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Title	Encapsulation of adsorptive particles into CNT-reinforced alginate gels for the development of high-performance adsorbent for cesium and strontium eliminations [an abstract of dissertation and a summary of dissertation review]
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Citation	北海道大学. 博士(環境科学) 甲第11335号
Issue Date	2014-03-25
Doc URL	http://hdl.handle.net/2115/55352
Rights(URL)	http://creativecommons.org/licenses/by-nc-sa/2.1/jp/
Type	theses (doctoral - abstract and summary of review)
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File Information	Vipin_Adavan_Kiliyankil_review.pdf (審査の要旨)

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学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

Encapsulation of adsorptive particles into CNT-reinforced alginate gels for the development of high-performance adsorbent for cesium and strontium eliminations

（吸着性粒子をカーボンナノチューブ補強アルギン酸ゲルに内包するアプローチを用いたセシウムとストロンチウムを除去するための高性能吸着材の開発）

The candidate, in this study, had developed a novel adsorbent by encapsulation of the functioning particles into CNT-reinforced alginate based beads for cesium and strontium elimination (CNT: carbon nanotube). Simultaneous elimination of radioactive cesium and strontium is an unsolved problem. For decades, scientists are familiar with various transition metal cyano ferrates as well as zeolites to eliminate the radioactive cesium and strontium. However, it is unfeasible to use such material directly in water because of their small particle size; this leads to the further decontamination. Moreover, due to their low permeability, the large-scale application in fixed-bed columns has been impractical. Caging of the adsorptive materials into alginate beads with the beads being reinforced with highly dispersed multi walled carbon nanotubes (MWCNT) is the candidate's key idea. MWCNT was also found to be capable of enhancing the elimination efficiency for cesium and strontium.

Firstly, the candidate successfully synthesized ferric hexacyanoferrate (Prussian blue), sodium cobalt hexacyanoferrate and zeolite-A; these functioning materials were then being encapsulated in MWCNT-reinforced calcium alginate beads. The resultant beads were stable and showed high adsorbing capability for cesium and strontium. The key adsorbing materials such as Prussian blue, sodium cobalt hexacyanoferrate and zeolite-A were synthesized and then being purified scientifically. The physiochemical properties of these adsorbents were evaluated by the candidate using various techniques such as scanning electron microscope (SEM), x-ray diffraction (XRD) measurement, Fourier transform infrared spectroscopy (FT-IR), thermo gravimetric analysis (TG-DTA). These functioning materials were then being encapsulated in micro-porous beads using sodium alginate as the immobilizer and calcium ion (Ca^{2+}) as the cross-linker. MWCNTs were used for reinforcing the alginate based beads.

The candidate had then conducted numbers of experiments for evaluating the performance of the adsorbent. This includes the batch and the continuous flow with fixed bed columns. Kinetic, equilibrium and column breakthrough studies were also performed by the candidate. Mathematical fitting of the experimental data on the adsorption isotherm model was in the order Langmuir isotherm greater than Freundlich isotherm. Adsorbents with Prussian blue, sodium cobalt hexacyanoferrate and zeolite-A as the functioning elements showed adsorption capacities for cesium were 143 mg/g, 133 mg/g, and 113 mg/g, respectively. While for strontium, the adsorptive capacities were 55 mg/g, 72 mg/g and 107 mg/g, respectively. The kinetic models pseudo second order gave better fitting than pseudo first order. The performance of the adsorbents stabilized within a broad range of pH values as well as the ionic strengths. The fixed bed column adsorption experiments demonstrated that the bead-type of adsorbents were applicable for large scale treatment of the radioactive cesium and/or strontium contaminated water samples.

In conclusion, the candidate showed familiarity with, and critical understanding of the relevant literatures; the methods adopted were appropriate to the subject matter and properly applied; the research findings were suitable set out, accompanied by adequate exposition and discussion, and the quality of English and the general presentation were satisfactory. The recommendation of the examination committee was that "the degree be awarded".