Use of Nanotechnology in Remediation of Radionuclides and Heavy Metals/Metalloids

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Human civilization has significantly improved human life standards, but it also resulted in degradation of the environment through releasing many contaminants such as heavy metals/metalloids (Hg, Cd, Pb, As) and radionuclides (Cs, Sr, Co, U, Th etc). Nuclear power energy has been rendered as one of the cleanest fuel sources. However, the falling coolant system has caused nuclear plant accidents such as Three Mile Island, Chernobyl, and Fukushima releasing a huge amount of radionuclides, such as ^{137}Cs and ^{90}Sr. Nanotechnology as a new emerging novel remediation technology is characterized by its high efficiency and high selectivity. This presentation is the summary of Han's group in remediation of heavy metals and radionuclides. The major heavy metals/metalloids have been globally significantly increased in releasing into the surrounding environment since the Industrial Revolution, including As, Cd, Cr, Cu, Zn, Pb, Ni, and Hg. Their global potential environmental effects were assessed with novel indices including Ratios of Loading to Global Soil Background, Ratios of Loading to Global Earth Crust Background, and Capital Burden etc.

Here we present 3 major types of novel nanomaterials (Nanocasted mesocarbons, Functionalized mesosilicon and Magnetized calixarene) for removing heavy metals and radionuclides. Nanocasted mesocarbon was developed for the adsorption of Co, Cs, Sr, Pb, and Hg in water. Ferulic acid-mesocarbon was attained with post-synthesis with the maximum adsorption capacity of 35, 65, and 33 mg/g for Co^{2+}, Sr^{2+}, and Cs^{+}, respectively. Ascorbic acid-mesocarbon was synthesized with self-assembly method leaded to the sorption of Hg^{2+} and Pb^{2+} with a maximum adsorption capacity of 80.6 and 66.3 mg/g, respectively. The two types of mesocarbons would be promising for the treatment of radionuclide and industrial heavy metal contaminated water. In addition, SH-functionalized MCM41 also showed a selective adsorption of Cs at a maximum capacity of 29.24 mg/g.

Calixarene has been extensively studied for extractants, transporters, stationary phase, electrode ionophores, and optical/electrochemical sensors etc. Two heteroatom calixarene, 4-sulfonic calix[4]arene and O,O-bis(diethoxyphosphoryl)-calix[4]arene, were utilized to synthesize a magnetic supramolecular composite for the adsorption of three primary radionuclides—Co, Sr, and Cs—from nuclear waste water. The Fe_3O_4-mesosilica-calix structure of the synthesized complex was confirmed. This multifunctional complex combined advantages from the heteroatom upper-rim functionalized calixarene which potentially targets transition metals, the porous structure of mesosilica, and the magnetic separation property of Fe_3O_4. In multi-cation solutions, the adsorption capacity of P-Si-MN reached 1600 mg/g. Whereas, in mono-cation systems, the maximum adsorption capacity of P-Si-MN for Sr was 50,000 mg/g. Both sorbents exhibited high adsorption capacity for Cs, around 200 mg/g. A magnetic heteroatom-functionalized calixarene complex was successfully synthesized and demonstrated as a novel strategy for the treatment of multi-cation contaminated nuclear wastewater.