Selective Detection of Thorium (IV) in Aqueous Systems Using Advanced AIE Materials

Water-Soluble AIE Sensor for Thorium Detection

Madhusudan Ghosh[1], Sachin S. Kadlag[1,2], Kallola K. Swain[1,2], Prabhat K. Singh[2,3]*

[1]*Analytical Chemistry Division, Bhabha Atomic Research Centre, Trombay-400085, INDIA*
[2]*Homi Bhabha National Institute, Anushakti Nagar, Mumbai-400094, INDIA*
[3]*Radiation & Photochemistry Division, Bhabha Atomic Research Centre, Trombay-400085, INDIA*

*****E-mail for Correspondence: prabhatk@barc.gov.in*

Thorium (Th), a naturally occurring radioactive element critical to India's strategic nuclear energy programs, also poses significant health risks due to its radiological and chemical toxicity. Accurate detection of Thorium in water is essential not only for environmental monitoring and health safety but also for ensuring its safe and sustainable utilization within the Department of Atomic Energy's initiatives. Traditional detection methods like ICP-MS require complex setups, while optical sensors offer cost-effective, simple, and selective solutions. However, achieving effective aggregation-induced emission (AIE)-based turn-on sensing for Th(IV) in 100% aqueous media has been a challenge due to the need for water-soluble, low-background fluorescence fluorophores.

A novel fluorophore, tetra(4-sulfophenyl) ethylene (SuTPE), was developed, exhibiting significant emission enhancement upon aggregation induced by Th(IV) in pure water. This fluorophore demonstrated remarkable sensitivity with a limit of detection to 56 ppb and high selectivity, even in complex matrices such as tap and seawater. The underlying sensing mechanism was thoroughly validated using several techniques, including steady-state and time-resolved fluorescence, FTIR, SEM, AFM, and DLS. The aggregation of Th(IV) effectively restricts the intramolecular rotation in SuTPE, thereby blocking nonradiative decay pathways and significantly enhancing its fluorescence intensity.

This method establishes a significant precedent for environmentally friendly, aqueous-phase detection of Th(IV), effectively addressing the limitations of traditional organic solvent-based sensors. The study also investigated dual-metal interference and demonstrated very less impact from U(VI), a common co-contaminant with Th(IV), thereby ensuring precise and reliable detection. Advanced computational analysis further validated the superior interaction of SuTPE with Th(IV) compared to other metal ions, underscoring its high selectivity. This work not only offers potential for monitoring natural radioactive elements in environmental water bodies to enhance health safety standards but also paves the way for developing more robust AIE-based sensors for detecting other toxic elements.

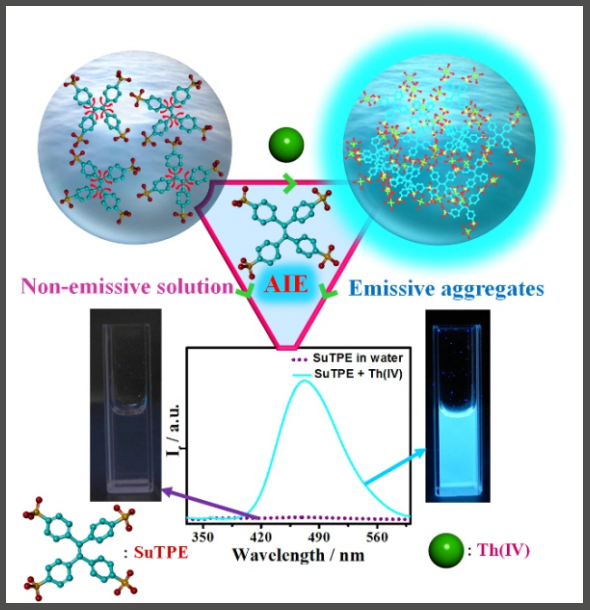

Fig.: Schematic representation of Th (IV) induced aggregation of SuTPE and the molecular structure of SuTPE (ACS Applied Materials & Interfaces 16 (2024), 57004-57016)

Reference:

Advanced AIE Materials for Environmental Monitoring: Selective Sensing of Thorium(IV) in Aquatic Systems, M. Ghosh, S. Kadlag, S.V. Bhosale, S. V. Bhosale, K. K. Swain, A. Ghosh, P. K. Singh*, ACS Applied Materials & Interfaces 16 (2024), 57004-57016.