Sorption Studies of Radionuclides from Simulated Low Level Waste using Green Biosorbent

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Abstract

In view of the disadvantages associated with conventional methods for metal removal, there is a need for alternative, cost-effective technologies. In recent years, biosorption process has been considered as an efficient and eco-friendly alternative treatment technology for the removal of metals from radioactive wastes. The subject matter of this study is to evaluate a natural, viable and low-cost adsorbent – Dry Cowdung Powder (DCP), for the removal of ^{137}Cs(I) and ^{60}Co(II) from simulated low level radioactive waste. Experimental parameters like pH, sorbent dosage, contact time and temperature of the sorption process were optimized and maximum uptake of 66% and 90% was observed for Cs(I) and Co(II) respectively.

This green technique was further employed to check the effect of different salts on the biosorption process of both the metal ions applying Hard and Soft Acid Base (HSAB) theory. Metal ions and salts were categorized into hard and soft acids and bases to understand the reaction mechanism of biosorption process. Thermodynamic parameters such as ΔG°, ΔH° and ΔS° determined the exothermic nature of the process with an enthalpy change of -4.18 kJ.mol^{-1} and -2.70 kJ. mol^{-1} for Cs(I) and Co(II) respectively. This method possesses rapid kinetics, thus the process was time and energy efficient.

Keywords: Dry Cowdung Powder, Biosorption, Green Technique, Thermodynamics, HSAB Theory.

Introduction

Radioactive waste can remain hazardous for a few days or for thousands of years depending upon their radioactive half-lives. Treatment of this waste is an important objective to ensure that the radiation exposure to an individual and the environment does not exceed the prescribed limit. Solvent extraction, chemical precipitation, ion exchange, membrane process, solar evaporation and sorption are conventional and recently developed methods reported for treatment of radioactive waste[1]. This study is focused on removal of Cs(I) and Co(II) ions from simulated low level radioactive wastes by biosorption process using green biosorbent - Dry Cowdung Powder (DCP).

^{137}Cs is produced by the fission of uranium and is not a naturally occurring radionuclide. Nuclear reactor operations form the largest source of ^{137}Cs. It has a half-life of 30.17 years and it emits one to two high-energy beta particles. Approximately 85% of all ^{137}Cs decays result in the emission of a 0.662 MeV gamma ray[2,3]. ^{60}Co is the most stable radioactive isotope of cobalt with 5.27 years of half-life. It is produced in the structural steels and other alloys of nuclear reactor vessels and internal components from neutron activation of ^{59}Co. It emits two highly energetic gamma rays of 1.17 MeV and 1.33 MeV and poses an external exposure hazard[4].

Biosorption process has long been investigated by most researchers using different types of biomass for the removal of Cs(I) and Co(II) from aqueous media. For example activated sludge[5], microalgae haematococcus pluvialis and chlorella vulgaris[6], porous tuff[7], extracted chitosan[8], bacteria isolated from spent nuclear fuel pools[9], lemna gibba[10], spent black tea (camellia sinensis)[11] are the biological materials that have been used for the uptake of Cs(I) and Co(II) from waste waters.

Literature review reveals the characterization studies of DCP carried out by previous researchers[12,13]. It sheds light on the acidic and basic moieties present on the surface of the biosorbent which act as active sites for bonding. DCP has been employed without any pretreatment. This inactive non-living biomass has an inherent property to bind and concentrate metal ions from aqueous surrounding which enables faster and easier adsorption[14].

Material and Methods

Radiotracer technique has been used for the quantification of results in which small amount of radioactive isotope is added in order to trace the chemical reaction of a certain element in the system. The amount of a radioactive tracer necessary for an experiment is normally so small that no detectable radiolysis occurs in the system[15]. Radioisotopes employed as tracers were obtained from the Board of Radiation and Isotope Technology (BRIT), Trombay, Mumbai. The chemicals used for the experimental work were of A. R. grade. Dry Cow Dung (100 mesh) was provided by Keshav Shrushti Research Centre (Thane, India) and due precautions were taken to avoid contaminations.

Low level radioactive waste composition was obtained from Tarapur Power Plant and batch solutions were prepared containing Cs(I), Sr(II), Co(II), NaI and $NaNO_3$. Radioactive ^{137}Cs and ^{60}Co were added to the respective solutions which were then mechanically agitated with known amount of DCP and 15 mL of final volume. The resultant solution was