A new adsorbent for removing radioactive cesium ions from nuclear wastewater

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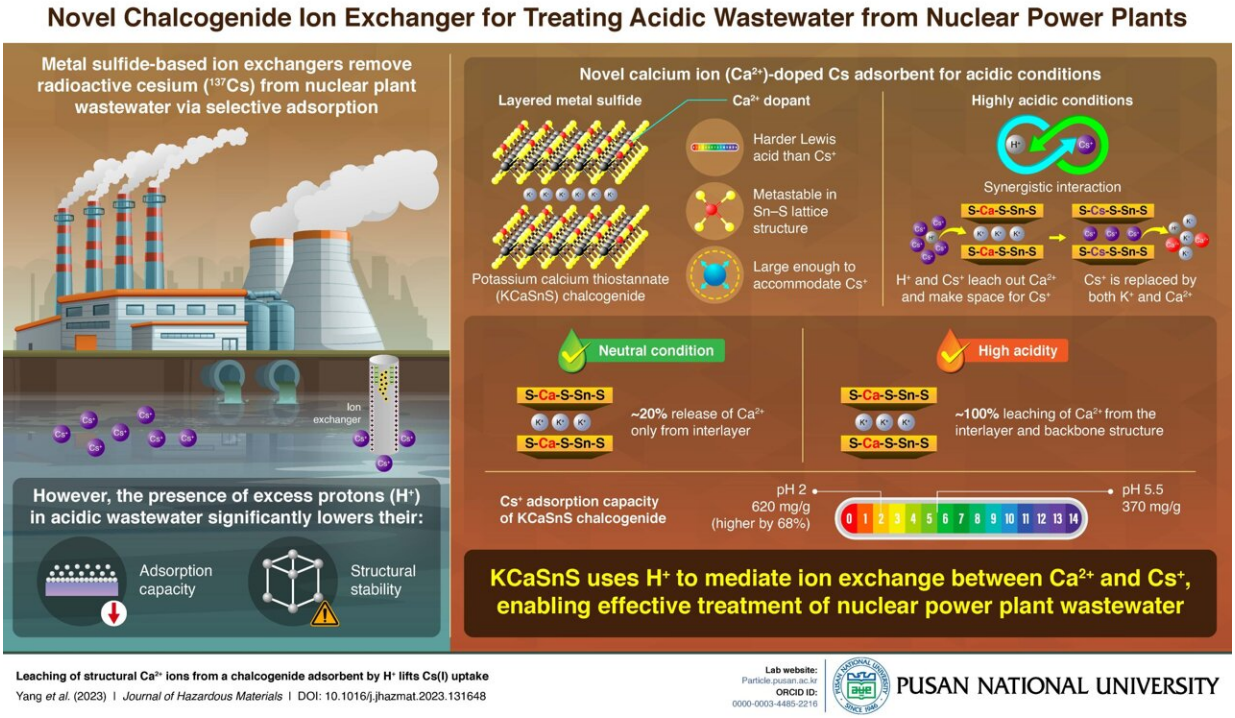

Pusan National University researchers developed a new calcium (Ca^{2+})-doped ion exchanger for the removal of radioactive cesium ion (Cs^+) from acidic nuclear powerplant wastewater. The adsorbent leverages an otherwise problematic excess of protons in acidic wastewater to leach out Ca^{2+} ions, facilitating Cs^+ adsorption. Credit: Kuk Cho from Pusan National University, Korea

Nuclear power is typically considered a cleaner way of generating power

compared to fossil fuels. It does not release air pollutants and greenhouse gasses like carbon dioxide as by-products. However, it creates radiotoxic waste that needs proper treatment to prevent adverse environmental and health conditions.

One of the major by-products of the nuclear fission process used for power generation is ^{137}Cs (an isotope of cesium), a radioactive element that has a half-life of 30 years and is often removed from nuclear powerplant (NPP) wastewater via selective adsorption using ion exchangers. However, this process is severely hindered in acidic wastewater where excess protons (H^+) impair the adsorption ability and damage the lattice structure of the adsorbent.

Recently, a team of researchers led by Prof. Kuk Cho from Pusan National University, Korea, found a way to turn this adversity into an advantage. In their breakthrough work in *Journal of Hazardous Materials* they have presented potassium calcium thiostannate (KCaSnS), a new layered calcium (Ca^{2+})-doped chalcogenide ion exchanger.

It utilizes the typically problematic H^+ ions in acidic wastewater to enhance the cesium ion (Cs^+) adsorption process. Essentially, the Ca^{2+} ions from KCaSnS are leached out by H^+ and Cs^+, making way for Cs^+.

"Through a transformative approach, the troublesome proton was converted into a functional agent by incorporating Ca^{2+} into the Sn–S matrix, resulting in a metastable structure. Moreover, Ca^{2+} is a harder Lewis acid than Cs^+ and can thus leave the lattice easily because of its weaker affinity to the Lewis soft base S^{2-} under acidic conditions. This provides a large enough space for Cs^+ to reside after its release from the lattice structure," explains Prof. Cho, speaking of the mechanism underlying the action of KCaSnS.

In the study, the team used the hydrothermal process to synthesize the

novel KCaSnS ion-exchange material, which was then used to investigate the adsorption of a non-radioactive isotope of Cs^+ (to avoid radioactivity exposure) in different solutions with pH values ranging from 1 to 13.

The team found that at pH 5.5 (neutral condition), the Cs^+ adsorption capacity was 370 mg/g, whereas at pH 2 (strongly acidic), the capacity increased by 68% to 620 mg/g. Remarkably, this trend was completely opposite to what previous studies had established.

The researchers attributed this observation to the fact that under neutral conditions, the Ca^{2+} was leached out only from the interlayers, which accounted for around 20% of the total spots available for Cs^+ to be adsorbed by the S^{2-} ions in the Sn–S matrix.

In contrast, under highly acidic conditions, nearly 100% of Ca^{2+} ions were leached out from both the interlayer and the backbone structure, allowing more Cs^+ ions inside the lattice. Additionally, in all cases, interlayer K^+ was involved in the ion exchange.

These results establish KCaSnS as a promising candidate for the removal of radioactive ions from NPP wastewater. The insights gained from this study could open up new avenues for the development of high-performance adsorbents for highly acidic environments. "The impressive adsorption capacity of KCaSnS can help alleviate the challenges associated with managing radioactive waste by providing a practical solution for reducing the volume of radioactive waste produced during spent fuel reprocessing and decommissioning of nuclear power plants," says Prof. Cho.

More information: Chenyang Yang et al, Leaching of structural Ca2+ ions from a chalcogenide adsorbent by H+ lifts Cs(I) uptake, *Journal of Hazardous Materials* (2023). DOI: 10.1016/j.jhazmat.2023.131648

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