Preparation and evaluation of alginate-assisted spherical resorcinol–formaldehyde resin beads for removal of cesium from alkaline waste

Charu Dwivedi\(^a\), Amar Kumar\(^b\), Kuttan Ajish Juby\(^a\), Manmohan Kumar\(^a\),* Piaray Kishen Wattal\(^b\), Parma Nand Bajaj\(^a\)

\(^a\) Radiation & Photochemistry Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India
\(^b\) Process Development Division, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, India

**HIGHLIGHTS**

- Synthesis of resorcinol–formaldehyde spherical resin beads.
- Use of bio-compatible calcium alginate beads as template.
- Characterization of the synthesized beads using TGA, UTM SEM and BET surface area analysis techniques.
- Application of the synthesized beads in removal of cesium ions from aqueous waste.
- Sorption and kinetic studies of cesium ion removal by radiotracer technique.

**ARTICLE INFO**

**Article history:**
Received 16 April 2012
Received in revised form 18 June 2012
Accepted 19 June 2012
Available online 28 June 2012

**Keywords:**
Sorption
Sorption kinetics
Equilibrium
Cesium removal
Resorcinol–formaldehyde

**ABSTRACT**

A novel method of synthesis of spherical resorcinol–formaldehyde resin was developed, using calcium alginate beads as template. Batch sorption experiments were carried out, to remove cesium ions from aqueous alkaline solutions, using the synthesized resin beads. The effect of operating variables, such as the initial cesium ion concentration, sodium ion concentration, and contact time, on the sorption of cesium ions was studied. Equilibrium data were found to fit better to Langmuir isotherm equation, with a monolayer sorption capacity of 490.2 mg/g, and the complete elution of the sorbed cesium ions was also possible. Sorption data were also analyzed in terms of both Lagergren first-order and pseudo second-order kinetic models, and were found to follow pseudo second-order kinetics at lower initial cesium ion concentration. The kinetic parameters were determined at different initial concentrations. The process mechanism was found to be complex, consisting of both film diffusion and intraparticle diffusion. Sorption data were also analyzed, using a Boyd plot, which confirmed that the rate-limiting step is the film diffusion.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

The management and disposal of radioactive waste is an issue relevant to almost all the countries. The radioactive waste is generated from the use of radioactive materials in industry and medicine sector, as well as from research and nuclear establishments. Among the various radionuclides present in the nuclear waste stream, \(^{137}\)Cs is of special concern, because, along with \(^{90}\)Sr, it constitutes a major source of heat in the nuclear waste. This radionuclide has a long half-life, and is a biological hazard [1]. So, its removal from the nuclear waste streams, before discharge to the environment, is necessary. A variety of methods, based on liquid/liquid extraction, solid/liquid extraction, ion-exchange processes, etc., have been proposed/used for the removal/recovery of \(^{137}\)Cs from nuclear waste. Currently, the ion exchange has emerged as one of the most effective and attractive processes for the treatment of these cesium-bearing waste waters [2–7]. This process is flexible, simple, compact, efficient enough to achieve decontamination factors of several orders of magnitude, and does not require any hazardous organic solvent. Removal/recovery of cesium from different types of nuclear waste streams, using various types of materials, such as aluminosilicates, phosphates (like ammonium molybdophosphosphate (AMP)), ferrocyanides, hydrous oxides of multivalent cations, pillared clays, and resorcinol formaldehyde resin, has been previously studied by many researchers [8–13]. Among these, only resorcinol–formaldehyde (RF) resin has been considered as a satisfying option for removal of Cs\(^+\) ions from highly alkaline media because of low-cost, safety, availability, selectivity, easy operation and efficiency considerations [14]. Moreover, the other...