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Mechanochemistry Applications in the Remediation of Potentially Toxic Elements

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Extended Abstract

Mechanochemistry is a synthetic approach that utilises mechanical forces, such as grinding, shearing and friction, to initiate or sustain chemical reactions. Mechanochemical synthesis has been widely explored in pharmaceutical materials, nanoparticles, MOFs, and battery materials studies. Due to its solventless nature, scalability and low energy consumption mechanochemistry has found applications in recycling valuable materials, such as polymers [1] and electronic waste[2]. Notably, researchers have investigated mechanochemistry as a greener alternative for remediating contaminated soil as it can be easily scaled up [3].

Our project focuses on applying mechanochemical methods to address potentially toxic elements specifically uranium (U) and arsenic (As), in mine tailings. Currently, remediating arsenic involves energy-intensive high-temperature processes or liquid extraction methods that generate additional environmentally harmful waste streams. Meanwhile, the waste resulted from uranium ore processing is typically stored in tailing dams or settling ponds as slurry, without effective long-term remediation processes on a large scale. Our novel approach aims to fill this gap.

Our project targets the mechanochemical synthesis of meta-zeunerite (MZ), a stable, secondary uranium and arsenic mineral with the formula [$Cu(UO_2)_2(AsO_4)_2 \cdot 8H_2O$]. MZ has been discovered near an abandoned uranium mine in South Terras, Cornwall, UK. Studies have shown that MZ can be used to precipitate uranium and arsenic from groundwater due to its low solubility and high stability [4]. Successfully synthesising MZ using mechanochemical methods could offer a promising approach for remediating uranium and arsenic in soil and mine tailings.

In our poster presentation, we demonstrate the mechanochemical synthesis of MZ using uranyl nitrate hexahydrate [($UO_2(NO_3)_2 \cdot 6H_2O$)] and copper nitrate trihydrate [$Cu(NO_3)_2 \cdot 3H_2O$], along with arsenic pentoxide (As_2O_5), arsenic trioxide (As_2O_3), or an arsenic waste sample. We fully characterised the synthetic samples using X-ray Powder Diffraction, Fourier Transform Infrared Spectroscopy, Scanning Electron Microscopy and Inductively Coupled Plasma-Optical Emission Spectroscopy. Results indicate that MZ is the main phase when As_2O_5 is used as the arsenic source. When replaced with As_2O_3, only the reagents are observed in the product. To address this, we introduced solid oxidants such as sodium chlorite ($NaClO_2$) and calcium hypochlorite [$Ca(ClO)_2$], which facilitated the oxidation of As(III) to As(V) and led to the appearance of MZ. Additionally, we successfully synthesised MZ using arsenic tailings containing 67w% As_2O_3, validating the feasibility of our approach.

Beyond MZ, our research explores the mechanochemical formation of other arsenate salts, including Fe-arsenate, Cu-arsenate, and Ca-arsenate. For further details, we invite you to visit our poster.

References

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