guide the design of more effective remediation strategies and inform policies aimed at ensuring safe drinking water supporting regions struggling with arsenic pollution. This work aligns with the UN Sustainable Development Goals 6: Clean Water and Sanitation and reinforces the UK's role in addressing critical environmental challenges and most notably in tackling global water crises, water security and public health.

With growing concerns about climate-driven changes to groundwater quality, this study underscores the importance of continued investment in synchrotron-based research to solve pressing environmental challenges. The ability of XMaS to provide molecular-scale insights was critical in achieving these findings, which demonstrated the value of UK-funded large-scale research facilities in driving transformative discoveries. We are grateful for the support of XMaS and EPSRC in making this research possible and look forward to further interdisciplinary efforts in safeguarding global water resources.



Figure CS6. Dr. Jagannath Biswakarma (centre) helping children understand the groundwater quality in his hometown Assam, India.

⁵ J. Biswakarma et al., *Environ. Sci. Technol. Lett.* **11**, 1239-1246 (2024)