

ABSTRACT

The application of various bio-sorbents as adsorbent medium for the removal of contaminants such as heavy metals from wastewater effluents has become a common basis of research. However, there are few economically and environmentally sustainable adsorption processes available for the treatment of wastewater streams. Nevertheless, amongst the equipment used for adsorption in wastewater treatment processes, fixed bed columns have been used extensively on an industrial scale. In this study, the performance of a layered adsorbent column was studied for the removal of chromium and copper using egg and sea shells as adsorbents. These bio-sorbents were used in their raw form, i.e., no form of chemical or energy intensive modification was conducted. Therefore, application of these bio-sorbents in this study was attributed to them being low-cost and locally available.

The bio-sorbents were analysed for their inherent properties using the following analytical techniques: Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM/EDS), X-ray fluorescence (XRF), X-ray diffractometer (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and Brunauer-Emmett-Teller (BET) analysis. The surface area, pore sizes and volumes of both bio-sorbents were found to be relatively high. Thus, rendering them highly porous. A porous surface texture entraps contaminants, therefore, enhancing adsorption. The SEM/EDS revealed strong peaks of calcium, carbon and oxygen as the major components of egg and sea shell bio-sorbents. These carbon and oxygen elements constitute carboxylic and carbonate functional groups. The FTIR showed the presence of other functional groups including acyl halides, alcohols, aldehydes, alkanes, amines, esters and ketones. These functional groups are capable of interacting with the chromium and copper ions during biosorption. The structures of the bio-sorbents studied were found to be crystalline, with calcium carbonate as the main constituent whose calcium ions go through an ion-exchange process with the metals in solution. The surface pH and charge of the adsorbents revealed their basic nature which makes them good neutralizing agents for acidic solutions. Therefore, no pre-treatment measures may be required when treating acidic solutions like acid mine drainage (AMD).

The batch experimental setup (a 2^4 full factorial design matrix) was generated using a tool known as the design of experiments (DOE) to avoid the tedious one-factor-at-a-time approach, for the screening and identification of factors that have a significant influence on adsorption.

The factors investigated were initial metal concentration, solution pH, adsorbent dosage and adsorbent type. All factors together with their interactions showed a significant amount of influence on metal removal with the exception of adsorbent type. Single and multicomponent batch experiments were conducted to compare the level of affinity that each bio-sorbent has with both chromium and copper and to establish the interference between the respective metal ions. Sea shell powder was found to have a high affinity towards both metals in comparison to egg shell powder. This may be due to the fact that sea shells are more crystalline with a higher CaCO_3 content and a higher surface area than egg shells.

Fixed bed experiments were performed for the layered column in order to explore the effect of adsorbent bed height and flow rate on breakthrough analysis. The arrangement of bio-sorbents in the beds was also investigated. The beds improved in performance with an increase in bed height and a decrease in flow rate. The different beds followed the order; sea shell on top of egg shell > egg shell on top of sea shell > sea shell > egg shell. Therefore, layered adsorbent beds are more favorable, and may be the solution to the development of a process for the removal of metals in a mixed metal solution through a one-step removal process instead of running the solution through two or more columns packed with different bio-sorbents. The experimental data obtained for all four different adsorbent bed set-ups (single and double layered) fitted well with the Thomas and Yoon-Nelson models.